Handbook of Research on Teacher Education in the Digital Age

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Chapter 26
Creativity, Digitality, and Teacher Professional Development:
Unifying Theory, Research, and Practice

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ABSTRACT

This article describes the development of a trans-disciplinary framework for creative teaching using technology. In recent years, the authors of this paper (and collaborators) have sought to better understand the role of creativity in educational technology. Our approach seeks to inform theory, research, and practice. In this piece we step back to provide a big-picture view of the process of developing a theoretical framework for creative, transformational teaching with digital technology. We describe the development of our ideas over time, through research projects focused on highly creative teachers and their practices. We describe how we have applied these ideas in teacher education courses devoted to creativity and technology, and developed rubrics for evaluating creative products. At a meta-level we aim to provide a rich example of the reciprocal nature of theory, research, and practice in educational technology. Through this we hope to provide one example of how such a theory/research/practice development process works, with the goal of informing future work of this type.

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INTRODUCTION

You can't pursue any kind of inquiry without a relatively clear framework that's directing your search and helping you choose what's significant and what isn't...If you don't have some sort of a framework for what matters — always, of course, with the proviso that you're willing to question it if it seems to be going in the wrong direction — if you don't have that, exploring the internet is just picking out the random factoids that don't mean anything...You have to know how to evaluate, interpret, and understand...The person who wins the Nobel Prize is not the person who read the most journal articles and took the most notes on them. It's the person who knew what to look for. And cultivating that capacity to seek what's significant, always willing to question whether you're on the right track — that's what education is going to be about, whether it's using computers and the Internet, or pencil and paper, or books. Noam Chomsky

Theoretical frameworks play a critical role in the development of any field. In fact, it has been argued that the explicit use of theory is essential for the development of scientific understanding of a domain. This is of particular importance for research in fields such as educational technology, where the broad generalizations of theory have to work with the intricate realities of practice – both of which lie within a broader context of a rapidly changing technological landscape.

The challenges are obvious. Scholars seeking to develop theory, conduct research in order to develop abstract generalizations. They do so by finding patterns of causation and explanation from the complexities of the continually evolving "wicked problems" (Koehler & Mishra, 2008; Rittel, 1972; Rittel & Weber, 1973) of teaching with technology. Practitioners in the field, on the other hand, focus on the here and now, and see theory as often being disconnected from their daily lives as professionals. Thus, if theory or research in educational technology is to be of use to the practitioners, it must manage to both capture the richness of the lived experience of the educator, and identify broad themes and perspectives that work across cases. This implies that theory generation in fields such as educational technology must develop in a transactional relationship between research and practice, where each is valued for what it has to offer to the final theory or framework being developed.

How exactly such a transactional relationship works, though, is harder to describe. In our experience, specifically through the development of the TPACK framework, this is a complex and zigzag process, which rarely if ever matches the deductive *scientific method* often seen in textbooks. Practice, research and theory-development often occur in parallel, in a dialectic relationship, or in spirals of increasing complexity. This is why it becomes important that we have rich case studies of this process. Over the past few years we (the authors of this chapter) have been involved in just such a rich series of design experiments, to better understand the role and nature of creativity in teaching and learning specifically using digital tools. We have written and presented our work in a variety of venues and contexts: as theory, practice and research (Henriksen & Mishra, 2013; Henriksen, Mishra, & The Deep-Play Research Group, 2014; Mishra, Koehler, & Henriksen, 2011; Mishra, & The Deep-Play Research Group, 2012; Mishra, Henriksen, & The Deep-Play Research Group, 2012; Mishra, Henriksen & The Deep-Play Research Group, 2013).

Too often, research in educational technology has been characterized as being a-theoretical in nature, merely providing descriptions of phenomena—represented usually by descriptive case studies of interesting uses of technology for pedagogical purposes. A general dissatisfaction with this approach has led to a push for making educational research more scientific. This has led to the development of certain criteria by which to judge educational research. Either explicitly or

implicitly these criteria include a cluster of ideas, suggesting that educational research needs to emphasize facts (over opinion), develop precision in measurement (over mere observation), focus on quantification (over qualitative descriptions), and the development of better analytical tools (such as blind trials and controlled experiments). Though we agree that all of these issues are important for educational researchers to consider, we also believe that this list, by focusing on surface details of what constitutes science, misses the most important aspect of what makes research scientific. We argue that science is characterized, most importantly, by the infusion of theory and theoretical frameworks. In fact, it has been argued "theory alone is the distinguishing feature of the scientific enterprise… (and that) the activity is not science unless it involves an explicit theory" (Bernard & Ritti, 1990, p. 1).

We have argued elsewhere that theoretical frameworks provide us with a structure that lets us systematically study the phenomena under question, allows us to make predictions, and helps us guide practice (Mishra & Koehler, 2006). An explicitly articulated theory defines and gives meaning to the questions we ask, and helps us identify and select variables and measures, as well as allowing us to interpret the results. In fact, we would argue that even those who suggest that they are engaged in purely descriptive research do have theories that underlie their work. It is simply that these theories have remained implicit, and have not been articulated explicitly. Without these implicit theories (often called naïve or folk theories) it would be impossible to determine what to study, and how. The danger with such naïve theories, of course, is that, due to their unseen nature, they are not amenable to reflection, analysis and correction. As Mishra & Koehler (2006) write in the paper introducing the TPACK framework:

Theories, frameworks or models can be seen as conceptual lenses through which to view the world. They help us in identifying objects worthy of attention in the phenomena we are studying, highlighting relevant issues (and ignoring irrelevant ones). They can work as classification schemes by providing insights into the nature and relationships of the objects under scrutiny (Mishra & Koehler, 2006, p.1043).

The development of a theoretical framework, however, is a complicated process. This is further compounded in practitioner-based fields such as educational technology —where abstract theoretical ideas often run aground when faced with the complexities of practice. Though challenging, this is an important goal for all research and scholarship—not just in education. It thus becomes an important goal of scholars working at the intersection of research, theory and practice to document and describe the process of generating a theoretical framework.

In this article we describe the complicated process of development of a trans-disciplinary framework for creative teaching using technology. We have been engaged, over the past six years, in conducting what scholars might term a "design experiment" (The Design-Based Research Collective, 2003) that seeks to better understand the role of creativity in teaching and learning. Our approach has had a dual-focus—on the development of theory, while simultaneously informing practice. In this piece, we describe: the development of our ideas over time; through research projects that seek to study highly creative teachers and their practices; the instantiation of these ideas within multiple teacher education courses devoted to creativity and technology; and the development of rubrics to evaluate creative products. Through this process we seek to provide a rich example the reciprocal nature of theory and practice development in educational technology. Our hope is that by exposing this process we provide *one* example of how such a theory/research/practice development process works, and hopefully through that inform future work of this nature.

In this paper we seek to step back from immediacy of the work to provide a big-picture view of the process of developing a theoretical framework for creative, transformational teaching with digital technology. We describe how our initial ideas informed our research agenda and its instantiation in practice, and how this in turn fed back and influenced the development of instruments to measure our creativity—with a reciprocal influence on our theoretical ideas. Though this is a work that is far from complete, we believe that capturing and describing the manner in which this process has played out thus far, can offer insight into this complex process of theory generation.

THE BACKGROUND

As we begin exploring our entry into the subject of creativity, let us cover some background that helps make the case for just how important creativity is in areas of thinking and learning – and why it was of interest to us, and should be of interest to the reader.

In recent decades, creativity has increasingly become a topic of intense interest to the field of education (Plucker, Beghetto, and Dow, 2004). As a psychological trait, there are social, emotional, cognitive, and professional advantages associated with creativity (Sternberg & Lubart, 1996). Particularly when we consider the complex problems and environments of the world today, there is a definite need to focus more attention on creative thinking for students and educators (Cropley, 2003; Robinson, 2011; Sawyer, 2011).

Creative thinking is considered to be a necessary and valuable criterion for accomplishment in our high-tech, global, and interdependent society (Florida, 2002; Pink, 2005; Robinson, 2003; 2011). As the issues faced by society become more multifaceted, and knowledge becomes more profuse and diverse, innovative problem solvers are needed from K-12 and beyond (Zhao, 2012). In life, the ability to learn, improve, and grow relies on creative thinking and new construction, so creative people are often quite at an advantage throughout different aspects of life, and in making impact within their professional disciplines (Cropley, 2003; Sternberg, 2006; Subotnik, Olszewski-Kubilius, & Worrell, 2011). Given all of this, many educational scholars have emphasized the importance of developing thoughtful and effective frameworks for thinking about creativity in 21st century contexts, for the field of education at present and into the future (Jeffrey & Craft, 2004; Sternberg, 2006; Sternberg, Kauffman, & Pretz, 2002).

