Creativity in Action: University Students Use Metacognition When Completing Creativity Exercises

Sarah Zyfers

A thesis

submitted in partial fulfillment of the

requirements for the degree of

Master of Education

University of Washington

2019

Committee:

Susan B. Nolen

Nancy Hertzog

Program Authorized to Offer Degree:

College of Education

University of Washington

Abstract

Creativity in Action: University Students Use Metacognition

When Completing Creativity Exercises

Sarah Zyfers

Chair of the Supervisory Committee:

Susan B. Nolen

College of Education - Learning Sciences & Human Development

This qualitative study examines whether students used metacognitive strategies during creative action when completing a series of exercises designed to cultivate creativity. Twenty-three Honors students from the University of Washington, enrolled in a twelve-week interdisciplinary writing class entitled "What We Know and How We Know it," participated in this study. Students completed fourteen interactive creativity exercises and wrote reflections about their experiences. I examined data generated from reflections about five foundational exercises using Glaveanu's "Framework for Creativity" and Schraw & Dennison's "Metacognitive Awareness Inventory." I organized reflections from each exercise into separate activity systems and divided reflections into Thought Units (TUs). Then I coded and analyzed TUs using both frameworks. Based on the themes that emerged, I developed a third dataset. Analyzing co-occurrences across datasets enabled me to examine where students used metacognition within each activity system.

To show creativity in context, I describe one exercise (Exercise #12 - Object Connections) as an activity system, highlighting students' use of metacognition. This data helped me answer the questions a) does metacognition occur in creative activity systems, b) what type of metacognition occurs, and c) how does metacognition facilitate the interrelationship between elements in activity systems? Results indicated that students used metacognitive strategies (primarily "Monitoring Creative Activity") across all elements of these creative activity systems. Findings suggest that metacognition would enhance Glaveanu's "Framework of Creative Activity." This has implications for formal and informal instruction, providing support for innovative programs designed to cultivate creativity as diverse student populations grapple with complex, ill-defined problems.

Key words: creativity, metacognition, education, design thinking, abductive reasoning

Creativity in Action: University Students Use Metacognition When Completing Creativity Exercises

In the 2017 World Economic Forum's Global Shapers Survey, millennials cited the most daunting challenges that they would face during the course of their careers - climate change, overpopulation, global migration, food and water insecurity, social and political unrest, extreme poverty, educational and social inequity (www.inc.com/business-insider/worlds-top-10-problems-according-millennials-world-economic-forum-global-shapers-survey-2017.html). These challenges provide the backdrop for unprecedented changes in technology – artificial intelligence, genetic engineering, laboratories in space, even self-driving cars. This generation, more than ever before, will need creativity and innovation to address these "wicked problems."

One way to promote innovation in future scientists, engineers and business leaders - charged with the mission of solving these problems while ensuring their own success - is to cultivate creativity in the classroom. This priority is echoed by governmental entities and national advocacy organizations. The Partnership for 21st Century Skills (a coalition of leaders in the field of educational, Fortune 500 companies, foundations, researchers, and policy makers) (www.battelleforkids.org), as well as the National Research Council (NCR, 2007), and the National Education Association have identified creativity as one of the core competencies that students will need to succeed in the 21st century (Seely-Brown, 2006).

In spite of these recommendations, educational policy and federally mandated programs seem to squelch creativity by focusing on standardized testing, memorization, and conformity rather than embracing differences. Furthermore, with current pressure to promote STEM skills, academic disciplines are becoming increasingly siloed at all levels at a time when they would benefit most from sharing knowledge, resources, and ideas. Educators are riddled with whether

and how to cultivate creativity while burdened by overcrowded classrooms, changing demographics, policy demands, and budget cuts. In such an environment, it is understandable that teachers would become demoralized while students lose their passion for learning and creativity. To further complicate matters, there is no consensus on whether and how creativity can be cultivated within the domain of education.

Based on the need to overcome these obstacles and prepare students for the challenges that they will face, an interdisciplinary team from University of Washington – Professor Iain Robertson, a Landscape Architecture Professor; Dr. Leslie Herrenkohl, a Learning Sciences and Human Development Professor; and a Teaching Assistant/Graduate Student in Educational Psychology – piloted an interdisciplinary Honors writing elective called "What We Know and How We Know It." In this course students completed a series of fourteen creativity exercises and wrote reflections about their own creative activity afterwards. Creativity exercises provided context and content for writing, serving as "wicked writing prompts" that required deep reflection as students monitored creative activity and negotiated differences to come up with a variety of solutions to ill-defined problems.

When designing creativity exercises, Professor Robertson incorporated his extensive experience in design thinking, as well as principles from the discipline of Learning Sciences, to provide students with a new skillset and "design attitudes of mind" for addressing "wicked problems" and for thinking across settings and cultural contexts. Exercises highlighted Studio Design techniques and illustrated "complex and interconnected views of knowledge, practices, artifacts and the people who use them." Professor Robertson emphasized the following design-thinking practices in each exercise 1) do first, reflect later 2) take initiative in the face of ambiguity and uncertainty 3) take risks and engage publicly with still-forming ideas and

competing perspectives 4) surface and uncover underlying values. Professor Robertson explained that students "go through iterative cycles of framing and refining problem- and solution-spaces, and building artifacts that represent their thinking facilitated by frequent and ongoing interactions with studio instructors and peers. They begin to develop a solution, based on an initial appreciation of a situation, which in turn helps to shape the situation. The situation in essence "talks back" and the student learns to respond, changing or modifying the approach based on a new understanding of the problem" (e.g. Cross, 2001, 2007; Schon, 1987; Shaffer, 2005).

As Teaching Assistant and Researcher, my responsibilities were to assist students with classroom exercises, draw from current research in Learning Sciences and Human Development to substantiate exercises, provide relevant readings for students, help facilitate classroom discussions, and provide feedback on students' projects and written reflections. I was also a participant-observer in the classroom, taking fieldnotes notes on the creative strategies used by students as they engaged in these exercises. Many pertinent threads came to mind during my classroom observations including stages of the creative process, thinking strategies (divergent, associative, abductive, metaphorical, and design thinking), collaborative creativity, communities of practice, situated learning, and transformation through participation - each could be a dissertation in itself. Limiting myself to just one area of study seemed like a disservice both to Professor Robertson's curriculum and to the quality of students' effort. So, I set forth to find a theme or a model that would bring all of these elements together.

I found what I was looking for in the work of Vlad Petre Glaveanu, Associate Professor of Psychology at Webster University in Geneva, Switzerland. Like Professor Robertson, Glaveanu took an ecological systems approach emphasizing creative activity, interaction,

iteration, and transformation rather than person or product. Glaveanu developed a conceptual systems model of creativity that is grounded is sociocultural theory and ecological psychology, while synthesizing and extending earlier models of creativity. He defined creativity is "a form of action by which actors, materially and symbolically, alone and in collaboration with others, move between positions in ways that afford greater reflexivity and the emergence of novelty." Rather than focusing on intra-psychological variables (e.g. divergent thinking, openness to experience, neurological correlates) or the evaluation of products, his model of creative action "engages self-other, symbolic-material, and past-present-future relations that depict creativity as a social, situated, temporal act" (Glaveanu, 2013).

Glaveanu's model incorporated many aspects of Professor Robertson's class, but one resounding theme from the course curriculum (and from my own observations) was missing - metacognition. Glaveanu alluded to metacognition and reflection as essential in the interrelation between elements in a creative activity system, but he did not elaborate on this theme, nor did he include metacognition in his framework. Yet, in my observations students frequently used metacognitive strategies as they engaged in creative action, and metacognition was woven throughout Robertson's curriculum in the following ways. As an instructor, Robertson consciously modeled advanced creative and metacognitive thinking while constructing an open learning environment where students felt comfortable taking risks and making mistakes. He gave students daily opportunities to practice using metacognitive and creative strategies (understanding their own values and "funds of knowledge," sorting, generating patterns, making connections, seeing things from different perspectives, and reflection). Students also had the opportunity to experiment with and developed explicit awareness of the effects of their own mindsets on creative output. This curriculum also included readings about reflection, "design

attitudes of mind," and the creative strategies used during classroom exercises. These resources enabled students to develop declarative, as well as procedural and conditional knowledge of metacognitive and creative strategies. Fundamental was the action orientation of this class, where students were expected to "do" first, to discuss with each other, and then to reflect deeply on their experiences. As students noted in their final publication, group discussion and written reflection (a form of metacognition) were integral to each exercise and the locus of much learning – enabling students to develop conscious awareness of knowledge and strategy use.

Professor Robertson maintained that the metacognitive and creativity skills cultivated during these exercises are fundamental "designer attitudes of mind." He created his own list of essential design skills and "attitudes of mind" adapted from Costa and Kallick's sixteen "Habits of Mind" so that students would develop conscious awareness of such strategies. Costa and Kallick explained that these higher-level thinking skills are "mindful strategies" that require a "discipline of the mind that is practiced so it becomes a habitual way of working toward more thoughtful, intelligent action" when resolving complex problems and produce knowledge in challenging contexts where creativity is required (Costa & Kallick, 2008, preface xvii). In this class students participated in creativity exercises where metacognitive and creative "attitudes of mind" were considered "normative" ways of thinking and acting, modelled by "more knowledgeable others." Through action and reflection, students became consciously aware of these new ways of thinking. When "Monitoring Creative Activity" and "Planning" and students could experiment with these techniques to determine which worked best for them. Through "legitimate peripheral participation" in situated activities, students gradually become accustomed to these approaches, transforming their own "attitudes of mind" as they become full participants in this "community of practice" (Lave & Wenger, 1991). These "attitudes of mind" and the

environment created by Professor Robertson "afforded" transformation as students acquired new perspectives and strategies.

