**Bridging the Gap Between Developmental Science, Educational Practice and Creativity Infusion**:

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The Creativity Instructional Matrix is a cognitive approach to creativity and reflects up-to-date, robust findings about learning from the developmental sciences (e.g. developmental psychology, cognitive and linguistic science, developmental psychobiology and developmental neuroscience). Findings about children’s motivation, attention, memory, and cognition are embedded in our approach. The following summary is structured around Ostroff’s (2012) research-based “propellers of learning”: Motivation, Attention, Memory, and finally Cognition and Action.

**Motivation:**

Habituation and Novelty Preference: Habituation and novelty preference reflect children’s ability to encode quickly, while newness and change motivate learning (Dixon & Smith, 2008; Tamis-Lemonda & Bornstein, 1989; McCall and Carriger, 1993). Exploration sets up opportunities for learning, reflecting the brain’s responsiveness to novelty (Wolfe, 2006; Diamond, 1995; Lipton & Spelke, 2003; Quinn & Eimas, 1996; Saffran, Aslin, & Newport, 1996). Our approach uses strategies that employ repetition (thereby providing a predictable structure from which to divert), novelty and challenge, thereby maximizing engagement and motivation (Ostroff, 2012).

Confidence: Confidence helps children try and practice new things leading to cognitive gains. For instance, visualizing success increases the likelihood of success (Ayres & Hopt, 1990; Ranganathan, Seimionow, Lui, Sahgal, & Yue, 2003; Pascual-Leon et al., 1995). The Creativity Infusion approach helps teachers promote a growth-mindset (Kamins & Dweck, 1999) and to provide careful, constructive feedback while rewarding intellectual risk-taking (Beghatto, 2008). It also helps teachers implement lesson plans that highlight multimodal strengths, giving each student a way to shine (Gardner, 1993; Bellflower, 2008; Douglas, Burton, & Reese-Durham, 2008).

Play: Play is a child’s prime motivator, enhancing self-control, experimentation and conflict resolution, as well as promoting brain development (Barnett, 1984; Barnett and Storm, 1981; Schweinhart & Weikart, 1997; Pellis and Pellis, 2007; Einon, Morgan, & Kibbler, 1978). Play enhances learning even more than some forms of formal academic preparation (Irsch-Pasek & Golinkoff, 2003; Christakis, Zimmerman, & Garrison, 2007). Our model integrates play, including the use of handling collections, as a way to “cognitively prime” students for complex problem-framing and problem solving (Cheyne & Rubin, 1983; Vygotsky, 1978).

Communal Learning and the Zone of Proximal Development: Our brains and cognitive skills have developed in the service of social relationships, making joining a community (e.g. a community of peer readers, artists, and math users) a primary motivator. Joining a community bootstraps children upwards into learning the most complex skills of their lives, including language use and reading (Gray, 2009; Cooper & Aslin, 1990; Fernald & Kuhl, 1987; Saffron, 2003; Berger, 2006; Bruce, 2005; Smith, 1998). In the Zone of Proximal Development, learners co-construct new capacities in cooperation with more learned partners in a rich, structured environment (Vygotsky 1930/1978). Our model embeds protocols, prompts, dialogue, collaborative approaches and questioning strategies that develop a classroom community of learners (Finkel, 2000; Chorzempa & Lapidus, 2009; Gibbs, Rankin, & Ronzone, 2006).

**Attention:**

Self-regulation: Children’s ability to stay on task, actively participate in learning activities, and pay attention are the most important predictors of school success (DiPerna, Lei, & Reid, 2007; Ladd, Birch, & Buhs, 1999). A child’s attention capabilities predict development, IQ, problem solving and language skills (Bono & Stifler, 2003; Choudhury & Gorman, 2000; Lawson & Ruff, 2004). The ability to regulate arousal levels develops slowly over childhood with help from caregivers and teachers, an ability especially important for at-risk students (Bronson, 2000; Rimm-Kaufman, Curby, Gimm, Nathanson, & Brock, 2009; Blair & Razza, 2007; Buckner, Mezzacappa, & Beardslee, 2003). Study in the arts naturally lends itself to the development of self-regulation; our model develops self-regulation by using: inclusive principles (e.g. Universal Design for Learning) to reach every learner; warm-up strategies to increase mindfulness and help students maintain a calm yet alert physical state; supports for behavioral and emotional control; and reflective practices.