Building on Existing Work

Our work on creativity in teaching and learning has its precedents in, and builds upon, three previous lines of work. The first line of work was related to *the integration of technology in teaching,* i.e. *the TPACK framework*. Our work on the TPACK framework suggested the importance of considering teacher creativity thus bringing the idea of creativity to foreground of our thinking. Once creativity became something we were interested in, it led us to attempting to better define what creativity is. The second line of work we build upon is *a definition of creativity from existing research in this area*, which specifically draws from Besemer and O'Quin's (1999) work on the creative product semantic scale. We believe that focusing on *how* creative products are evaluated is of greater importance to educators than understanding personality characteristics of creative individuals (which has been the main focus on research on creativity). The third, and final, line of work that influenced our thinking came from Michele and Robert Root-Bernstein's work on *trans-disciplinary creativity*. This work emphasizes the value of thinking both within and across disciplines and identifies ways of thinking (or cognitive tools) that cut across disciplinary boundaries. It was in bringing these three independent lines of inquiry together that we have over the past

six years managed to develop a productive line of theory, research, and teaching. In the sections below we describe each of these lines of work and how it led to our current conceptualization of creativity and the creative process.

Building on the Past

Part 1: The limitations of the TPACK framework

In 2006 Mishra and Koehler introduced the TPACK framework. This framework, building on Shulman's work on Pedagogical Content Knowledge (PCK), suggested that the successful integration of technology for teaching requires teachers to have a sophisticated and integrated form of knowledge that emerged from the interactions between three different knowledge bases, knowledge of content, pedagogy, and technology. They suggested that TPACK in its application was a creative act, in which individual educators engage in specific contexts of practice. The TPACK framework has been incredibly successful, with the 2006 article receiving over 2400 citations on Google Scholar; and the TPACK scholar community, at TPACK.org, has compiled a bibliography of over 400+ articles. Yet, despite this success, the TPACK framework has two significant limitations—each of which, in its own way pushed us towards thinking about the role of creativity in teaching and learning. Taking each in turn.

The first limitation of the TPACK framework (that pushed us towards thinking of creativity) was that the framework does not speak to the overarching goals of education. It is relatively neutral analytic tool, which can be used for drill and practice as well as for inducing higher order thinking (Mishra, Koehler, & Henriksen, 2011). What was clear that one of the goals of education needed to be the development of more creative students and teachers, and that this goal aligned with the broader discourse in the field often contextualized as 21st century learning. Clearly, given the neutral nature of the TPACK framework, a discussion of the broader goals of the framework needed to come from outside of framework. Creativity, as contextualized above, was clearly something that needed to be addressed.

The second limitation of the TPACK framework is that it does not provide a process as to how technology integration actually takes place. It was clear that technologies often do not determine how they are to be used in pedagogical settings with specific content areas. What is needed is a thoughtful practitioner, the teacher, who creatively navigates the affordances and constraints of specific technical tools with the requirements of representing content for particular pedagogical approaches. It is clear that digital tools are often not designed for educational purposes and need to be repurposed in order for them to the integrated in teaching. This is because though different tools have different pedagogical affordances, the context within which the tools are used play a critical role in determining their success. Technology can also provide novel pedagogical opportunities that offer a new "zone of possibility" (Kereluik, Mishra, Fahnoe, & Terry, 2013, p.128; see also: Dirkin, 2009; Dirkin & Mishra, 2010; Mishra & Kereluik, 2011) beyond our current psychological understandings, explanations, and justifications. Because technologies develop so rapidly, often outpacing developments of our psychological conceptions, technology integration can pose important conceptual and practical challenges for educators. The idea of "zone of possibility" suggests that tools don't *determine* the outcomes but they do constrain or support certain practices, and this brings teacher creativity to the forefront.

In our writing the importance of creativity often emerged through an emphasis on the idea of design, in which the teacher is a designer of learning experiences. The interplay between the elements of technology, pedagogy, and content occurs in a complex educational landscape, in which teachers must be able to solve problems

creatively, and use technology as a solution to issues of content and pedagogy. How this process actually works was unclear—and prompted our first discussions on the importance of creativity for teaching and learning with digital tools.

Part 2: Defining Creativity Based on Besemer & O'Quin

As we got more interested in creativity we faced the challenge of defining what it was. Our review of the literature indicated that scholars have struggled to concretely define the construct, thus lacking agreement on *what* it is and *how* it should be defined (Baker, Rudd, & Pomeroy, 2001; Friedel & Rudd, 2005; Marksberry, 1963; Sternberg, 1999). For example, Plucker, Beghetto, & Dow (2004) determined after a review of 90 or more articles from peer-reviewed journals, that only 38% of these articles offered an actual definition of the term *creativity*. Despite all of the attention paid to creativity, particularly in 21st century learning contexts, we came to realize that it was an ill-structured construct that was seen by different people in different ways.

Therefore, in starting to consider a framework for creativity for our research and practice in educational technology, it became important to ensure that we had properly defined it. It needed to be defined in a manner that would speak to our own work and experience, as well as one that could be more generally applicable to other contexts, and of course be grounded in creativity scholarship overall.

A general review of the literature on creativity shows that most definitions do give, as a common base, at least two common factors, which include novelty (newness, originality, freshness, uniqueness, etc.) and effectiveness (value, usefulness, quality, etc.). This reflects the fact that creative work is *novel* in that it creates something that did not exist before (at least in that particular context or instance). But novelty alone is not enough – it must be connected to the value, quality, or usefulness of the work – it must also have value, quality, or be *effective* towards a purpose (Zhou & George, 2001). Sternberg and O'Hara (1999) suggested adding another component to the common definitional elements of novelty and effectiveness. They state that the factor of "task appropriateness" (p.255) is a way to account for the importance of context in creative work. This suggests that creative products (ideas, artifacts etc.) are sensitive to context, and must be judged within the domain they were created for – which is their "task appropriateness" or contextuality. For instance, a creatively constructed mathematical proof, or beautiful piece of artwork, will be quite different from each other, and even different still from other creative acts across other disciplines (Mishra, Henriksen, & the Deep-Play Research Group, 2012).

Our final definition emerges from Besemer's (1998) work on *the creativity product analysis matrix.* Besemer (1998) claimed that a creative product captures the essence of the creative process, to a certain extent. She referred to the dearth of creativity of product measures, and proposed the need for empirical studies to test and confirm measures for judgment of product. She also noted, and our observation conforms, that most measures of product work only in specific domains, which limits their usefulness. In addition, other measures use product as a "dependent variable and use it as a measure of a person's performance on a creative task" (p. 334).

Besemer's (1998) Creative Product Analysis Matrix (CPAM) is a domain neutral measure of product that can be used to evaluate a work of art, a new product design, or results of a creative process. This measure includes three related factors: Novelty, Resolution, and Elaboration and Synthesis. Each of these factors covers certain aspects that reflect the creativity of the product. Novelty speaks of originality of different kind and the element of surprise. Resolution covers

the valuable, logical, useful and understandable aspects of the product, that is, how well the product does what it is supposed to do. Elaboration and Synthesis is the "style" factor (p. 335). This factor measures the organic, elegant, and well-crafted aspects of the product. It covers the essence of the beauty of the product. Besemer (1998) found that her three-factor model was adequate to assess creativity of the products that she used. The model supported difference of opinion with consistency. Therefore, as she concluded, this matrix could be used as a backdrop to assess creative products.

The formal definition we offered worked along the similar dimensions as Besemer argued. These three definitional indicators are important, because they reveal how creativity can connect broadly with, and be judged within, multiple domains. We first introduced our definition in a Mishra and Koehler (2008) article, which laid out the fact that creativity has three general components – it is *Novel, Effective, and Whole*. We suggested that this idea of *wholeness* captures both the issue of style as laid out by Besemer as well as contextuality as specified by Sternberg and others.

Thus, we suggest that a creative solution is NEW, i.e. it is Novel, Effective, and Whole – or in other words, creativity is a goal driven process of developing solutions that are Novel, Effective, and Whole. The fact that we emphasized the evaluation of creative products (over other definitions) has significant implications for how this definition can be actually used by educators to evaluate creative works designed by students. We will discuss this later when we speak of our work in this area.

Part 3: Trans-Disciplinary Creativity

A third and critical precursor to our work in this area has to do with what has been described as *trans-disciplinary creativity*. The idea of trans-disciplinary is that there are ways of thinking that span domains, across the arts and sciences. This is an idea that has been touched upon by important thinkers in education and psychology. Many key educational thinkers have suggested that creativity, the arts, and imaginative thinking, are central to learning and thinking across a variety of disciplines (Bruner, 1990; Dewey, 1934; Eisner, 2004; Vygotsky, 1978).

Overall, our view of trans-disciplinary creativity has two strands: one that more generally describes how creative people work and function – how they get ideas and cross-pollinate them between disciplines; and another strand that focuses on how they think – the cognitive skills and habits of mind that help creative people think across disciplines. Both of these strands of trans-disciplinary creativity developed out of the work of Robert and Michele Root-Bernstein, most clearly expressed in their book *Sparks of Genius*, as well as in a key research study they conducted around scientific creativity among highly accomplished scientists.

The first strand of the theory reflects the fact that the ability to think creatively in any discipline is deeply connected to thinking in other, seemingly unrelated, subject areas. The Root-Bernsteins (1996, 1999, 2003) noted that creative artists think in similar ways that creative scientists do. And the converse holds true as scientists often engage in artistic activities and avocations that shape their thinking and insights. At a general level, trans-disciplinary creativity suggests that though disciplines have distinct differences, critical similarities between creative thinkers exist. As Caper (1996) noted, "Artistic creation and scientific investigation become hard to distinguish in their essence" (p.867).