In this study I examined aggregated data from students' reflections about five creativity exercises to see whether they used metacognition in creative activity systems, and if so, what the type of metacognition used during creative action tells us about the interrelation between the elements in an activity system. Then I showed how metacognition might be incorporated in Glaveanu's Framework. I illustrated my findings by looking more closely at students' use of metacognition in the context of one creative exercise (Exercise #12 – Object Connections) that I operationalized and defined as an activity system according to Glaveanu's model. The exercises that students completed in class served as a context for creativity, illustrating where metacognition occurred during creative action.

My hope is that this study will contribute to an understanding of the relationship between metacognition and creativity so that we may better define, cultivate and measure these fundamental skills. With a better understanding of the role of metacognition during creative action, we may be able to improve learning outcomes for all students - children and adults alike - across domains so they can develop innovative solutions to some of the world's most daunting challenges.

LITERATURE REVIEW

In this study I examined whether students used metacognition during creative activity as they completed a series of classroom exercises based on Studio Design techniques. I also explored the type of metacognition used by students in order to learn more about the interrelation between the elements of a creative activity system. In order to answer my research questions, I analyzed aggregated data from five creativity exercises and illustrated my findings by looking at students' use of metacognition in the context of one of these exercises (Exercise #12 - Object Connections) that I operationalized and defined as an activity system using Glaveanu's model.

In this section, I provide a brief overview of research on creativity and metacognition in order to introduce key concepts and provide context for the rest of my study. Then I review literature that explored the intersection of both domains to learn more about the role of metacognition in the development of creativity. Literature showed that the processes of creativity and metacognition were related, but most studies failed to capture the complex interactions that I observed in the classroom. The majority of models and research were domain-specific, focused on attributes of individuals or products rather than systems and sociocultural context, or portrayed creativity as a linear series of stages rather than an iterative, mutually constitutive process. These bodies of literature pointed to the interrelationship between metacognition and creativity; however, I could not find a framework that integrated the two in a situated, contextual system. Therefore, I would like to explore the possibility of adding metacognition to Glaveanu's "Framework of Creative Activity."

Overview of Creativity Research

Many scholars across disciplines have studied the nature of creativity - from the ancient Greeks to the Masters of Italian Renaissance, from American pragmatist and educational

reformer John Dewey to Russian psychologist Lev Semyonovich Vygotsky. So it is not surprising that numerous definitions and theories of creativity have been proposed. Most definitions include the concepts of novelty, utility, and perceived value but there is little agreement across disciplines. Some of the most enduring premises are outlined below; much of this earlier work has been incorporated into more recent research.

In 1926, a scholar named Graham Wallas proposed a model for creativity that is still used today. He described creativity as a four-stage process including preparation, incubation, illumination, and verification (Calonico, p. 16) (Hoff, 2014). The next wave of creativity research began in the 1950's when Guilford and Torrance studied the personalities and abilities of creators (Sawyer & DeZutter, 2009, p.80) (Guilford, 1950). Guilford posited that creativity involves two processes: "convergent thinking" and "divergent thinking" (Baer & Kaufman, 2012). Baer & Kaufman explained that "divergent thinking" included fluency (large number of ideas), flexibility (wide variety of ideas), originality (unusual or novel ideas), and elaboration (many details used to expand and enrich ideas) (Baer & Kaufman, 2012). "Convergent thinking" referred to the ability to combine those ideas into something useful by "focusing quickly on the one best solution to a problem" (DeHaan, 2009). Based on these findings, Torrance created a widely-accepted battery of psychometric tests measuring these abilities (Torrance, 1974).

In 1961, after discovering more than forty different definitions of "creativity" and sixteen definitions of "imagination," James M. Rhodes developed a new framework for evaluating creativity known as the "Four P's" (Person, Process, Product, Place/Press). Sternberg added "Persuasion" and "Potential" to this list. This framework is still used to categorize and study findings in creativity research.

In the 1980's, researchers began to move away from the study of internal mental processes to study the social and cultural dimensions of creativity and the distribution across people, tools, and environments (Sawyer & DeZutter, 2009, p. 80) (Amabile, 1983; Csikszentmihalyi, 1988; Hutchins, 1995). Csikszentmihalyi proposed a systems model of creativity in 1996 that extended Rhodes' notion of the "Four P's." This model incorporated three components of creativity – the domain of area of specialty, the field composed of experts or gatekeepers, the individual person who contributes something new to a domain (Calonico, p. 18). This second wave of creativity scholars were influenced by the work of Russian psychologist and sociocultural theorist Lev Vygotsky.

Vygotsky's View of Creativity

According to Vygotsky, learning and development (and creativity) occurred through interaction with others in a sociocultural environment. As Moran and John-Steiner (2003) explained, Vygotsky viewed the creative process as "interaction, tension, transformation, and synthesis over the parallel timescales of the creative act, the creative life, and historical cultural development." He studied the "origins and interrelationships of functions" within a sociocultural context rather than individuals or structures that had already been created. Moran and John-Steiner elaborated on Vygotsky's thinking by explaining that "development and creativity are dialectically related…as internalization or appropriation of cultural tools and social interactions" followed by the externalization or "construction and synthesis of emotion-based meanings and cognitive symbols." They explained that internalization involved a "transformation or reorganization of incoming information and mental structures based on an individual's characteristics and existing knowledge." Once expressed, these meanings and symbols were considered "embodied in cultural artifacts" or creative products. These two social processes (internalization and

externalization), as well as personality and culture, were in dialectical tension with each other and resulted in transformations that "expand culture." In this view, creativity and development were "interdependent," with creativity depending on development and development depending on creativity (Moran & John-Steiner, 2003, p. 62-63).

Glaveanu's Framework of Distributed Creative Action

Glaveanu is a social and cultural psychologist who studied the relationship between creativity and culture. He incorporated Vygotsky's sociocultural perspective while citing several concerns with earlier models of creativity. According to Glaveanu, most earlier models provided "static" definitions of creativity with a focus on products or person. They located creativity in the minds of individuals (which cannot be observed directly), or in the evaluation of a product, rather than an interaction of mutually-constitutive elements situated within a social, cultural, temporal context. Such linear models failed to capture creativity as an iterative, evolving, developmental process or system. He maintained that we need a "much more comprehensive framework" that integrated "social, symbolic, material and temporal aspects of creating" (Glaveanu, 2014 p. 9).

In response to these concerns, Glaveanu developed a conceptual systems model of creativity that synthesized and extended the earlier models described above. He used a sociocultural lens to show creativity as "a form of action by which actors, materially and symbolically, alone and in collaboration with others, move between actions, which affords greater reflexivity and the emergence of novelty." Rather than focusing on psychological variables (e.g. divergent thinking, openness to experience, neurological correlates) or specific domains and fields, Glaveanu's ecological systems model engaged "self-other, symbolic-

material, and past-present-future relations that turn creativity into a social, situated, temporal act" (Glaveanu, 2013).

Glaveanu's framework captured the interrelation between five key elements - Actor(s), Artifact, Audience, Action, and Affordances. Glaveanu's "Five A's" were reminiscent of the "Four P's" (Person, Process, Product, Press) defined by Rhodes (1961), but he reconceptualized these elements to capture the interaction between them. As he explained, all five elements were relational. Actors were defined by their interaction with audiences, action engaged with existing affordances and generated new ones, artifacts became agents within creative work. Glaveanu maintained that creativity emerged as a form of action engaged in by various actors (individual or groups), exploiting the affordances (material and symbolic) of the cultural world and leading to the generation of new artifacts. His framework conceptualized creativity as action or a form of "doing" situated within activity systems. This allowed him to study creative acts in concrete contexts by observing positions and perspectives involved and the consequences of moving between them for creative acts (Glaveanu 2014, pp. 23-27). This framework is depicted in Figure 1.

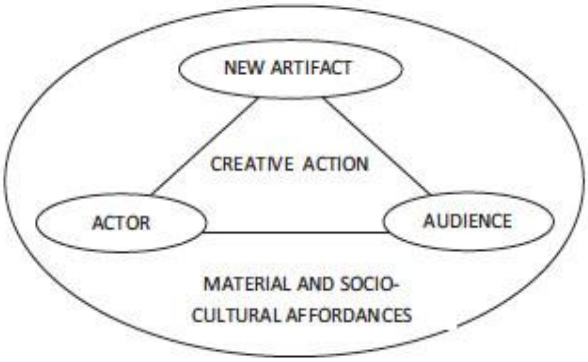


Figure 1. Glaveanu's "Framework of Creativity" incorporating the five A's – Actor, Artifact, Audience, Creative Action and Affordance (Glaveanu, 2013).

For Glaveanu, idea of "difference" was a resounding theme. He said that difference – between self and other, between objects and symbols, and past/present/future - was at the core of creative expression. Not only did creative require the generation of "divergent" thought, which implied difference. The existence of different perspectives (social, material, temporal) was "a condition for creative expression… It is precisely because self and other do not share the same position in the world and the symbolic does not have a one-to-one relation to the material that makes creative expression possible" (Glaveanu 2014, p. 26). As Glaveanu explained, "it is due to the passing of time and the ever-changing nature of both the person and the context that humans are driven to create in order to adjust to the world and grow within it" (Glaveanu, 2014, p. 27). This differentiation was expressed through action, and the quality of action depended on how differences were negotiated, manipulated, widened or bridged by the person in concrete cultural settings (Glaveanu, 2014, p. 76).