Executive Control : The creativity model used in our project conceives creativity as an executive-level process that draws on basic reasoning, higher-order thinking, affective skills, and psychomotor skills (Veon, 2014). Executive control is the job of the frontal cortex, the last brain region to develop. Executive control is fundamental to cognitive skills required for attention, including planning, decision making, inhibition, and flexibility (Goldberg, 2002; Holler & Greene, 2010; Welsh & Pennington, 1988; Muller, Lieberman, Frye, & Zelazo, 2008). Without executive control, even advanced students struggle in school (Goldberg, 2002). Attention and executive control – including creativity – can be improved by training (Doidge, 2007; Scott, et. Al., 2004). Our model employs strategies for developing attention and executive level skills, thereby providing structure while fostering independence.

Movement: Movement and action can significantly propel attention, helping student use pent-up energy to regulate arousal so that they can focus (Holmes et. Al., 2006). The more a child’s whole body is involved in any learning experience, the more engrossed and focused they are likely to be. Finding flow is the ideal for focusing and sustaining attention (Csikszentmihalyi , 1997; de Manzano, Theorell, Harmat, & Ullen, 2010). Our model uses creative movement throughout all art forms (not just dance) to teach cognitive concepts (Griss, 1994; Wood, 2008; Hruska & Clancy, 2008)), and recommends planning that allows time for intense, effortless attention and flow experiences to emerge over time (Shernoff, Csikszentmihalyi, Schneider, & Shernoff, 2003)

**Memory**:

The term memory can be misleading; there is no file system in the brain that holds individual memories (Ostroff, 2012). What we call memory consists of many abilities corresponding to various brain structures and their interconnections (Cycowicz, 2000). A better term is *remembering*, a verb, since memory is really a process of organizing information in various networks in real time (Wolfe, 2006). When we remember something, we conjure it in the present by assembling details based on our experiences and expectations (Reeder, Martin, & Turner, 2008). Working memory is a system of temporary storage for mental manipulation; the more skilled children are with working memory, the better they do academically (Gathercole & Pickering, 200; Swanson, Ashbaker, & Lee, 1996; Geary, Hoard, Byrd-Craven, & DeSoto, 2004; Alloway, Gathercole, Adams & Willis, 2005). By increasing the meaningfulness of information presented in lessons while controlling for working memory overload (Gathercole & Alloway, 2008), Creativity Infusion trainers use strategies that develop and use working memory to improve creativity.

Scripts, Schemas and Stories: Memories are updated with new information every time we conjure them up (Courage & Cowan, 2009). Scripts are mental mechanisms that link events and activities (“When we do this, then we always do that”), which help children predict what comes next (Nelson, 1996). Scripts are coordinated into larger, theory-like structures called schemas. A schema is an organizational tool with rules that the child can remember and use to make inferences in new situations (Reeder, Martin, & Turner, 2008). Scripts and schemas help student remember how to behave, to understand, and to predict their world. Stories are an emotionally engaging way of preserving and communicating information, scripts and schemas, as well as a way of understanding and representing our experiences (Pink, 2005; Fivush, 2000). Ironically, schemas – together with other cognitive mechanisms - are also at the root of stereotyping and prejudice (Hudson, 1988; Kahneman, 2011). Thus, our model both helps children develop healthy schemas by presenting multiple perspectives on a topic through arts integration and encourages using multiple perspectives during creative activity. Through drama exercises, VTS /CTM and other activities, it also encourages children to talk about their experiences and use stories so that they remember better. Thus, Creativity Infusion balances and integrates research about habituation and novelty preference (see **Motivation**, above) with research on memory.

Knowledge and Expertise: Children’s brains rely on already formed neural pathways to understand new information; the more knowledge or expertise a child has on a subject, the more they can remember new information (Bjorkund, Dukes & Brown, 2009). Through our model’s student-centered VTS/CTM and hands-on lessons, teachers find out their students’ expertise and connect it to the curriculum by building additional assignments from the bottom up – allowing students to shape the curriculum and thus promote engagement, ownership and relevance.

**Cognition and Action:**

Implicit Learning: Much of children’s learning happens without awareness or conscious effort; they learn to follow complex rules without realizing they are doing so. Research supports the notion of learning as an active process of construction and reconstruction by the learner with others (Moyles, 2005). Our Creativity Infusion PD for teachers includes ways of developing lessons based on student interests and building relationships between students with shared interests (via team or group work).