So, trans-disciplinary thinking describes the way that creativity involves *cross-pollinating* ideas between disciplines – pulling on ideas from one area to inspire creativity in another. This was demonstrated quite clearly in a study done by Root-Bernstein (1996) of forty scientists (including several Nobel Prize winners). This group of scientists were surveyed and interviewed on thinking skills, creative beliefs, and creative pursuits, hobbies, avocations, etc. The surveys/interviews

explored how their creative hobbies, avocations, and thinking skills connected to their success and scientific accomplishment over time. Most notably, significant correlations were established between scientific accomplishment/innovation and the tendency to have varied creative pursuits and avocations (particularly music and the visual arts). Accomplished scientists have varied creative interests and avocations, which they specifically attribute as strongly contributing to their professional creativity (giving credit to creative pursuits for motivating and improving their scientific thinking, innovation, and insights). This underscores a link between disciplines at the level of creative thought (Root-Bernstein, 1996), and in this first thread of trans-disciplinary creativity, shows that creative people draw inspirations from widely varied source material – bringing in ideas from their personal avocations to feed their professional creativity.

The second strand of the trans-disciplinary framework deals with meta-level cognitive creative skills, used by exceptional innovative thinkers. In the book *Sparks of Genius*, historical data noted by the Root-Bernsteins (1999), show that creative people generally use a subset of thirteen cognitive skills for thinking across disciplines. Working forward from the skills posed in this book, the Mishra, Koehler & Henriksen (2011) article, developed a compressed, but representative, set of skills. These seven thinking *tools* are the trans-disciplinary skills, as follows: *Perceiving; Patterning; Abstracting; Embodied thinking; Modeling; Play;* and *Synthesis*. In brief, these tools are defined as follows:

1. **Perceiving.** This is the first step to understanding anything. Observing involves paying close attention to information gathered through the five senses, with intent focus and curiosity. This also involves the mental recall component of sense memory.
2. **Patterning.** This tool works in two parts, including the act of recognizing patterns and forming them. This involves identifying a repeating form or a plan in a seemingly arbitrary arrangement, as well as the ability to combine components or processes in a regular way to create a pattern.
3. **Abstracting.** This involves capturing the essential nature of a thing. Abstracting means concentrating on one feature of a thing or process, in order to boil it down-to basics and grasp its essence. One key aspect of this is analogizing or comprehending a practical similarity between seemingly different things.
4. **Embodied thinking.** This tool involves two skills, which feed into each other—kinesthetic thinking and empathizing. Kinesthetic thinking is thinking with the body while empathizing requires imagining oneself in someone else's position, walking in their shoes, feeling what they might feel.
5. **Modeling.** This process involves representing something complex or difficult to experience, in real or theoretical terms, in order to study its nature, composition or purpose. Dimensional thinking, paired with abstractions and analogies, help create models of things or processes that explain the real world.
6. **Playing.** This is something that we do just for the fun of it. It may involve creating new rules or breaking the existing ones of established procedures. Simply put, play is using knowledge, body, mind and abilities for the pure enjoyment of using them. When imaginative or innovative people play with things or concepts or processes, they may open doors to new ways of thinking and transform ideas.
7. **Synthesizing.** The final cognitive tool ties together all of the previous ones. It entails putting different ways-of-knowing together,

> into synthesized knowledge. When we fully understand something our feelings, senses, knowledge and experiences come together in a multi-faceted and cohesive way. A person feels what they know and knows what they feel.

These skills are described in more detail in the 2011 article from Mishra, Koehler, & Henriksen. They argue that these *tools*, or habits of mind, comprise a framework for trans-disciplinary creativity and can serve as the basis for the kinds of curricula that are essential for the "conceptual age" (Gardner, 2007; Pink, 2005). While this article was published in 2011, it actually pre-figures work that was done earlier. Given the vagaries of publishing schedules and some of the other aspects of academic life and research we noted, most of the writing and thinking of this article occurred in 2008-2009. So that, when one of our first major research studies based on this framework began to develop in 2010, it was based upon constructs laid out in this 2011 article. This is just another key reflection of the web-like, branching, and non-linear path that the development of a program of research, theory and practice may take.

Synthesizing the pieces of our work. We have described the three key strands of work (TPACK, defining creativity and the work on trans-disciplinary creativity) that worked as the foundation of the work that we engaged in next. One way of thinking about this is that the work around TPACK defined the *need* for this work—clearly teachers and students needed this emphasis on creativity. The strand around defining creativity focuses on *what* it is that we are aiming for. Building on Besemer's work the definition products allowed us to identify the goals that we would like to achieve. Finally, the Root-Bernsteins' work on trans-disciplinary creativity and avocations as guiding creative output provided us with a preliminary roadmap of *how* we could achieve the goals of enhancing creativity in our students. Taken together these three approaches scaffold the work that we will describe below. Specifically, as follows, we will speak to (a) a research study of accomplished teachers that focuses on their creative output and processes; (b) a master's level course that utilized the trans-disciplinary framework of 7 skills to help teachers become more creative in their teaching; and (c) the development of a rubric to evaluate creative artifacts that come from this course.

A FIRST RESEARCH PROJECT: LEARNING FROM CREATIVE EDUCATORS

Laying the Groundwork: Foundations of the Study

The development of a research program such as the work that we are doing at Michigan State University often begins in theory and practice. But it also requires that some exploratory work into the phenomena occurs early on in the program, in order to understand some basic foundations, and to see that there really is a case for the phenomena at hand, in real world terms.

With respect to our program on creativity and trans-disciplinary thinking, some of this early work into trans-disciplinary thinking skills, in connecting it to the practices of excellent teachers, came in the form of a dissertation study. Elements of that study are already slated for a Teachers College Record article (Henriksen & Mishra, in press), and have appeared in other publications (Henriksen & Mishra, 2013; Henriksen, 2014).

In this particular study focused broadly on creativity among exceptional teachers, Henriksen (2011) examined whether such teachers used trans-disciplinary thinking skills, and how they implemented them into their successful teaching practices. This trans-disciplinary thinking aspect of the study will be the focus of a more in-depth research article, but since the study itself was one of several building blocks for the line of research

discussed in this chapter, we will broadly outline the basics and give a sense of its place in the larger program and trajectory of our work.

This study was grounded in seven trans-disciplinary skills identified above. Root-Bernstein had shown how trans-disciplinary thinking as a whole played out in the work and thought processes of the most creative and talented scientists. However, this phenomenon had never been studied among the best and most creative teachers. So, as one of her research questions, Henriksen (2011) examined whether such teachers use these thinking skills, and how these play out in their classrooms and teaching practices.

Crafting the Research: Methods of the Study

This qualitative study involved in-depth interviews teachers who had either received, or been a national finalist for, the National Teacher of the Year award. As National Teacher of the Year winners/finalists, these award-winning teachers most certainly qualified as successful and talented (as with the scientists noted in Root-Bernstein's work), but they can also be considered as *creative*. There is a strong body of work in educational research that asserts and demonstrates that creative teaching *is* effective teaching, and that these two constructs overlap quite a bit. So, creative teachers are effective teachers (Anderson, 2002; Bain, 2004; Bleedron, 2003, 2005; Chambers, 1973; Cropley, 1967, 2001; Davidovitch & Milgram, 2006; Esquivel, 1995; Fasko, 2000-01; Milgram, 1979; Newcomb, McKracken, & Warmbrod, 1993; Renzulli, 1992; Torrance, 1981, 1995). Moreover, Henriksen examined 15 randomly chosen applications for National Teachers of the Year (all of which were publicly available information online); and found that all of these had implicit and explicit mentions of creativity in their teaching philosophies, practices, and examples.

All interview data from long, in-depth (1 ½ to 2 hour) interviews with eight National Teacher winners/finalists, was transcribed, and then coded in three iterations of coding, to identify salient themes. The three rounds of codes helped to develop a set of themes that was both based on the research questions of the study (framed around creativity and trans-disciplinary thinking), and emergent (any interesting ideas and common themes that seemed to emerge). An inter-coder reliability measure was applied with a secondary coder, for a reasonable and acceptable measure of 76% (Hruschka, Schwartz, John, Picone-Decaro, Jenkins, & Carey, 2004). And several of Creswell's eight verification techniques for qualitative research were also used, to verify the methodological practices (Creswell, 1998; 2005). For more detail on the other aspects of this study not covered in this chapter, see Henriksen and Mishra (in press).

Looking Across the Data: Findings of the Research

This study showed that, across the board, trans-disciplinary skills were thought of as highly valuable and frequently used by these eight and successful and accomplished teachers; and that these skills help to enrich their effectiveness and classroom creativity. Not only did all of the teachers in the study talk more generally about the ways that they value these skills, they also gave specific details on their implementation. Each of the teachers in the study gave examples and noted the ways that each of these skills played out in their classrooms and teaching practices.

Generally speaking, each skill seemed to function in a slightly different way, as was noted in the way that the teachers' spoke about them. While we are not able to go into complete detail or review of the data in this space (since this part of the study is slated as the complete focus of another article), we will give a quite overview of the themes of how these skills play out, with a brief example or quote from one of the teacher's in this study.