Glaveanu's model captured many aspects of Professor Robertson's curriculum – the idea that creativity was a series of iterative actions that occurred in an ecological system, the importance of interaction with others, the idea that affordances and constraints either facilitated or limited creativity, an emphasis on the material nature of creativity. But one key element emphasized by Professor Robertson was missing in Glaveanu's model - metacognition. Reflection and metacognition were resounding themes in Robertson's class; however, there was very little mention of these components in Glaveanu's theory. Glaveanu alluded to the importance of reflection when "perspective taking," but only once did I find mention of "metacognition" in his writings. In this passage, he gave a nod to thirty-year-old research from Armbruster (1989) and Bruch (1988), and he remarked that his framework (particularly the move between actor and observer) required "considerable metacognitive skills and strategies." He said

that “Particular developments in this direction, such as the concepts of metacreativity and creative metacognition, can help us refine our understanding of the mental processes involved in perspective taking” (Glaveanu, 2015, p. 176). He maintained that an added value of his model was that it “asks us to go beyond metacognition and understand its context of social interaction,” yet he did not elaborate further (Glaveanu, 2015, p. 176). It seems that Glaveanu’s theory would be enhanced by greater elaboration of the relationship between metacognition and creativity, as well as the addition of this key component in his framework. Before delving into research that showed a link between these two processes, I will provide a quick overview of metacognitive research to contextualize the rest of my study.

Overview of Metacognition Research

Metacognition has been loosely defined as “thinking about thinking.” Flavell (1979) and Brown (1987) brought this idea to the attention of educational researchers in the early 1980’s. They explained that metacognition included explicit knowledge of cognition, strategy repertoire and usage, and the skills needed to regulate cognition such as planning, monitoring, error correction strategies and evaluation. They explained that learners engaged in a reciprocal process of understanding their own knowledge, regulating, and utilizing this knowledge. Armbruster (1989) summarized the work of Baker and Brown (1984), explaining that metacognition was an executive function that oversaw, regulated, and orchestrated cognitive activities. Metacognition included an individual’s knowledge of and ability to control their own cognitive functions. Control (or self-regulation) included setting goals, planning the next cognitive move, monitoring and evaluating the effectiveness of strategies, and revising cognitive strategies. Armbruster also cited research from these scholars demonstrating the value of metacognitive training in

skill/strategy use, self-regulation (orchestration, overseeing and monitoring skills), and awareness of cognitive skills (Armbruster 1989) (Baker and Brown, 1984).

In a three-part dissertation, Braten (1991) presented Vygotsky as the "precursor" to metacognitive theory. He explained that Brown's early metacognitive research was derived from Vygotsky's theory of cognitive development (Braten, 1991). Braten maintained that, for Vygotsky, cognitive development was the increasing control or mastery of one's own cognitive processes. "Elementary psychological processes" are transformed into "higher psychological systems," and eventually into functional systems through speech (the key mechanism for attaining deliberate, voluntary control of their own cognition). According to Braten, Vygotsky was particularly interested in the transference of "other-regulation to self-regulation" (Braten, 1991, p. 190) (Brown, 1987).

Schraw and Dennison Develop the "Metacognitive Awareness Inventory"

Schraw & Dennison, leaders in metacognition research and practice, expanded on the work of Brown and Flavell (Schraw & Dennison, 1994). They explained that "Knowledge of Cognition" included three subprocesses that facilitated "the reflective aspect of metacognition: declarative knowledge (knowledge about self and strategies), procedural knowledge (knowledge about how to use strategies), and conditional knowledge (knowledge about when and why to use strategies)" (Schraw & Dennison, 1994, p. 460). "Regulation of Cognition" included several subprocesses that facilitated the control of learning including "Planning," "Information Management Strategies," "Comprehension Monitoring," "Debugging Strategies," and "Evaluation" (Schraw & Dennison, 1994, p. 460). They maintained that the use of these strategies would have improved performance by enabling students "better use of attentional resources, better use of existing strategies, and a greater awareness of comprehension

breakdowns" (Schraw, 1998, p. 114). He noted four ways to increase metacognition in classroom settings including promoting general awareness of cognition, improving knowledge of cognition, improving regulation of cognition, and fostering and environment that promotes metacognitive awareness (Schraw, 1998, p. 118).

Based on this information, Schraw & Dennison developed a self-report inventory called the "Metacognitive Awareness Inventory" (MIA) that measured 52 items related to the component processes described above on a 5-point Likert scale. This inventory was shown to be internally reliable, with test-retest reliability of .85 (Hargrove & Nietfeld, 2015, p. 295) (Schraw & Dennison, 1994). The MIA has been used ever since due to its strong predictive validity for test performance and self-monitoring in academic tasks (Hargrove & Nietfeld, 2015, p. 299).

Based on a synopsis of literature, the six components of metacognition can be defined and adapted to creativity as follows. "Knowledge of Cognition" enables students to understand their own knowledge base, strategy repertoire, strengths and weaknesses (as well as how, when and why to use existing knowledge and creative strategies) so that they can predict outcome and choose the most effective strategies when solving creativity problems (Bransford, 2000, pp. 12-18). When "Planning" students review objectives, establish goals, allocate the necessary time and resources for a task based on an assessment of whether their own knowledge is "full, rich and flexible enough to provide the potential for creative restructuring" and for the effective externalization of these ideas (Armbruster, 1989, p. 179). "Monitoring Creative Activity" is used throughout creative action to monitor understanding of a problem, evaluate ideas, and predict the effectiveness of the creative strategies used relative to goals and objectives (Armbruster, 1989, p. 180). With this information, students can determine whether they need more information and whether they need to modify actions to keep the project on track

(Bransford, 2000, pp. 12-18). Students use "Information Management Strategies" to slow down, selectively focus, review, or take a break to let ideas incubate when they encounter obstacles or lack the understanding they need to solve a problem. This also involves the conscious use of strategies to generate and organize ideas and information (brainstorming, diagrams, lists, elaboration) (Schraw, 1994, p. 479).

Hargrove elaborates on this work by emphasizing that "learners must not only continue to gain a greater understanding of their knowledge as they cognitively manage tasks. The regulation aspect requires the learner to engage in the reciprocal processes of accurate monitoring and control processes that allow for adjustments to be made in response to monitoring feedback. Thus, the relation between knowing and doing becomes essential for effective problem solving and ensuring that a cognitive goal has been met" (Hargrove & Nietfeld, 2015, p. 295) (Nelson & Narens, 1994).

Reflection as a Metacognitive Process

Though not specified by Schraw and Dennison or by Glaveanu, reflection is an important component of metacognition and of creativity. Both Hargrove and Robertson included reflection in their curriculums so it seems worthy of more study. Robertson frequently mentioned Donald Schon's seminal work, "*The Reflective Practitioner*." In his handout entitled "Reflection – Think About It!," Professor Robertson referred to Schon's work as he elaborated on the role of reflection in the development of design ideas. Robertson maintained that "synthesis results from reflection, it is the essence of creative thought." He noted that "to practice effectively we must reflect on our design actions and then alter our designs in response to those reflections, reaching a synthesis - a design - through this iterative process."

Hargrove (2011) shed more light on this theory, explaining that Schon (1987) saw design as a reflective activity where designers constantly monitored their own activities, strategies and processes in a "reflective conversation with the situation." As Hargrove explained, Schon broke reflection into two kinds of action: "reflection-*in*-action" and "reflection-*on*-action." Reflection-*in*-action referred to thoughts that occurred during creative action, "during which we can still make a difference to the situation at hand – our thinking serves to reshape what we are doing while we are doing it." This behavior could be classified as "Monitoring Creative Activity," leading to "Planning," "Correcting Comprehension," and the use of "Information Management Strategies." Schon defined reflection-*on*-action as "thinking back on what we have done in order to discover how out knowing-in-action may have contributed to an unexpected outcome," or post-activity reflection on the activity. "Reflection-*on*-action" could be classified as "Evaluation" (Hargrove, 2011, pp. 9-11) (Schon, 1987). In this study I looked at students' "reflection-*in*-action" because it could be captured by and integrated into Glaveanu's framework of creativity in action. The reflection that occurred after creative action was essential, but it could not be captured by Glaveanu's Framework of Creativity "in" action.

Moran and John-Steiner touched on the relationship between reflection and difference when explaining that Vygotsky considered the reflective function to be assisted by imagination. They summarized that a person must be "in an oppositional, critical or reflective relationship with reality in order to fully internalize a concept's meaning. The imagination provides the capacity for this type of critical relationship" (Moran & John-Steiner, 2003, p.71). Glaveanu built on this theory when explaining that creativity was rooted in and required "difference."

In the interest of purposefully creating ambiguity and encouraging students to learn through action, Professor Robertson offered no guidelines for how to write reflections. So, I

turned to other sources for deeper understanding of written reflection as metacognition. In her book entitled "Reflection in the Writing Classroom," Kathleen Blake Yancey paraphrased a section from John Dewey's seminal work *How We Think: A Restatement of the Relation of Reflective Thinking to the Educative Process*. She alluded to the similarity between reflection and the purposeful use of metacognition by explaining, from Dewey's perspective (1993), that a reflection was "goal-driven and sequential, controlled by the learner because he or she wants to learn something, to solve a real problem, to resolve an ambiguous situation, or to address a dilemma. It relies on a dialogue among multiple perspectives, as the learner contrasts the believed and the known with presuppositions and necessary conclusions" (Yancey, 1998, p. 9). Yancey broke this down into three process 1) goal-setting, revisiting and refining, 2) revising in light of retrospection, and 3) articulating the learning that has taken place (Yancey, 1998, p. 9). This sounds very much like the criteria outlined by Schraw and Dennison including the metacognitive processes of "Planning," "Comprehension Monitoring," "Debugging Strategies," and "Evaluating."