Emotion: Emotion, reason and learning are strongly linked and share common brain processing areas (Caine & Caine, 1994). Emotions often determine whether or not children focus on and remember new information. Small amounts of adrenaline can spark performance and enhance motivation, attention, and memory, while positive feelings encourage creativity and flexible problem solving (Nadler, Rabi, & Minda, 2010). Thus, children’s emotional needs in the learning process must be met since lasting learning experiences have emotional significance for the learner. The arts are emotionally engaging, and the key ingredients in our model are designed to create meaning through affective experience (Taylor, Marienau, & Fiddler, 2000; Taylor, 2010), while each lesson is designed with an emotional hook (Schuh & Rea, 2001)

Metacognition: Students comprehend and retain complex concepts much better when they are sensitive to the actual process of learning (that is, knowing about one’s cognitive strategies as well as applying knowledge to tasks at hand) (Gardner, 2001; Light, 1990). Using words that reference mental states help children develop metacognition, and allowing students to take the role of teacher helps them to understand and switch perspectives (Astington & Pelletier, 1998; Strauss et. Al., 2002; Ellis & Gauvin, 1992). Our model makes lessons and classroom agendas clear, incorporates active reflection on the learning process, and clarifies what cognitive skills contribute to a creative mindset to help students understand how to apply them (Gardner, 2001; Veon, 2014).

Articulation: Explaining your thoughts not only communicates your knowledge but also increases your knowledge; it helps make implicit knowledge explicit (Vygotsky, 1986; Willingham, Nissen, & Bullemer, 1989; Bower & King, 1967). Questioning (including asking yourself questions) is part of this process and contributes to increased comprehension (Rumel, 1991; Trabasso Suh, 1993; Chi, Bassok, Lewis, Reiman, & Glasser, 1989). For children, explaining how they solve a problem is as important as solving it. Our model provides time for students to ask questions, take other perspectives, and to articulate their thoughts and reasoning.

Collaboration: Children can do more collaboratively than they can do independently; children transform shared knowledge into individual knowledge. Cognitive development is greatly enhanced when partners of different skill levels work together. Collaboration enhances performance on future solo work (even tasks unrelated to the initial collaboration). Our model takes advantage, when appropriate, of turning solo work into collaborative learning and to work within the zone of proximal delvelpoment.

*The significance of these scientific findings about learning on the development of our model*: These “propellers of learning” together with our research-based Professional Development form the matrix in which we iteratively develop our Model. The data collected according to our Project Management plan will ensure that our Model is working as planned and that the findings from developmental science are used in the classroom to guide effective teaching practices and promote student learning.

Example of research aligned to Specific CIM Objectives:

**S1.8 R Recognizes that interpretation relies on context (the implicit and explicit cues/clues that suggest how we should assign meaning to something); combines cues/clues from disparate contexts in an artwork to generate unusual meaning**

Thomas B. Ward (Cognition, creativity, and entrepreneurship. Journal of Business Venturing 19 (2004) Another process with a special link to creativity that has also undergone careful experimental examination is analogical reasoning or transfer, the application or projection of structured knowledge from a familiar domain to a novel or less familiar one (e.g., Gentner et al., 2001; Holyoak and Thagard, 1995). Analogy, or the mapping of knowledge from a familiar domain to a less familiar one, is central to creative developments in science, art, music, and literature…. Commonly cited examples of analogy in creative endeavors abound, such as Rutherford’s use of a solar system as a model for how the hydrogen atom was structured and Robbins, Laurents, Bernstein, and Sondheim’s adaptation of Shakespeare’s Romeo and Juliet to the context of a 1950s New York City gang conflict in West Side Story. Meticulous case studies have also detailed the role of analogy in major creative accomplishments, such as Kepler’s reasoning about planetary motion (Gentner et al., 1997), Edison’s development of an electric light distribution system (Basalla, 1988; Friedel and Israel, 1986), and the Wright brother’s efforts to craft a workable flying machine (Crouch, 1992). Not surprisingly, then, analogy has been a key ingredient in proposals for enhancing creativity (e.g., Gordon, 1961) and has been listed as a component process in cognitive process models of creativity (e.g., Finke et al.,1992). The transformational power of analogies derives, at least in part, from the fact that good analogies connect the familiar and novel domains at very deep levels, not merely at the surface (e.g., Gentner, 1983, 1989; Gentner and Toupin, 1986).