Perceiving, with all of its focus on careful observation, was noted as a skill that helped these teachers to build an understanding of their students and their learning progress, along with the classroom overall. It became part of developing a sensitive awareness to the profession practice of teaching. And several of the teachers noted its criticality as the first step to understanding anything, as a skill that they worked to impart to students. One National Teacher of Year winner, Sarah Wessling, stated it as such,

I teach my students critical thinking skills for my language arts courses, and the first step is always observation. If we are not careful observers, we have no chance of doing any of the other work that we need to do to be creative, so observation is the first step…I set out to be a careful observer as a teacher.

Patterning was discussed as a ways to help the teachers understand classroom/learning trends, and to help students see connections. While patterning in some ways played out as a skill they tried to develop in their students across disciplines, it was also something that they saw as necessary in broader terms in their teaching. Another teacher in the study, a middle school science teacher, noted that,

As you become more expert in the age level at which you're teaching, you see patterns. When I approach a new topic, I immediately start to chunk it out into what would I see as a flow from the viewpoint of an 11 and 12 year old mind. What is it that they know and what's the foundation? What can I find out what they know about it? Where do I go from there? What are the sizable chunks? What's the angle of the attack? What's the way to make it relevant to their lives? That is a pattern of teaching, and in the structure of the day…I find I have to have a pattern to help accommodate attention spans.

Abstraction was discussed as being a skill that was valuable as a pedagogical approach to help in explaining complicated ideas or processes in a more relatable form. Toward this end, the teachers gave numerous instances of how abstraction plays out across different teaching topics and themes. For example, Cindi Rigsbee, a middle and high school language arts teacher, described how she begins with a smaller encapsulation of an idea to get toward something bigger and more complex. She stated that,

I start off the year teaching students all the elements of a short story so that they're ready to understand the elements of a novel. We abstract out from, in very small pieces, the things that they are going to see in a bigger way which will be harder to pinpoint as quickly, like plot. In a novel characters are going to be so much more developed than they are in a short story. Setting - in a short story it may be one place, in a novel it's going to change and will be different places. Theme - there can be several themes in a novel whereas a short story is probably going to focus on just one thing.

Embodied thinking was thought to be invaluable for helping to make learning experiences active and engaging. The award-winning teachers in this study were able to provide varied examples of how bodily thinking and empathy (the two components of embodied thinking) helped students to physically connect with ideas. For instance, Michael Geisen, a National Teacher winner in 2008, commented that,

I get kids up and moving and acting things out. Oftentimes they're playing out the role of molecules or something like that. When we're learning about the seasons and what causes the seasons - the path of the sun through the sky - we get up and actually trace the path of the sun through the sky with our arms…We trace that arc out, then we might make it into a little dance move, like "Oh, yeah!

It's wintertime!" Then in the summer it's a much higher arc and starts way up in the northeast… Whenever possible I'll go through a lot of different exercises where they're actually using their bodies to understand a science idea.

Modeling was a way of making learning more real and tangible to students, through representing objects or ideas that might otherwise be hard to understand. The teachers described how models happen everywhere in teaching, whether in creating a schema for writing in language arts, or for ideas in math and science. Models help make ideas, or different to grasp objects or concepts, into a more concrete thing. One National Teacher finalist who taught elementary school, noted that they were useful even with little children, in making geometric shapes more tactile. She noted that,

When we're studying polyhedrons, I have students actually make them with toothpicks and gumdrops…we're making little models to give a demonstration of how they work or look. And we do stuff like that all the time. Again, the students are creating something, they're using their hands, they're talking about it, and they have that accountable talk. They're using all different modes of thinking within modeling.

Playing was viewed by the teachers as a critical way to make learning fun and promoting a curiosity for ideas and learning in their students. Since intellectual play is crucial to being able to engage with ideas, and get excited and motivated to learn more, each of the teachers reflected on how meaningful play was a part of their teaching practice. Alex Kajitani, a middle school math teacher, talked about how play makes learning from, and saves students and teachers from the more "humdrum" aspects of standard curricula. He described it as such,

Play is…I think it's actually crucial and it's necessary. The truth is as teachers we often have to deliver the exact same kinds of lessons. So some days when I have all my classes doing the exact same thing, I deliver the same lesson five times. Sometimes I just have to let things get weird or let things get fun. I do different characters to talk about how math relates to different subjects. One special character is 'the Math Comedian,' and he tells jokes…The students love it.

Synthesizing involved the totality of who these teachers are and how they bring their knowledge together and use the previous skills for more comprehensive and creative learning. This particular skill can feel a bit more abstract to talk about, since it involves a kind of synthesized knowledge, where we know what we feel and we feel what we know. But it came about strongly in this study, in terms of how these award-winning teachers view themselves and who they are, as being deeply connected to teaching practice. The overall theme of this full study was *we teach who we are*, which is where the entire synthesis piece came in. Sarah Wessling, the 2010 National Teacher winner, summed it up as such,

Outside pursuits always factor into your thinking about your classroom or your students - all the time…I think that we teach who we are, and I know that I teach who I am. So, if I am really into kickboxing, I see how facets of that experience connect to things that we're learning in class…I think that's true all of the time, that whatever it is that interests you…how that energy manifests itself in the fabric of the classroom.

IMPORTANT TAKEAWAYS: SUMMARIZING THE RESEARCH

A major piece of this study was in the finding that trans-disciplinary skills are not only valuable in the thought process of highly successful teachers – they are also frequently used in their classroom practice. Every teacher in the study

provided several concrete examples and spoke in detail about the ways that these trans-disciplinary skills integral to effective and creative teaching practice. In general, how they used each of these skills tended to revolve around a particular theme of teaching and learning. *Observation* enhances awareness of classroom dynamics, and of students and their learning progress. *Patterning* was important for helping teachers to understand and assess trends in classroom situations, events, and again, in student learning. *Abstraction* was often used as a technique to help clarify and explain complex ideas in a more clear and understandable form for students. *Embodied thinking* was a way of making learning more active and exciting, by connecting ideas to physicality. *Modeling* was noted as an effective tool for making learning more comprehensible, by making ideas, objects and themes, more realistic and concrete for students. *Play* was essential to creativity in teaching and learning, because it is what makes learning fun for teachers and students, and helps to develop a sense of curiosity about ideas. *Synthesizing* overall became a function of who each of these teachers is as a person. This skill was reflected in how connect to creative thinking in both their teaching and their lives. The notion that *we teach who we are* therefore became central to these teachers, and was exemplified throughout the study. Overall, the trans-disciplinary (or creative-cognitive skills) discussed with these accomplished teachers were seen as being highly relevant within creative teaching practices, each in its own way.

APPLYING RESEARCH AND THEORY INTO PRACTICE: CREATIVITY IN OUR TEACHING

Even as we were engaged in research (on the creative practices of the most accomplished teachers) and developing our definitions of creativity, our team was invited to develop a course on creativity to be taught in the Master's of Educational Technology Program at our college. The MAET program is grounded in the TPACK framework (AACTE, 2008; Mishra & Koehler, 2006) with an expectation that graduates will, over time, develop and demonstrate knowledge that is deep, complex, fluid, and flexible, so as to meet the demands of current and future learning contexts. This is done by an approach called "deep-play" (Koehler et. al., 2011), which is an engagement with rich problems of pedagogy, technology, and content and their interrelationships. This is seen as a creative process, seeking to construct new ways of seeing the world, and new approaches to using technology, in order to develop innovative pedagogical solutions. As described in the TPACK framework, we believe that the best way to learn about educational technology, design, research and scholarship is by actually engaging in educational technology design, research, and scholarship. In our master's program this means real-world engagement with tools, pedagogies and their relationship to content domains. In our approach, participants engage in deep conversations about their practices through opportunities to experiment and play with ideas, tools and subject matter and finally, reflect on their own learning.

Though creativity had been a critical part of the program overall, there was no specific course devoted to it. The work we had been doing in this area seemed appropriate to develop a course that would focus on creativity in teaching and learning. Thus, in the fall of 2008 we offered the first version of a course with that title: *Creativity in Teaching and Learning*. It was at that point that our work, which had only existed in the realm of theory and research, descended into the marshy swamplands of practice.

At the foundation of this course was the idea of trans-disciplinary creativity – specifically the 7 trans-disciplinary skills that we had identified in Mishra, Koehler and Henriksen (2011). We believed that an emphasis on this form of knowledge (trans-disciplinary knowledge) allows learners to both be immersed in disciplinary practices, and yet

also transcend them. Thus, trans-disciplinary approaches eschew traditional distinctions between art and science, applied and pure knowledge. This approach seeks to find commonalities between strategies and habits of thought used by creative individuals in any discipline. By emphasizing these 7 cognitive tools learners move beyond looking for one *correct* solution, towards an approach that integrates different solutions, viewpoints, or perspectives.

These 7 cognitive tools were interwoven through the design of the master's seminar. Students spent 2 weeks engaged with each of the 7 cognitive tools during which they participated in reading *Sparks of Genius*, completed a range of assignments, and developed and carried out thinking exercises. Each module had an activity-based assignment that motivated students to utilize each of these trans-disciplinary cognitive skills.