Yancey expanded upon this in a way that was reminiscent of both Vygotsky and of Glaveanu in her discussion of synthesizing differences. She said that "In method, reflection is dialectic, putting multiple perspectives into play with each other in order to produce insight. Procedurally, reflection entails a looking forward to goals we might attain, as well as a casting backward to see where we have been. When we reflect, we thus project and review, often putting the projections and reviews in dialogue with each other, working dialectically as we seek to discover what we know, what we have learned, and what we might understand" (Yancey, 1998, p. 6). In this passage, Yancey emphasized bridging ideational, material-symbolic, and temporal differences through reflection during the creative act of writing.

In an assigned reading, students studied Carol Rodgers' examination of John Dewey's thoughts about "systematic, reflective thinking." She described the purpose of reflection, the process, and how it differed from other forms of thought. She identified four criteria that characterized Dewey's concept of reflection: 1) the purpose of reflection was to make meaning (relationships and continuities) from disparate elements of experience, 2) reflection was a meaning-making process moving a learner "from one experience to the next with a deeper understanding of relationships and connections to other ideas," 3) reflection was "a systematic, rigorous, disciplined way of thought," akin to the scientific process, and lastly 4) "valuing personal and intellectual growth" is inherent in the idea of reflection (Rodgers, 2002, p. 845). These scholars seemed to believe that reflection was a transformative process that required intention and occurred in community through interaction with others.

Similarly, Hacker (2018) conceptualized writing as a metacognitive process by defining it as 'the production of thought for oneself or others under the direction of one's goal-directed metacognitive monitoring and control, and the translation of that thought into an external symbolic representation (Hacker, 2018, p 220) (Hacker, Keener, and Kirchner, 2009, p. 154). Hargrove also connected metacognition to written reflection. He said that journaling was a "form of independent reflection used as a tool to reflect on their own problem-solving, generate thought iteratively through the writing process or illustration, and document an increasing understanding of one's metacognitive thought and creative transformation" (Hargrove, p. 23). These conceptions of metacognition encompassing reflection (or vice versa) were reminiscent of Schraw, Dennison, Glaveanu and Robertson.

Research Showing the Link between Metacognition and Creativity

Several scholars have explored the role of metacognition in the development of creativity, arguing that there is a relationship between these processes (Kaufman & Beghetto, 2013, p. 160) (Davidson & Sternberg, 1998; Feldhusen & Goh, 1995). Studies were limited, but research showed that metacognition was one of the key factors in creative problem-solving (Armbruster, 1998; Hargrove, 2012; Pesut, 1990; Sanz de Acedo Lizarraga, 2013; Swartz; 2001).

Bruch (1988) and Armbruster (1989) were among the first scholars to link creativity to the growing study of metacognition. Bruch built upon the work of Sternberg (1982), redefining nine elements or executive processes used during problem-solving for the study of "metacreativity." She proposed the following information management strategies for creativity: identifying the problem; choosing and attending to creative processes and strategies; selecting ways of representing internal and external information; allocating time and resources for creative action; monitoring thinking, feeling and experiences during the creative process; listening to feedback; translating feedback into an action plan; and implementing an action plan. This research provided a framework for studying internal observations of creative processing (Bruch, 1988, pp. 115-117).

In the 1989 edition of the *Handbook of Creativity,* Armbruster examined creativity from the perspective metacognition, explaining that creativity should be considered a cognitive process because it requires perception, learning, thinking, and remembering. The creative process also involved the acquisition of knowledge and skills, the transformation of knowledge into new forms, and the rendering of these forms into shareable product. Each stage entailed cognition (Armbruster, 1989).

Armbruster explained that metacognition played a very important role in creativity and was likely a significant component at each stage of the creative process. She used Wallas' four stage model of the creative process to show where and how metacognition is used. During "Preparation," creative individuals used metacognition to assess whether their knowledge was "full, rich and flexible enough to provide the potential for creative restructuring" and to control or regulate the "encoding of flexible representations of knowledge" (Armbruster, 1989, p. 179). During the "Incubation" stage, creative individuals appeared to have an unconscious ability to manage the restructuring of knowledge (acquired during the preparation stage) into new mental structures that meet their goals (Armbruster, 1989, p. 179). Creative individuals may have been particularly attuned to recognizing creative "Illumination" when "a coherent cognitive representation" had occurred. During the "Verification" stage, the creative individual consciously measured the product against both an internal standard and an anticipated external standard (Armbruster, 1989, p. 180). Armbruster's insights on where and when metacognition occurred throughout the creative process were insightful, but this framework reflected a linear process and focused on the creative "individual," rather than situating creativity in a sociocultural context.

Feldhusen drew from Sternberg (1998) and Isaksen & Treffinger (1985) to argue that individuals could learn a set of metacognitive skills, process and strategies for processing new information and for drawing from the knowledge base that they had acquired during creative thinking and problem-solving. He explained that these strategies facilitated processing and the transformation of information to yield new syntheses or products (Feldhusen, 1995). This research was frequently cited; however, it focused on the individual rather than an integrated activity system.

Kaufman & Beghetto (2013) maintained that creative metacognition was "a special form of cognition that helped people monitor and develop their creative competence." They defined creative metacognition as "a combination of creative self-knowledge (knowing one's own creative strengths and limitations, both within a domain and as a general trait) and contextual knowledge (knowing when, where, how and why to be creative)." This included knowledge about specific context, tasks, strategies, and knowledge about oneself. This also encompassed self-reflection, self-regulation, and self-monitoring. They highlighted that creative metacognition was both domain-specific and domain-general (Kaufman & Beghetto, 2013, p. 160).

Sanz de Acedo Lizarraga (2013) looked at the links between and the contribution of metacognition to verbal and graphic creative potential of students. They explained that metacognition was an essential variable in the creative process, enabling the regulation of convergent/divergent thinking and balancing one's knowledge of cognition and creativity with the ability to control actions in alignment with evaluation. They explained that the relationship between metacognition and creativity has been suspected but not yet proven, because much of the "incubation" phase of the creative process in unconscious. This contribution was significant, but it was domain specific addressing only verbal and graphic creativity. Whereas Robertson's class (and this study) looked at cultivating the very cognitive processes required for creativity across domains- such as perception, patterns, sorting, symbols and meaning, making connections, synthesizing differences, and reflection. Our study explicitly embedded metacognitive strategies into the context of creativity and attempted to study them in a variety of ways. Despite these studies showing the relationship between metacognition and creativity, there is very little empirical support showing the correlation between the development of metacognition skills and increasing creativity scores within the domain of education.

Puryear highlighted the intersection of cognitive development, developmental views of creativity, and the role played by metacognition in both. He argued that creativity was a developmental cognitive process and that the metacognitive aspects of creativity had "a theoretical basis in this process." He believed that future researchers should focus on the interaction effects of metacognition on traditional measures of creativity, especially ideation and product evaluation (Puryear, 2014).

In a subsequent publication, Puryear used Runco's "Ideational Behavior Scale," Schraw & Dennison's "Metacognitive Awareness Inventory," and the "Creative Behavior Inventory" to test the moderating effect of cognitive factors on the relationship between creative ideation and creative production. He presented "The Cognitive-Creative Sifting Model" to illustrate the skills used in processing and transforming the information that influenced these associations. He reported a large, statistically significant moderator effect for overall metacognition and medium to large moderator effects across "previous theoretically proposed aspects of metacognition." He also observed differences across subcomponents of metacognition which "paralleled theoretical connections between metacognition and creativity." He suggested further studies using more diverse creativity measures, as well as tests for other cognitive "sifters." He presented several implications for educational practice, particularly regarding creatively gifted (Puryear, 2015). This was a significant contribution to the intersection of metacognition and creativity; however, Puryear focused on the evaluation of person and product, rather than interrelated elements in a socio-cultural context, and his model seemed too complicated for practical use.

Valgeirsdottier and Onarheim (2017), scholars from the University of Denmark, investigated the influence of "process awareness" on the creative process of a design team. In this study they defined process awareness, identified when and where in the design process it

occurred, and related process awareness to metacognition. They defined process awareness as "the skill that allows a person to become conscious of the cognitive processes involved in a creative process so they can adjust the creative process accordingly" (Valgeirsdottier & Onarheim, 2017, p. 217). They maintained that knowledge of and consciously planning, monitoring and reflecting on one's own creative work (and the work of one's teammates) enabled designers to become more strategic in choosing creative actions and advancing their own creative process. They concluded that process awareness was an "important creativity skill, and a crucial mechanism to enhance all stages of the creative process." They argued that metacognition differed from process awareness because it was a "higher level of cognition" that provided "an overview of all cognitive activities," an "umbrella concept" under which process awareness falls. This study articulated the role of metacognitive processes in creativity and captured many of the nuances that I observed in Robertson's classroom, but it failed to capture the interrelationship between the elements of an activity system which Glaveanu described so well (Valgeirsdottier & Onarheim, 2017, pp.216-226).