Since our course is fully online, our students participate from all over the world. Most of our course participants are teachers, educators, and experts in their fields. While some of these teachers recently started their practice, others have been in the profession from a long time and hold expertise in what they do. Their topic areas also vary from arts to science, math to history, to technology and more. Some of these participants also teach students with special needs. The commonality is that they come to the course with a desire to learn and create, with little to no technical knowledge of research in creativity in teaching and learning. This somewhat levels the playing field for all of them and makes the course assignments more engaging and personal. A few key themes about the design of the course and the assignments that should be identified upfront are as follows.

First, students early on in the semester identify a content area that they teach in, and explore ideas in this area through different lenses. Throughout the semester, the same key concepts are explored in different ways—pushing the participants to "re-see" the same content through different trans-disciplinary lenses. Second, technology, though critical for the implementation of these assignments, is never foregrounded. Rather, students are expected to independently find the appropriate tool that is best suited for their work. Third, and finally, all the assignments are open-ended with no predetermined guidelines about the final nature of the projects to be delivered. Combined with the range of topics being covered and the range of technologies being used, it should be no surprise that the kinds of student work that emerge throughout the semester differ greatly from each other. This diversity, of course, offers significant challenges to the instructors who have to offer feedback and grades to the participants on the work they complete for the course.

EXAMPLES IN ACTION: WHAT DO THESE IDEAS LOOK LIKE IN STUDENT WORK?

To give a better sense of how these ideas occur in student work and projects, we describe how we took the theoretical ideas of trans-disciplinary thinking and applied them to the design of the coursework. We offer specific descriptions of assignments and of one example of student work for each of the skills.

Perceiving. This module activity required course participants to choose a well-known or familiar image, artifact, sound, song, movement, taste, scent, or other part of their core sensory understanding of their respective topic areas, to observe this familiar thing and to re-image it in a new form. During their observations of the chosen item, each of them focused both on how s/he experience her/his topic, and what it looks, sounds, feels, tastes, smells, and moves like.

Upon completing observing their items, all participants re-imagine and re-present it in their work space. Their re-imagined representation should communicate the topic in a way that ap-

peals to a different sense than originally identified and be represented in an appropriate way (chosen by them). They represent and report their topic in a way that is most applicable to them: a video, song, poem, written paragraph, etc., and through a 500-word essay, reflecting back to the readings for this module.

Sample student work. A second-grade teacher whose topic was *interacting with non-fiction* chose the National Geographic logo as her familiar image. She then re-imagined the logo using two modes of representation: video and poem. She created a short stop-motion animation film, and a poem. The following is an excerpt from this poem.

The realm of nonfiction
Wrapped up in a simple, yellow frame
Stands for more than just its surface
It stands for the people
The places
The events
That make up our being
The realm of nonfiction
Wrapped up in a simple, yellow frame
Is our yesterday
Our today
And our tomorrow

Patterning. This module activity was divided into two parts for the course participants. First, identifying existing patterns in their topic areas, and second, coming up with a new pattern that could be applied to the same content. This was followed by a 500-word essay reflecting on the activity and readings.

Sample student work. In this example, a middle and high school math teacher sought to identify patterns in prime numbers. Although he found no evidence to describe an overall pattern between these numbers, he came up with several visual representations to create new patterns between them. This image (Figure 1) depicts one of his representations. He called this pattern 'prime waves', where he plotted sinusoidal waves for each prime number increasing the phase by the value of the prime number.

Figure 1. Pattern of prime numbers in the form of sinusoidal waves

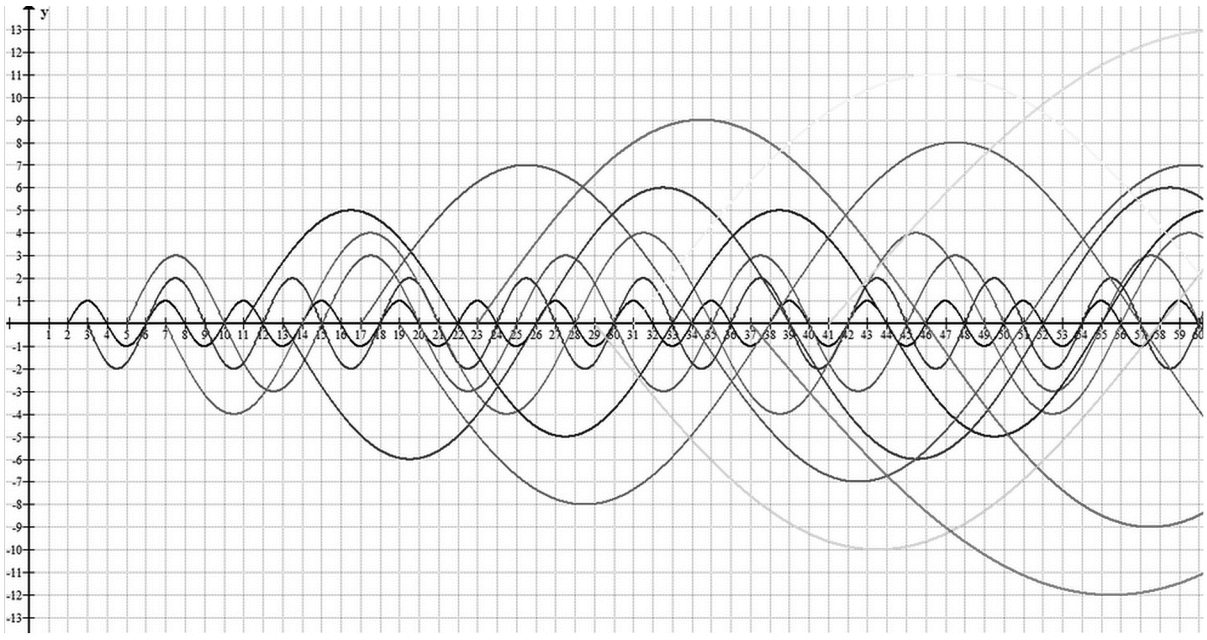
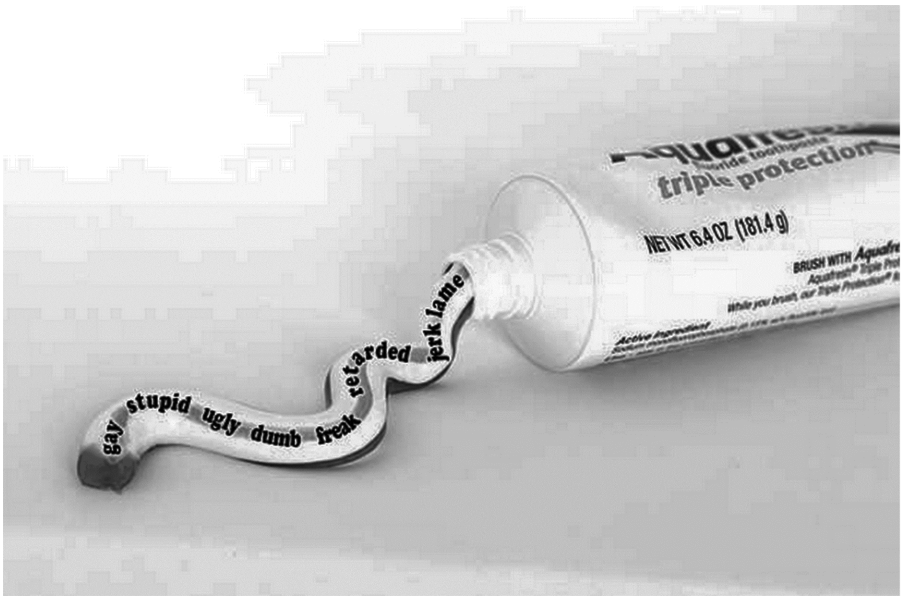


Figure 2. Squeezed tube of toothpaste was used to show analogy with words said on the internet. They cannot be taken back. An example of abstracting.



Abstracting. In this module activity, the course participants were expected to explore various abstractions for an idea, topic, object, or person related to their content area or topic. Then, they abstracted a single element from their respective topic areas and created their own representations of the abstraction through two different mediums, with a goal of showing the essential quality of their topic areas through two complimentary means. As always, this activity was supported by a 500-word reflection.

Sample student work. A technology coach at an international school worked on the topic of digital citizenship. He explored the idea that words, once put into the Internet, cannot be taken back. He employed an analogy of squeezing a tube of toothpaste and how difficult it is to get it back in (see Figure 2). In addition to this, he then created an audio clip commenting on how "friendship can be fragile," and we need to be more careful with what we say to people on the Internet. Both these abstractions represented the idea of Internet etiquette of being a good digital citizen.

Embodied Thinking. In this module, the course participants were asked to think of aspects in their respective topic areas that are normally considered as something they think about with their own bodies. They were then asked to express their potential body experiences for their topics using any creative modality of their choice to display the transitional process of thinking with their bodies.

Sample student work. In this example, a middle school social studies teacher explored the cycle of Chinese dynasties as running in circles or going on a merry-go-round. She expressed her emotions of feeling this circular motion via a palindromic poem and an image of a circle made of this poem, where she explored how running in circles feels tiring and relieving at the same time.

dynasty
unending circle
new ruler beginning
increasing popularity
favor gaining
power coming with peace

but struggle causes change
switching rulers
repeating itself
in cycle
cycle in
itself repeating
rulers switching
change causes struggle but
peace with coming power
gaining favor
popularity increasing
beginning ruler new
circle unending
dynasty

Modeling and Dimensional Thinking. This module activity required our course participants to consider one aspect of their topic areas dimensionally and create a graphic representation of the many dimensions. To do this, they looked at their topic areas from different perspectives. Like all the other modules, they reflected on this activity using a 500-word essay.

Sample student work. A US and World History teacher used the modeling activity to look at the World War II, specifically the Nazi movement, from the perspective of German people. She modeled their feelings in a burning flame (Figure 3), and showed what emotions gave them warmth on the surface, and were also fueling the movement

Figure 3. A model of the emotions of German people towards the newly-formed Nazi party during the Second World War

in the core. She used the following graphical representation for this activity.

Playing. In this module, the course participants looked at the last six modules and identified where play had occurred and what specific aspects of it had emerged. Having identified this, they created a meaningful and playful activity for the individuals (students, colleagues, etc.) they work with, and reflected on this activity using the 500-word essay.

Sample student work. A teacher of English and Theater chose the topic Educational Musicals and created a playful activity where he imagined an object (say a ball) and transformed it into a new imaginary object while miming the transformation. Each student then followed this process by taking the center stage and creating a new object. The following images show them playing on stage (Figures 4, 5).

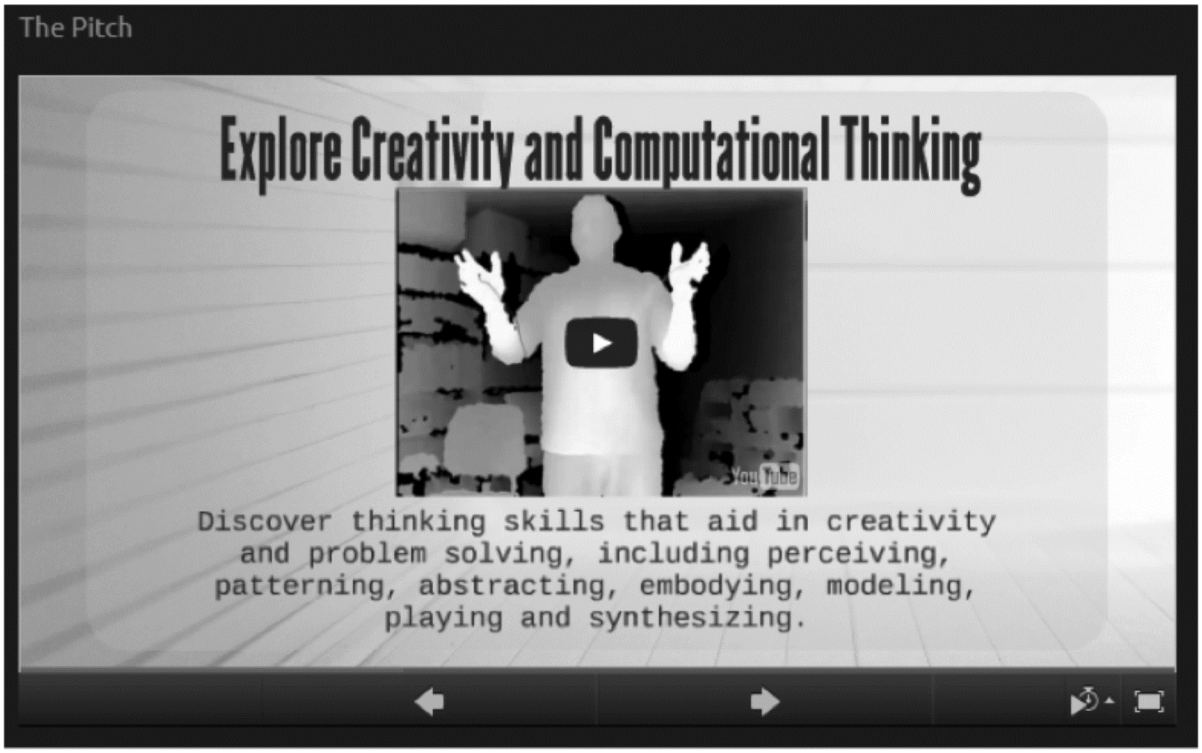
Synthesizing. In this final module, each student was asked to demonstrate a synthesis of his/her work in the course by creating three sales pitches intended to sell a new, creatively enriched curriculum to his/her school administrators and fellow teachers. The three pitches were made using an essay called the *White Paper*, an *elevator pitch*, and a tweet of 140 characters or fewer.

***Sample student work*.** An outreach coordinator of the Art and Science at a middle school working on bridging the gap between the two disciplines took algorithms as his topic area and worked throughout the semester at representing the aesthetics in computer programming. In his synthesis, he underscored the inherent beauty in computer programming through his *white paper* where he connected to previous readings, noting how "Writing a program 'can be like composing poetry or music…programming can give us both intellectual and emotional satisfaction' (Knuth, 1974, p. 670)." For his elevator pitch, he created a multimodal Prezi presentation (Figure 6) where he emphasized on the thinking skills satisfied by computer programming and algorithms. He also

Figure 4. Showing module activity Play where one of our course participants (seen in center in Figure 4) is demonstrating how the activity will be played

Figure 5. Showing module activity Play where one of our course participants (seen in center in Figure 4) is demonstrating how the activity will be played

Figure 6. A slide from Prezi-based elevator pitch for the synthesis module



wrote a tweet (Figure 7) in the form of a computer code, pitching his ideas and website to a wider audience.

Besides these seven assignments, there was a second thread of assignments focused on students' personal creativity. This line of assignments emerged from our research that showed that creative individuals are creative across disciplines (as shown in the Henriksen dissertation study). In these assignments (Called the "Creative I") students explored different three aspects of creativity and connected it to their personal and professional lives. The first aspect they explore is that of defining the creative process, which they do through interviewing a creative person, such as an artist, songwriter, designer or scientist. The students then reflect on the interview and what it means to them as individuals. The second part of the assignment expands on the idea of cross-pollination of ideas across disciplines, by asking participants to represent ideas from the class through rewriting the lyrics of an existing song. The third, and the final, part of this series of assignments asks participants to think about a space that they find engaging and conducive to creativity. Through exploring the architecture of space, asks them to explore this space physically and mentally to think and feel what makes it special. They also take 5 to 15 photographs of this space from multiple perspectives to capture the elements that make this space interesting. Like the other two assignments, they are asked to reflect on this activity. Together these three assignments constitute of the Creative 'I' assignment that takes the findings of Henriksen (2011) and puts them to practice.

TAKEAWAYS AND CHALLENGES FROM TEACHING CREATIVITY

Three noteworthy processes and outcomes were evident in students who participated in the course. First, students reported struggling through several of the activities for many of the cognitive tools. As the course was composed of a diverse mix of teachers, over the years, their content areas have ranged from kindergarten literacy to adult medical education, and from heat transfer to the lived experiences of soldiers in World War I. Many students reported that they had initial difficulty in thinking about their topics in new ways, using the seven cognitive tools. This speaks to the difficulty faced by teachers who have not been pushed to thinking creatively about their content and suggests that this is something that needs further work if we are to fostering transformative, trans-disciplinary teaching and learning.

Second, despite the frustrations and tensions, it was clear that many students *enjoyed* doing the work. After overcoming their initial reluctance to re-think and re-imagine their content areas students overwhelmingly reported enjoyment, and more importantly professional growth. Students reported that re-thinking their content areas made

Figure 7. Tweet pitch from a student in CEP 818 course as a part of the Synthesis module

them understand them more fully and rendered them more able to help their students understand the content material on a deep and integrated level.

Third and finally, students were able to think deeply about their own learning of the material, and even more importantly, however students were able, to integrate the material into their own teaching. Students were able to demonstrate their learned understanding of the seven cognitive tools and also their ability to teach with these tools in curriculum plans and activities they developed for their students.

Finally, an important challenge faced by the instructors of the course, as mentioned above, has to do with evaluating the work being done by the students. Despite the obvious demonstrations of creativity by the students in representing their content through varied means and schemes, it was difficult to come up with a consistent, reasonably rigorous approach towards providing feedback to the students and evaluating their work at the end of the semester. This does not of course come as a surprise to those of us engaged in teaching creativity, but it does speak to the need for better evaluation approaches for creative output. It is to this that we turn next.

Evaluating the Creative Artifact: The Development of a Novel, Effective, Whole Rubric

Up to this point, in looking across the development of our program of research theory, and practice around creativity, we have described various aspects of our framework. This includes how we began with a definition for the term (Novel, Effective and Whole), how and why we developed the trans-disciplinary framework for creativity, and how it has become a part of our teaching practice through the Master's course on creativity in teaching. And in recent years, we have been bringing these aspects together, in using the Novel, Effective and Whole definition, to evaluate some of the creative artifacts (a few of which are described above), created by students in the course.