Research Shows that Creativity can be Taught

I found much research showed that creativity, once thought to be innate, could be taught (Al-khyat, 2012; Hargrove, 2013; Sanz de Acedo Lizarraga, 2013). Similarly, there was a rich history of infusing metacognitive training into instructional contexts and content domains such as mathematics, reading, writing, and general problem-solving (Hargrove & Nietfeld, 2015, p. 295). But little research has been done about the benefits of metacognitive training in the development of creativity. Ryan Hargrove, Associate Professor at the University of Kentucky, explored the link between teaching metacognitive skills and the development of creativity and problem-solving ability (Hargrove, 2013). He reasoned that because metacognition was an essential

aspect of creativity, developing metacognitive knowledge and strategies should boost creativity. Reminiscent of Robertson's curriculum, Hargrove developed a 16-week course called "Design Thinking Explorations" where he integrated creative problem-solving activities, associative thinking strategies, and the explicit instruction of metacognitive knowledge and skills (within a metacognitive instructional framework). He included variety of creative strategies that allow students to "externalize ideas and make associations" so that they could "develop ideational strategies best suited to their skills, needs and the type of problem." After introducing creative thinking strategies, he gave students opportunities to practice "action-oriented metacognitive skills in authentic, domain-specific, design-based tasks."

In a field-based study, Hargrove's treatment group had significantly higher scores on fluency and originality measures compared to matched peers after the completion of this course. Outcome measures of creativity showed novel responses and contextual appropriateness (Hargrove & Nietfeld, 2015, pp. 297-302). The treatment group also received higher ratings on a summative, domain-specific project judged by external design experts (Hargrove & Nietfeld, 2015, p. 291). Professor Robertson would agree with Hargrove's synopsis that this curriculum "encourages students to develop a greater understanding of their own cognitive processes, how to regulate their problem-solving processes, and how to increase their ability to generate creative problem-solving solutions in design-based problems" (Hargrove & Nietfeld, 2015, p. 292). However, Hargrove, like many others focus on evaluating person and product rather than looking at the interrelationship between elements of an activity system.

In this literature review, we see that there is a rich history of research in metacognition, creativity, and the intersection of both. But this research and the resultant models were inconsistent. Furthermore, they failed to capture the rich interrelationship of metacognition with

the elements of a creative activity system and the iterative, situated nature of both processes. Integrating students' use of metacognitive processes onto Glaveanu's Framework of Creativity could help explicate the interrelationships between these two processes and between the elements of "creative activity systems" as they completed exercises.

METHODS

Research Questions

During the course of this qualitative study I had ongoing discussions with my team, observed a group of students as they worked together to complete this series of creativity exercises, took notes on my observations, and conducted an extensive review of literature on creativity, metacognition, and the intersection of the two. Through this iterative process, I identified several key themes and developed the following research questions related to the role of metacognition in creativity. My research questions were: 1) does metacognition occur in creative activity systems, 2) if so, what does the type of metacognition used by students during creative action tell us about the interrelation between the elements in an activity system, and 3) how does metacognition facilitate creative action in the context of problem-solving activities?

Setting

This study took place in Mary Gates Hall, Room 206, on the University of Washington Seattle campus during the Winter Quarter of 2017. There were approximately 29,000 undergraduate and 12,000 graduate students, representing all demographics, at this Seattle campus. The Honors program enrolled approximately 1,300 students per year.

Participants

This class was designed and instructed by Professor Iain Robertson, Landscape Architecture Instructor from the College of the Environment. Sally Zyfers, a Graduate Student from the College of Education (Learning Sciences and Human Development) assisted with curriculum development, instruction, and support.

Research participants included twenty-three, undergraduate Honors students from the University of Washington (twelve women and eleven men). Participants were selected based on

their qualification for and admittance into the University of Washington Honors Program; their enrollment in an interdisciplinary academic program focusing on experiential learning, research, and critical thinking; and their decision to enroll in this elective writing class. Students ranged in age from 18-21. They represented all four grades and variety of majors including Computer Science, English, History, Bioengineering, Journalism, Musical Composition, Chemical Engineering, and Physics. Participants electively enrolled in this interdisciplinary writing class called "What We Know and How We Know It" (HONS205), where they used Studio Design techniques and a series of classroom exercises designed to cultivate creativity as vehicle for exploring writing styles, strategies, and content.

This class met three times per week (Monday, Wednesday and Friday) from 9:00 AM – 12:00 PM. During each class students participated in classroom exercises designed to cultivate creativity. The quarter-long curriculum included fourteen classroom exercises, as well as a series of "Limbering Up" exercises, and two projects (an analysis of academic papers from different disciplines and a final group publication). These exercises were developed by Robertson to elicit the skills and "design attitudes of mind" required by designers through action and reflection. Exercises were also used as context for exploring different writing styles, strategies and content. Students were assigned readings that prompted further thought on the exercises that had been completed in class. Students were also required to write and submit reflections on the thoughts and experiences they had during creative action. Professor Robertson provided all of the materials for this class from his unique, personal collection of cultural objects. A detailed description of the materials provided is included in descriptions of each exercise.

Data Collection Procedures

A rich variety of data was collected from sources including students' written reflections, artifacts created by students in response to classroom exercises, the final publication created by students, "ethnographic" field notes from participant-observer observations of classroom exercises, photographs taken during classroom exercises, course materials developed by Robertson (syllabus, handouts, prompts for creativity exercises), and notes from conversations with my team.

Observations were collected in a natural, non-manipulative classroom setting. As researcher, I was both a participant-observer and Teaching Assistant who interacted freely with students and participated in classroom exercises and discussions when appropriate. I took extensive, hand-written notes during each class. The data collection took place over a twelve-week period of time, 3 times per week, for a three-hour timeframe during each (totaling approximately 108 hours).

I collected qualitative data from written reflections that students generated after the completion of each creativity exercise. Reflection was an important part of the course design. After each class, students were required to reflect and write about the experiences they had when completing creativity exercises. Guidelines for quality, depth, length and content for written reflections were left intentionally vague. Students submitted reflections to Canvas, an on-line learning management and scheduling system provided by the university.

Selection of creativity exercises for data analysis

I selected five out of the fourteen exercises presented in class. My intent was to select qualitatively different exercises that were foundational to the rest of the class, while minimizing redundancy. This would allow me to examine whether the type of metacognition that students

reported varied depending on the dyads that were in play and different types of tasks. Each of the five exercises selected emphasized a different foundational skill or "attitude of mind" that students practiced and built upon in subsequent exercises throughout the rest of the quarter (identifying funds of knowledge, sorting, constraints, reframing from the perspective of different mindsets, and making connections). Each exercise required the production of different types of artifacts (physical objects, ideas, methodologies, mind maps, and performances). The five exercises selected also gave students the opportunity to experiment with a variety of different affordances, constraints, and group configurations (individual at-home work, fluid groupings that changed according to students' interests, cooperative and competitive small groups, and whole class activities). With such variety, I expected that the types of metacognition reported would vary across tasks, exercises, and dyads of the activity system. The exercises that I chose are described below, along with a brief explanation of why I chose each one. A list of all fourteen exercises is included in the Appendix.

Students completed Exercise #1 (My Journey to Here) individually at home prior to the start of class. They were instructed by email to describe "the how's, whys, what's and wherefores of the journey that has brought you to this class" on a single sheet of unlined sheet of paper and to use this "Artifact" to present themselves to their peers on the first day of class. Students had to consciously draw from prior knowledge of their own cognition, interests, skills, and experiences (with minimal guidance and little awareness of their audience) to produce this "Artifact." This exercise also included the element of "performance" as an artifact. I selected this activity allowed students to work unilaterally and to purposefully reflect upon how their prior knowledge informs decisions made during creative action.

In Exercise #2 (Knot that Sort), students were invited to "visit" and "sort" the collections of objects "tantalizingly arrayed (or mysteriously concealed in boxes!) on tables around the room." This exercise, more than any other, emphasized process over product as students worked together, migrating from table to table in different group configurations, to sort miscellaneous objects (souvenirs from travels, white plastic pull tabs from milk/juice cartons, smooth grey stones, etc.) according to subjective criteria. Artifacts included the unique methodologies students used for sorting objects and their sorting arrangements. I chose this exercise because it was a fluid group activity (giving students the opportunity to work with a variety of individuals, thinking styles, materials, and ideas) and because the process of sorting (words, ideas, objects, people) is essential in any creative activity.

In Exercise #3 (Pulp Friction), students were instructed to tear three pages out of a 1950's pulp fiction novel and to write a new 3-page story using only the words on pages selected. They wrote stories individually as a homework assignment. They presented their stories in class the next day and discussed challenges, strategies and solutions. In this case, "Artifacts" included the stories that students wrote and, arguably, the variety of methods they developed to sort and organize words. I chose this activity because it built on the prior exercise by enabling students to sort words, and it highlighted both the benefits and challenges of working with constraints.

In Exercise #4 (Boring Postcards), students were asked to select a "boring postcard" from an old book by the same name that included photos of state parks with no people, highways to nowhere meandering into distant sunsets, empty cafes and beauty salons, parking lots filled with 1950's sedans. Then, working in small table groups, students were instructed to write captions for the postcards that they had selected and to identify the mindsets used when writing captions. After this practice round, they were asked to write ten more captions and identify the

corresponding mindsets – working individually at home. When they reconvened, they discussed their responses and generated a list of the most frequently used mindsets. I chose this exercise because it gave students the opportunity to experience the effect that different mindsets and perspectives could have had on creative ideas and output. This also gave students the opportunity to practice consciously developing awareness of, shifting, synthesizing, and externalizing different perspectives.