This reveals just one further example of how theory and practice can spur on new directions for research. Toward this end, we have recently created and been using a flexible rubric, based on the Novel, Effective, and Whole definition, to evaluate creativity shown in the artifacts created by students in CEP 818. This research began as we started to realize that despite the importance of creativity in teaching and learning, the topic often gets short shrift because it is thought of as difficult to evaluate – too subjective for teachers to use in considering student projects. And while we cannot and should not be rigidly defined or evaluated, it is still important to have a somewhat objective gauge on it, to consider how it plays out in products or projects, and to give teachers a way to assess creative products. Lord William Thomson Kelvin once noted that an inability to measure a thing that we are speaking of is a "meager and unsatisfactory" kind of knowledge (Thomson, 1891, p, 80-81). In order to really understand what creativity means, and how it functions within a discipline such as teaching, it was important not only to develop a meaningful definition, but also to gauge it in students work (Mishra, Henriksen & the Deep-Play Research Group, 2013).

As instructors, we had been observing some of the unique and interesting project work that students in CEP 818 created for the course. And while individual student projects were certainly diverse and rooted within the context that each of these teachers (our students) worked within – we recognized that many were quite creative for their context, while some others didn't feel like they displayed quite as much creativity. This required us to consider what makes some of the student work more creative and some of it less so, and how do we operationalize and measure that (not necessarily for grading purposes, but at least in the context of research on creativity).

As we considered ways that other researchers had studied or evaluated creativity in student work,

we needed a sense of the existing instruments for creativity measurements. So we began to conduct a content analysis of existing instruments for measuring creativity, through examination of two core APA databases of measures and instruments. What we found was that among the pool of existing creativity measures, most instruments focused on things like personality inventories, or psychometric tests of individuals' divergent thinking skills. Specifically, we found that of 83 measures of creativity currently listed on APA's PsycTESTS database, just 3 were devoted to evaluating products or artifacts. The rest of the measures were split between three broad categories: 29 instruments were self-reports measures of creativity; 12 were personality inventories and 11 instruments measured attitudes and interests. And while these things are valuable in a psychological context, within the context of a classroom, they are not really things that a teacher has much control over. Teachers' have most influence over either the climate of a classroom (creative environment), or the project work that their students produce (judgment of creative products). And both of those areas were among the smallest categories instrumentation, and somewhat lacking in available measures.

So, in connecting back to practice, we realized that our students were doing a wide-variety of open-ended and creative projects in the CEP 818, *Creativity in Teaching and Learning* course, and that this was a useful opportunity to begin investigating and evaluating the evaluation of creative products in teaching and learning. We decided to develop a flexible (somewhat open-ended) rubric, for assessing creative products/projects, and use this as research on our students work in the course.

Our decision to focus on measuring the end products of creative process stemmed from two reasons. One is that the creative process is something that cannot always be seen by the outsider. At the end of the day, what we have is just what the creative process produced. So, in our view, that was important to evaluate. Another reason came from our attention to actual classroom contexts where must regularly evaluate and judge student work. Though creative process is important and valuable, as educators we must develop better measures and rubrics to speak systematically about the creative products that students do. If we wish to emphasize open-ended assignments, project based learning, and creativity in education, this task becomes even more important.

A good rubric must define what it is that will be measured, and we had already developed a fairly clear definition for what we thought creativity is, based on Mishra & Koehler's (2008) three-part Novel, Effective, and Whole, definition. We described these components earlier in the paper, and each of these three aspects tends to touch on a different part of creativity:

So, working forward, we set up a measure that quite simply provides a score between 1 and 5 for each of these Novel, Effective, and Whole dimensions. The rubric gives qualitative definitions at each score point as well as providing examples (or anchor artifacts) to give a scorer an idea of a range of products that may be expected at each point.

We started by having two researchers independently look across and become familiar with each project in the data set. From the first three iterations (semesters) of the course, there were over 350 different student generated artifacts that we had collected. After the researchers developed a strong overall sense of the data, they began to work at applying the rubric, by conducting a preliminary coding of a subset of the projects. This preliminary coding went along with a series of back-and-forth discussions, aimed at building a shared and consistent understanding of how to apply each of the different score points between 1 and 5, along each of the three NEW dimensions. Once consensus had been reached on the scoring guidelines for the projects/data, the researchers checked their own sense of the rubric and data, by doing an inter-rater reliability test (having the two

Table 1. From Mishra & Koehler, 2008 (adapted from Besemer & O'Quin, 1999)

Creative solutions are…	
Novel	Fresh, unusual, unique, surprising, startling, astonishing, astounding, germinal, trendsetting, radical, revolutionary, influential, pioneering
Effective	Valuable, important, significant, essential, necessary, logical, sensible, relevant, appropriate, adequate, functional, operable, useful, user-friendly
Whole	Organic, ordered, style, arranged, organized, formed, complete, elegant, graceful, charming, attractive, refined, complex, intricate, ornate, interesting, understandable, meaningful, clear, self-explanatory, well crafted, skillful, well made, meticulous

coders independently code 10% of the projects, and check scoring agreement). There was 87% agreement between the coders.

As noted, the rubric gives a definition for each score point and more importantly, gives some example anchor projects to demonstrate and typify each of those number scores, with examples of projects from different contexts (i.e. anchor the coding with examples of what each score might look like, using examples of teaching artifacts that our students create based in different subject matters or contexts, etc.). The rubric definitions are somewhat brief, and are aimed at helping any coder/scorer understand a verbal description of the scoring. But the verbal definition of each score is not enough (since people can perceive qualitative descriptions/judgments differently). This is why the score point definitions for Novel, Effective, and Whole are given along with visual description offered by anchor examples. In terms of the definitions, a score of "1" for novelty would demonstrate: "Lack of anything unique or novel, and lack of content or substance to even offer opportunities for novelty." While a score of "5" for novelty would offer: "Strong qualities of uniqueness, in ways that could be exciting or interesting to learners – is very novel or different from other examples in the data set and shows a relatively very novel approach to teaching of subject matter (in relative terms to other teaching artifacts/ projects in the course)."

Thus far, the research from this first round of project coding has been described in another publication (Mishra, Henriksen & the Deep-Play Research Group, 2013), and is currently being written up in more detail for a journal article. Beyond this, we are currently engaged in rating a whole range of other, more recent student artifacts (from more current versions of the creativity course) as an ongoing test of this rubric. The rubric has become a part of our practice within the course, and is linked to our research and our trans-disciplinary framework for creativity.

LOOKING FORWARD, LOOKING BACK

Over the past six years or more we have been engaged in this work on better understanding how creativity can be brought into teaching and learning and the role that technology plays in this process. This had led to multiple publications (over 20) and conference presentations where we have shared our evolving conceptualization of our ideas. An important venue for our work has been the journal *Tech Trends,* taking advantage of an invitation to write a series of articles broadly under the rubric *Rethinking Creativity and Technology in the 21st Century.* This series has allowed us to explore and expand upon our research, to publish first drafts, as it were, of our ideas. This combined with articles written for other journals has meant that our work has been continually tested by reviewers and editors alike, pushing us to maintain both high quality and productivity. One key to our work is its

collaborative nature. Though led by the first two authors of this chapter (with the third author as a group member) the Deep-Play Group is a shared commitment by a range of graduate students and faculty (some at other institutions) to push the boundaries of what we know about the application of new technology to creative pedagogy.

The diagram below provides a bird's eye view of the work we have been engaged in.

The connections between different components of a program of research, theory and practice, (like what we have been trying to build in our current work), become inextricable and web-like in how they connect to each other. Sometimes research drives practice and sometimes vice-versa (or they may act on each other simultaneously in a back-and-forth, dialectic relationship). And theory can emerge from research or practice, or it can push it along. As we reflect on our experiences of developing this ongoing area of work, it can be hard to look back and always say which aspect was driving which. Instead they often talk to each other in a dialogue, informing the work of the larger whole, in complex and often non-linear ways.

At one level we have reached a kind of point of cusp in this line of work. We have over time developed a framework that allows us to think deeply about the role of creativity in teaching and learning. We have applied it to teaching a master's level seminar for practicing teachers (with some work also having gone into professional development of teachers). That said, we have extensive plans for the future of this work, along multiple directions. These include looking at how new digital technologies such as 3D printing and computational thinking can be used to instantiate these trans-disciplinary skills; an international survey on 21st century learning; the role of aesthetics in science learning (both in popular science video programs and in the daily work of scientists). We have tentative plans for two books, one emerging out of the Henriksen (2011) dissertation research focusing on exemplary teachers; and another, currently being planned, focusing on the habits of mind of significant trans-disciplinary thinkers (i.e. people who have succeeded in one domain even while having had significant training in some other domain, such as a mathematician who also excels in music or vice versa).

CONCLUSION

There are a few key themes that stand out in our work. First, as mentioned, is its intensely collaborative nature. Creativity is a wide and complex domain of inquiry and if we are to make headway in this area we have to marshal the intellectual resources and expertise of a wide range of individuals. In this the Deep-Play Research group has been key, providing a steady flow of graduate students with somewhat aligned interests and yet with enough diversity that pushes us as a group to think and work widely.

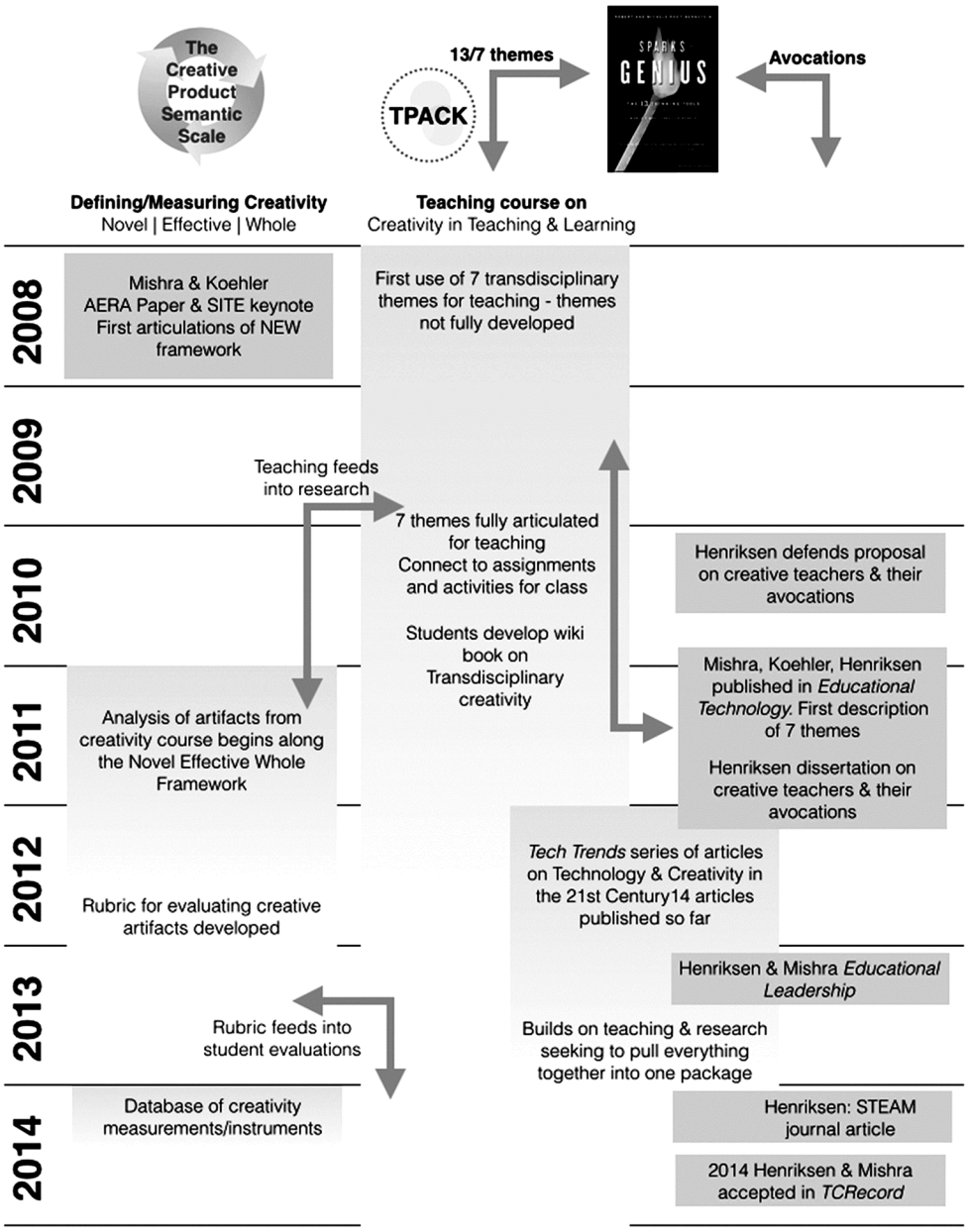
A second theme has been a willingness to take risk, at multiple levels. At one level it is a willingness to put our ideas out there even as they evolve. We believe strongly that the best test of an idea is to have others question and probe it. At another level it is a willingness to take our ideas, as they are, and implement them in our practice (such as the creativity in teaching and learning course).

A third theme, and maybe the most important one, has been to focus on broad theory even while engaged in the nitty-gritty details of practice. It is this focus on theory that integrates much of what we do and that allows us to go beyond the information given to explore new approaches and ideas.

Mishra and Koehler (2006) point to three specific benefits provided by theoretical frameworks: description, inference, and application

1. Theories are *descriptive* allowing us to describe phenomena in powerful ways by providing concepts and terminologies to make sense of the world and explain things

Figure 8. A bird's eye view of the design experiment of the reciprocal relationship between theory, practice and scholarship on creativity in teaching and learning with digital tools



accurately. We believe that our work over the past 6 years or so has allowed us to get a better handle on some of the ideas essential for integrating creativity in pedagogical contexts.

2. Theories are *inferential*, allowing us to make predictions about things we have not yet understood well enough to know what to look for and where to look. Our work on creativity allows us to make inferences about the kinds of contexts that would enhance creativity in teaching and learning and ones what would not. The work on trans-disciplinary creativity in particular offers an innovative lens for thinking about teacher training and professional development.
3. Theories allow stakeholders in educational settings to guide real world *applications* by providing an appropriate level of analysis to bridge the gap between theory and practice, description and design. Our work has been deeply connected to bridging these gaps– through our dual focus on broad theoretical ideas combined with a commitment to practice.

In conclusion, we must reiterate that this is ongoing work and this paper offers just a snapshot of a complex, winding, and non-linear process. And more than anything else it is the complex nature of this process of developing theory, research and practice that we highlight. If our experience tells us anything it is that building this bridge between theory and action, research and practice is a complex one. Our approach has been to take on all of them somewhat simultaneously allowing us to see just dialogic and transactional this act can be. The myth of the scientific method is that there is a simple linear line from facts to hypothesis to theory. Our experience shows that the real story is far more complex.

Sir Peter Medawar (1963) once wrote a paper provocatively titled "Is the scientific paper a fraud?" Answering that question in the affirmative he wrote, "I mean the scientific paper may be a fraud because it misrepresents the process of thought that accompanied or gave rise to the work that is described in the paper (p. 377)" Nowhere is this complicated process reflected more clearly than in the zigzag manner in which our work has progressed.

This is akin to the "crippling deficit" inherent in all narratives attempting to make sense of the past (even the immediate past, as in this article), as pointed out by Jorge L. Borges. As Borges wrote, in reviewing E. T. Bell's classic *Men of Mathematics*, "the chronological order of its events doesn't correspond to its logical and natural order. The definition of its elements very frequently comes last, [and] practice precedes theory" (quoted in Manguel, 1996, p. 22). A reader of this narrative may have faced a similar "deficit." A keen reader, for instance, may notice a 2014 publication identified as being a thematic precursor to a dissertation proposal defended in 2010, and other such time bending facts. Ideally, recent events and activities build on activities and events that are past, to show a linear, progressive narrative. However, the vagaries of journal publishing schedules, the immediate pressures of teaching, the intricate negotiations with co-authors, and the contingent, haphazard nature of life itself have sometimes played narrative havoc with what might otherwise be a clear timeline. In some sense, this contingency lies at the heart of the phenomenon we seek to understand: creativity, and its role in teaching and learning.

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KEY TERMS AND DEFINITIONS

Creativity: A process or way of thinking by which things that both novel and effective and produced. In addition to these elements of newness/originality, and effectiveness/value, creative ideas or products also frequently have an aesthetic sense that is tied to context. In effect, this makes them Novel, Effective, and Whole (or NEW, as termed in the acronym described in the chapter by Mishra, Henriksen & Mehta).

Deep-Play Research Group: A research group comprised of faculty and students from Michigan State University (with collaborators from other institutions) focused on ideas and work that deals with issues of creativity, technology and 21st century teaching and learning. For more information, see: http://www.deep-play.com.

Design-Based Research: Research methods by which interventions are designed and applied in iterations in real-world settings in order to better determine theory and generate new ideas and processes for learning and instruction.

Rubric: An instrument or measure designed to determine scoring and performance standards for a certain population, project or context.

Theoretical Framework: This is the structure that supports the theory of a research study or line of research endeavor. The framework describes the theory that connects to the line of research and explains why a given research problem is of interest for study. It organizes a use of theory to allow research to uncover the meaning, nature, and challenges of a phenomenon. This allows a line of research to provide knowledge and understanding to act in more informed and effective ways.

TPACK (Technological Pedagogical Content Knowledge): A framework for teacher knowledge for technology integration. This framework describes the kinds of knowledge that teachers must have about technology, pedagogy, and content -- as well as the complex interactions and intersections of these knowledge types. The interaction of these bodies of knowledge, both theoretically and in practice, produces flexible knowledge needed to successfully integrate technology use into teaching.

Trans-Disciplinary Thinking: A schema for thinking that involves thinking across disciplines and/or making connections between disciplines. This includes connecting between ideas or disciplinary content in different areas often thought of as disparate, but with connections and links that allow each different area to better explain the other.