In Exercise #12 (Object Connections), students were divided into two teams. In round one, students took turns selecting unrelated objects (old cell phones, plastic souvenirs from foreign travels, raffle tickets, seashells, playing cards, etc.) from a corrugated box. Then they were asked to make a connection between the object that they selected and another object already on the table (on a piece of butcher), draw a line between objects to illustrate the connection, and describe the connection as quickly as possible to their classmates. Students helped each other during this practice round, working together to create better connections with each turn. At the end of round one, each team developed a list of criteria for judging the "value" of the connection on a scale from one to five. During the second round, this activity changed from collaboration to competition. Students competed to make the most "valuable" connection, all the while building on each other's ideas. At the end of round two, each group voted on the "most valuable" connection based on the criteria that they had developed in the previous round. Artifacts included the connections that students made, the butcher paper diagrams depicting connections, the judging criteria developed students, and the presentations that students did to convince each other to vote for their connections. I chose this activity because it incorporated strategies used in the four prior activities (drawing from their own knowledge, sorting, constraints, and mindsets). This exercise also gave students the opportunity to shift perspectives

between “Actor” and “Audience” during the course of creative action and to negotiate differences between people, objects and ideas.

Data Organization and Analysis

After determining which exercises to analyze, I assembled narrative data from transcribed fieldnotes that I had taken during my classroom observations, as well as the relevant chapters that students had written for their final group project (a printed bound publication summarizing each exercise) and the instructions that Professor Robertson had distributed prior to each exercise. This data provided background information, context and rich description for this write-up. I also used fieldnotes to triangulate student reflections.

Then I downloaded students’ written reflections from the Canvas website to Word files. I created a separate Word file for each exercise. Each file contained reflections that each student had written about their experiences during the completion of a given creativity exercise. I organized data according to exercise, rather than student, because this enabled me to study creativity in context with each exercise being a unique activity system (consistent with Glaveanu’s theory), rather than focusing on “person” or “product” as my unit of analysis.

Then I separated students’ written reflection into consistent units of meaning or thought units. Each Thought Unit (TU) contained a single, measurable thought that was related to creative activity. In most cases, a TU was comprised of 1-5 sentences where student reported and reflected about the thoughts and actions they had when solving creative exercises. I reviewed these TUs 3-4 times during different stages of the organizational process to ensure consistency of unit (see below).

I used Atlas.ti 8, a qualitative data analysis and research software program, to code and analyze TUs for each exercise. I used two frameworks to generate deductive codes and to

analyze my data – Glaveanu's "Framework of Distributed Creative Activity" and Schraw and Dennison's "Metacognitive Awareness Inventory." I also generated a third set of codes based on related themes that emerged during my preliminary analysis. A list of all of the codes that I used, definitions for each code, and examples of TUs assigned each code is included in Appendix A.

Glaveanu's "Framework of Creativity" enabled me to study where, when and how students engaged in creative activity as they solved the problems presented in these exercises. Glaveanu's framework included three dyad pairs that mediate a "Creative Action" triangle within a material/social/cultural/temporal environment of "Affordances" that facilitates or constrains creative action. This activity system emphasized the interrelationship between five elements, which Glaveanu refers to as the "five As." The "five A's" included Actor students who participated in creative action, either alone or as part of a group; Audience (anyone who assisted, contributed, judged, critiqued, or used the artifacts created by Actors); Artifacts (externalized solutions to creative thought; responses to the exercise prompts including material objects, concepts, words, ideas, models, methodologies, performances, or presentations); Creative Action (the actions/activity used by Actors when solve problems including "Internal Creative Action" (Ideation, Incubation, Insight) and "External Creative Action" (Execution, Implementation or Performance); and finally, Affordances (what the environment offered the creator to guide, facilitate or constrain creative action. Included exercise prompts/instructions, material objects, tools and technologies, methodologies, past work, assigned readings, objects, symbols. Material object, people, and culture both allow and constrain creative action). This model captured creative activity "in context" and "in the relational space between "Actors" and their

"Audiences," the production of "New Artifacts," and "Material/Social/Cultural Affordances." I used the following dyad pairs and elements to code data deductively (Glaveanu, 2014, pp. 1-91).

- Actor(s)-Artifacts
- Audience-Artifacts
- Actor(s)-Audience
- Internal Creative Action
- External Creative Action
- Affordances

Schraw and Dennison's "Metacognitive Awareness Inventory" provided clear definitions and an established framework for analyzing the metacognitive processes that students used during learning episodes. This instrument was designed to assess self-reports of self-regulated learning skills across disciplines. While often used for language arts, the processes described are domain general and can be applied to creative processes. I adapted Schraw & Dennison's definitions for use in a creative context (see literature review). I used this adapted framework to code and analyze TUs from student reflections indicating the conscious use of the following metacognitive processes during creative activity (Schraw & Dennison, 1994, pp. 476-479) (Schraw 1998 p. 115).

- Knowledge of Metacognition
- Planning
- Use of Information Management Strategies
- Monitoring Creative Activity
- Correcting Comprehension

Based on Glaveanu's "Distributed Model of Creative Action" and the themes that emerged during the first two levels of coding described above, I created the following set of inductive codes to capture a more nuanced analysis of the metacognitive processes students used during creative activity.

- Social Differences
- Material Differences
- Temporal Differences
- Conundrums
- Constraints
- Synthesis

After coding data from student reflections using the codes described above, I used the tools provided in Atlas.ti 8 (frequency tables, co-occurrences, query tools, and quotation retrieval) to analyze the data. I looked for patterns or themes in the data, compared datasets and quotations to determine where (within G's framework of distributed creative action) students used metacognitive actions/strategies. I selected quotations from student reflections to support and illuminate key findings.

I put much time and thought into the initial preparation of my data, since the units that I selected would be the foundation of my analysis. This step would determine the reliability and frequency of data that would be coded, and if done properly would minimize the possibility of redundancy, inadvertently coding the same thought multiple times, while helping to ensure that no pertinent data was lost within a verbose paragraph.

Several factors, inherent in this study, made coding challenging. In order to ensure coding consistency across a variety of students and exercises, I created the following guidelines

to address each challenge. I referred to these guidelines frequently when coding to check my own assumptions and to ensure consistency.

a) Inconsistent Written Expression - Students' reflections were highly subjective, oftentimes personal, and varied in terms of depth, complexity, fluidity of expression, and effort allotted to this process. I read each reflection multiple times in order familiarize myself with different writing styles, tones and the tenor adopted by each student. Through this process, I became very familiar with the data and confident in my interpretations.

b) I experimented with different units of analysis – phrases, sentences, paragraphs, and thought units to determine which would be most reliable and replicable. After much trial, error, and discussion with my advisor, I chose single thought units as my unit of analysis. This unit of analysis seemed like the best way to minimize redundancy and would allow me to capture writers' intent while ensuring the accuracy and consistency of my own interpretation.

c) I maintained students' original words, sentence structures, and paragraph as much as possible, considering these to be conscious decisions that students made for organizing their own thoughts into meaningful chunks. If thought and action were tightly interwoven in one simple sentence, I considered it to be one TU. If students elaborated on their thinking process with great depth, including different examples and unrelated threads in one paragraph, I kept the paragraph intact as one thought unit to avoid duplicating coding for a single thought or idea.

d) I chose not merge sentences, but I broke longer paragraphs into smaller units if they contained more than one idea or conflicting thoughts about the same experience. I separated detailed action steps into separate thought units. If students reported taking a

new tact as a result of significant insight, or if an action lead to a significant new tangent, I separated the two (such as expressing frustration with the constraints of an exercise but later realizing that this limitation resulted in an action that they wouldn't have discovered without this constraint). Often this was signaled by words such as "however," "on the other hand," "I tried to reconceptualize my approach…"

e) Different Dyads. I separated any clear demarcations between dyads in the activity system; for example, when students switched from reporting on the production of a new artifact to observations of other students' work.

f) Temporal Inconsistencies. In order to maintain the integrity of the analytical frameworks that I selected, I was very deliberate in coding only the thoughts/actions that occurred during creative action – not before or after (see literature review). Schraw and Dennison were very clear about which processes occur before, during or after a learning episode. Similarly, Glaveanu's Framework was designed to describe the interrelationship between elements during creative action. However, student reflections were written after the fact, with a range of content including what they thought/did during creative action as well as thoughts that they had afterwards and related experiences from the past. In some instances, group discussions were part of creative action/ideation and sometimes group discussion followed the activity. Oftentimes temporality was signaled by students' use of the past tense, prepositions of time, contextual clues, examples from the past, or suggestions for future action.

g) Oftentimes students connected the current exercise to prior learning. If the students' intent was express to "Knowledge of Cognition," that would help them plan and strategize for the current activity, I coded it as such. But if it was more in the vein of

reminiscing, or by way of introduction setting the stage for the reflection that would follow, I did not code it.

h) Researcher Consistency. Several of the MIA components were similar to elements in Glaveanu's activity system. For example, both "Use of Information Management Strategy" and "Creative Action" involved the deliberate selection and use strategies to complete an action – but one is related to metacognition and the other to creativity. And "Monitoring Creative Activity" could be confused with "Internal Creative Action." To avoid double coding and "coder drift," I made a clear distinction between the codes in these two frameworks and focused on the research questions.

i) Researcher Objectivity. Some interpretation and "reading between the lines" were necessary when analyzing student's subjective reflections, but I tried to refrain from imposing my own interpretation onto students' written words.

RESULTS

To illustrate how students used metacognition during creative action, I will present data generated from reflections that students wrote about their experiences when completing a series of five (out of fourteen) creative exercises. I coded students' reflections using two sets of deductive codes and one set of inductive codes (codes are defined in Appendix A). From this data, I obtained 578 Thought Units (TUs); 329 of these TUs described creative thoughts and actions that students had while they were in the process of completing creative problem-solving exercises, and 249 of these TUs reported thoughts that students had after the completion of the exercises. Even though much rich thought (which contributed to future creative action) occurred after the completion of each exercise, I decided not to analyze these reflections. This data was outside the scope of my study, since Glaveanu's model was designed to capture the interrelationships that occurred during (not before or after) creative activity.

First, in order to determine whether metacognition occurred during creative action, I examined frequency data to show the relevance and utility of the models I selected for this study. Then I studied co-occurrence data to determine which of the metacognitive processes described in Schraw and Dennison's "Metacognitive Awareness Inventory" were reported when each element in Glaveanu's "Framework of Creativity" was in play. I also presented frequency and co-occurrence data generated from a series of inductive codes, related to Glaveanu's theory, that I developed after the first round of coding to see if this information would help clarify my research questions.

Once the relationship between metacognition and creativity had been established, I looked more closely at aggregated co-occurrence and query data from Atlas.ti to study the types of metacognition that the students used, as well as the creative processes that occurred when

students used different types of metacognition. This gave me a better sense of the interrelation between metacognition, the elements in the activity system, and the creative process. I highlighted the metacognitive processes that occurred most frequently within the Creative Action triangle, as well as when the dyads that mediated creative action were in play, and when affordances and constraints were highlighted.

To illustrate the use of metacognition within different contexts of creativity, I provided a brief overview of the similarities and differences in the use of metacognition with different tasks across all five exercises. Then I described Exercise #12 (Object Connections) in more depth as an activity system using Glaveanu's Framework. I used query data and quotations from student "Actors" to illuminate the use of metacognition in context as they generated solutions to this exercise. This helped further my understanding of how students used metacognition during Creative Action and how metacognition might be incorporated into Glaveanu's Framework.

My results indicated that students used metacognition when each of the dyads that mediated creative action were in play; as they engaged in the processes of internal and external creativity within the Creative Action triangle, and as they grappled with social/material/cultural affordances and constraints. Students also used metacognition (especially "Monitoring Creative Activity") when grappling with the differences that they encountered during creative action – different internal ideations or "conundrums" (their own thoughts, feelings and ideas), as well as differences between themselves and others, between the materials and symbols they worked with, and between the affordances and constraints in their environment. They monitored their own creativity (and that of others) as they developed aware of, synthesized, and externalized new "courses of action" that arose from these differences. These interactions occurred in the context

of each creativity exercise (defined as separate activity systems) as students completed a variety of tasks. The data that I generated, relative to each research question, is presented below.

Research Question #1 - Does metacognition occur during creative activity?

First, I used frequency data from the 329 TUs that occurred during creative action, aggregated from all five exercises, to establish the relevance of the two analytical frameworks that I selected (Glaveanu's "Framework of Creativity" and Schraw and Dennison's "Metacognitive Awareness Inventory"). Then I used this aggregated data to show that there were co-occurrences between metacognitive processes and the elements of Glaveanu's Framework. My findings are described below.

The elements in Glaveanu's "Framework of Creative Action" occur in most thought units

Frequency data showed that students consistently referred to all five elements of Glaveanu's Framework of Creativity in written reflections about their creative activity in each of five exercises. This showed the utility of Glaveanu's framework in my study. One dyad of the creative activity system was at play (sometimes more, individually and in combination) in most every TU. The majority of TUs occurred within the "Actor(s)-Artifact" dyad (85%), with 27% in the "Audience-Artifact" dyad and 13% in the "Actor(s)-Audience" dyad. Both "Internal Creative Action" (81%) and "External Creative Action" (53%) were reported with great frequency. Similarly, "Affordances" were reported in 79% of meaning units. Constraints were coded across all exercises as well, but with much less frequency (21%). These frequency data are shown in Table 1.

Metacognitive processes identified by Schraw and Dennison occur in most thought units

Frequency data showed that the deductive codes for five out of six components described in Schraw and Dennison's "Metacognitive Skills Inventory" occurred consistently during

creative action, with TUs distributed throughout all 5 exercises. Metacognitive processes occurred in most every thought unit across all five creative problem-solving exercises. "Monitoring Creative Activity" occurred much more frequently that the other components (72%). "Planning" (18%), "Knowledge of Cognition" (9%), "Implementing Information Management Strategies" (12%), and "Correcting Comprehension Errors" (7%) also occurred but with less frequency. "Evaluation" occurred after the completion of creative action, so it was not coded in this study. These data indicate the utility of Schraw & Dennison's MIA as an analytical framework in my study (See Table 2).

Inductive codes occur during each problem-solving exercise

As I reviewed students' reflections, several of Glaveanu's underlying themes became apparent: material, social, temporal, and ideational difference as well as the synthesis of these differences. I developed corresponding inductive codes based on these themes and analyzed them to see if any additional patterns would emerge to illuminate my understanding of the relationship between metacognition and creativity. "Material" differences occurred in 64% of TUs, "Social" differences occurred in 26%, "Temporal" differences occurred in 2%, and "Ideational" differences occurred in 17% of TUs. "Synthesis" of these differences was suggested in 62% of TUs. Frequency data suggesting the occurrence of all of these themes is shown in Table 3.

This frequency data suggested that all the elements described in Glaveanu's "Framework of Creativity," five of the six metacognitive components presented in Schraw and Dennison's "Metacognitive Awareness Inventory," and all of the inductive codes related to "differences" were frequently reported in all five exercises. These frequency numbers indicate the utility of all three datasets in this study.

Data suggest that metacognition occurs across all elements of Glaveanu's Framework

The aggregated co-occurrence data in Table 4 was collected from students' reflections about five creative exercises. This data suggested that five out of the six components described in Schraw & Dennison's "Metacognitive Awareness Inventory" occurred across all five elements of Glaveanu's "Framework of Creativity." This occurred when the three dyad pairs that mediated creative activity were at play. This also occurred within the creative action triangle and as students managed affordances and constraints during creative action. I will discuss data from Table 4 in more depth when addressing the following research question.

Research Question #2 – What does the type of metacognition used by students during creative action tell us about the interrelation between the elements in an activity system and the creative process?

The data shown in Table 4 indicated that five out of six metacognitive processes co-occurred with each element of Glaveanu's framework during creative action in every exercise studied. I examined this aggregated data to see what the types of metacognition used by students suggested about the interrelationship between elements in Glaveanu's activity system as they completed creativity exercises. First, I highlighted co-occurrence between different metacognitive processes in the same TU. Then I looked at the metacognitive processes that occurred most frequently within the "Creative Action" triangle. I also examined the metacognitive processes that occurred when the different dyads that mediated this creative action were in play and when student worked with the affordances and constraints that facilitated and limited their creative activity. My findings are discussed below.

Co-occurrences between metacognitive processes

Occasionally, two metacognitive processes occurred in same TU, but the order was inconsistent across dyad pairs and exercises. For example, "Monitoring Creative Activity" co-occurred with 59% of reports indicating use of "Information Management Strategies," 50% of reports citing "Knowledge of Cognition," 41% when engaged in "Error Correction" and 29% of "Planning." This was consistent with Schraw (1998), who maintained that there was a relationship between knowledge and regulation of cognition and that all of the processes were "intercorrelated" (Schraw, 1998, pp. 114-116). This suggested that there may have been a reciprocal relationship between these components, with students using "Knowledge of Cognition" and "Monitoring Creative Activity" to inform their conscious use of the other metacognitive components and vice versa. This also suggested that metacognition was a unique, individualized process with students drawing upon different strategies at different times depending on the declarative, procedural and conditional knowledge they had of the skills in their repertoire, as well as their interpretations of the tasks at hand. This co-occurrence of metacognitive processes is shown in Table 5.

Metacognitive processes co-occur with all elements in Glaveanu's Creativity Framework

Co-occurrence data from Table 4 indicated that five out of six types of metacognition occurred when all of the dyad pairs that mediated creative action were in play: "Actor(s)-Artifact," "Audience-Artifact," "Actor(s)-Audience." All MIA components also occurred as students engaged in "Creative Action" and when students worked with "Affordances" and "Constraints" during creative action. The kinds of metacognition that occurred when each element was in play provided information about the interrelation between "Actors," "Audience," "Artifacts," and "Affordances" during "Creative Action."

If we look at Table 4 more closely we can see that, while all types of metacognition described by Schraw and Dennison (except "Evaluation") occurred during creative activity, "Monitoring Creative Activity" occurred much more frequently and consistently than the other components both within the creative action triangle and when the dyad pairs that mediated creative action were in play. This prevalence of "Monitoring Creative Activity" seemed to indicate that students monitored their creative activity as they interacted with all of the elements in the Framework.

"Monitoring Creative Activity" was followed in frequency, across all elements, by "Planning" and "Use of Information Management Strategy." Very few codes for "Knowledge of Cognition" occurred. When "Knowledge of Cognition" occurred, it was usually at the beginning of a reflection by way of introduction, oftentimes linking new knowledge to prior knowledge to create a context for the learning that follows. Similarly, "Planning" usually occurred at the beginning of a reflection or after students encountered a challenge that required added focus. Very little "Error Correction" occurred during these interactive exercises. This could have been because error correction usually occurred after the completion of creative output (rather than during the creative process). This could also be explained by the fact that this class focused more on exploring the creative process than perfecting products; furthermore, there was little emphasis on finding "the right" solution to the problems presented. Because most "Evaluation" necessarily occurred after creative action, there were few reports of this metacognitive skill.

Metacognition occurs within the creative action triangle

As shown in Table 4 above, metacognition co-occurred with notable frequency within the activity triangle where creative processes took place. "Monitoring Creative Activity" was the most frequently coded component. The other four metacognitive processes ("Planning,"

"Implementing Information Management Strategies," "Knowledge of Cognition," and "Error Correction") also occurred throughout written reflections but with much less frequency. The fact that "Monitoring Creative Activity" occurred in most every TU was not surprising since students monitored their own creative thoughts and action through written reflection (which constituted each TU that was analyzed) as they completed creativity exercises.

The frequency of co-occurrence between metacognition and "Creative Action" merited closer analysis. Glaveanu echoed decades of creativity research when explaining that "Creative Action" included both "Internal Creative Action" (Ideation, Incubation, and Insight) and "External Creative Action" (Execution, Implementation or Performance) (Glaveanu, 2015). I coded these functions separately because Glaveanu mentioned them both, because they both occurred within the Creative Action triangle, and because both processes were mediated by "Actor(s)," "Audience," and "New Artifacts." In many instances both "Internal Creative Action" and "External Creative Action" occurred in the same TU with metacognitive processes. This suggested that metacognition may have played a role in facilitating the regulation of (and between) these two functions. It is also interesting to note that, while most studies of creativity focused on the externalization of creative thought, the students in this study reported more metacognition during "Internal Creative Action," than they did with "External Creative Processing."

Metacognition occurs as students externalize internal thought through action

Table 4 shows that "Internal Creative Action" and "External Creative Action" almost always co-occurred with metacognitive processes. In all three cases (internal, external and combined) students used "Monitoring Creative Activity" approximately 4-7 times more than the other four process. The prevalence of "Monitoring Creative Activity" in all three instances

suggested that this component may have played a key role in mediating the externalization of thoughts generated during ideation, incubation, and insight. Perhaps students engaged in "Monitoring Creative Activity" as they moved between internal creative thought and the externalization of ideas through creative action. This data could also suggest that "Monitoring Creative Activity" played a role in transforming internalized affordances into externalized artifacts through the process of creative action (Glaveanu, 2014, p. 53). It seemed that thought was required for creative action, but monitoring "doing" also promoted the development of new ideas in an iterative cycle of thought and action. Glaveanu explained that the material distribution of creative work relied on the interplay between internalization and externalization conceptualized by Vygotsky. He wrote that "The use of material artifacts is first internalized by creative actors and later materialized in action, as interrelated processes. The relation between mind and world is based on processes of acquisition, transformation, expression – all integral to creative acts" (Glaveanu, 2014, p. 53).

According to creativity scholars discussed in the literature review, this process occurred throughout creative activity, but it was difficult to capture the complex relationship between thought and action through coded analysis using these two frameworks. While this interplay was essential to creative activity, there may have been a misalignment between models. Or perhaps students were not consciously aware of or may not have articulated the relationship between thought and action in their written reflections. Students' reflective texts did, however, provide some evidence of the nature of this relationship.

Many students drew on "Knowledge of Cognition" as they "Planned" and generated ideas for Exercise #1. Zachary, who was more reflective than most, captured the process of his fellow-

classmates when he wrote about this dynamic. When "Monitoring Creative Activity" he wrote the following.

> For me, this exercise was an attempt to organize and structuralize this vague continuum that was my past and my life. In the moment, it is hard for me to pinpoint the exact source of my emotions but when I draw upon my current knowledge and experiences it allows me to sort of brush away some of the ambiguity and uncertainty present in my past and truly assess what it meant to me retrospectively…. What was cool about this exercise is that it allowed me to draw together all those separate events and meaningful lessons into a cohesive narrative of my life. I tried to just go with the flow and add what felt natural. As I thought about what to include, the patterns of behavior I normally associated with my life began to solidify into a causal chain….This is a process that began long before this assignment, but I feel this exercise brought a new level of self-awareness to the process itself.

Zach alluded to several metacognitive process that guided him through this process of internalizing affordances (personal history, past experiences, accumulation of knowledge), ideating, and externalizing ideas in the form of a written narrative that he presented to the class. He demonstrated "Knowledge of Cognition" as he described the "vague continuum" of knowledge, culture and experiences that he had accumulated over the course of his lifetime. As he incubated and ideated during the "Internal Creative Action," the patterns of his behavior began to solidify into a "casual chain." It was interesting that in naming his own process he mirrored the "causal chain" between internalization and externalization that occurred during creative activity. He seemed to monitor his own creative action through writing as he tried to

capture the totality of these past experiences "that began long before this class" and relate them to his present choices and patterns of behavior. Then he attempted to externalize this history by weaving it all together into a cohesive narrative, a "New Artifact," that was meaningful to him. He said that this exercise brought a new level of self-awareness to the process itself ("Knowledge of Cognition"), which will presumably inform future creative ideation and action.

Metacognition occurs when the dyad pairs that mediate creative action are in play

Co-occurrence data in Table 4 showed that metacognition was reported with great frequency in all of the dyad-pairs that mediated the creative action described above. There were significantly more reports of metacognitive processes in the "Actor(s)-Artifact" dyad than "Audience-Artifact," and "Actor(s)-Audience" dyad pairs. "Monitoring Creative Activity" co-occurred with much greater frequency in each dyad the other four metacognitive processes, and similarly, occurred with much greater frequently in the "Actor(s)-Artifact" dyad. The other MIA components were relatively consistent and infrequent across elements. This data indicated that student actors reflected more when they were interacting with "Artifacts" or finding unique solutions to problems during creative action than they did when interacting with peers, audience, or their own evaluation of other students' products.

"Planning," the second most frequently cited metacognitive process, also occurred most often in the "Actor(s)-Artifact" dyad. In keeping, "Planning" occurred most when students were negotiating "Material Differences" as both of these codes related to the production of a physical artifact. "Planning" and "Knowledge of Cognition" invariably occurred at the beginning of a reflection, while the other metacognitive processes were more evenly distributed throughout a reflection. "Implementing Information Management Strategy" occurred less often, but this component also appeared most frequently when the "Actor(s)-Artifact" dyad was in play and

when students negotiated “Material Differences.” “Knowledge of Cognition,” “Error Correction” and “Evaluation” occurred must less frequently during creative action.

Ivy used several metacognitive skills as she thought about (“Monitoring Creative Activity”) the interrelationship between all three mediators - herself as an “Actor” who was creating and presenting a “New Artifact” that would appeal to her “Audience.” She engaged in “Planning” when determining her goals for this assignment, thinking of the best strategy, and selecting the content for her discerning audience. She demonstrated declarative, procedural, and conditional “Knowledge of Cognition” by explaining that she got anxious when doing presentations, had a tendency to reflects “broadly on her life” in stressful situations, that she wanted to emphasize her command of “letters, books, words, and thought” in this presentation because her drawing skills were limited. While “Monitoring Creative Activity” and “Planning” she wrote, “Once I began the process, I quickly realized that “my journey to here” was a lot more complex than I expected… Knowing that others will be watching me present my “art”—and they will be reading this reflection, too!—made it a lot more nerve-wracking than drawing poorly-drawn stick figures, connecting them with colorful arrows, and telling my own story actually were…. How could I present a mixture of just the desirable amounts of creativity, quirkiness, humor, and intellect?” Her reflections seemed more inspiring than her externalization - she included the events that she thought would be most interesting to her audience and simply stopped when she filled up the page.

Material, social, and ideational differences are associated with specific mediators

According to Glaveanu, creativity was rooted in difference and began when an actor became awareness of the social, material and temporal differences “between what is and what could be.” These “differences” seem to emerge from the interaction between specific dyads.

Data in Table 6 suggested that 95% of all "Material Differences" occurred when the "Actor(s)-Artifact" dyad was at play, 31% occurred in the "Audience-Artifact" dyad, and only 13% occurred in the "Actor(s)-Audience" dyad. Likewise, 83% percent of all "Social Differences" occurred when "Actor(s)-Artifact" dyad was in play, 76% in the "Audience-Artifact" dyad, and 38% occurred when the "Actor(s)-Audience" artifact was in play. In keeping, 95% of "Conundrums" occurred when the "Actor(s)-Artifact" dyad was at play, and 25% occurred in the "Audience-Artifact" dyad. These percentages dropped significantly when the "Actor(s)-Audience" dyad was at play. Based on the co-occurrence of these "differences" with specific mediators, it seemed that "Material Differences" arose when dyad pairs that included "Artifact" were in play; "Social Differences" occurred when dyads that included "Actor" and/or "Audience" were in play; and "Ideational Differences" were affiliated with either or both mediators.

Metacognition occurs when students synthesize social, material and ideational differences

Data suggested that students used metacognition as they developed awareness of, synthesized, and externalized these different perspectives within the "Creative Action" triangle through internal and external creative action. Glaveanu explained that the externalization of internalized ideas and affordances occurred in several stages – first "Actors" developed an awareness of different perspectives. Then "Actors" synthesized these different perspectives and developed a "new course of action." Finally, "Actor" externalized these ideas in a way that recognized this new course of action (Glaveanu 2015). Co-occurrence data and queries suggested that metacognition occurred during all three of these stages as students engaged in creative action. This is described in more detail below.

Metacognitive strategies occur as students develop awareness of different perspectives. Co-occurrence data in Table 7 shows that students used metacognitive strategies frequently as they consciously reflected upon and developed awareness of the different perspectives between themselves and others (collaborators, peers and audience), materials and symbols, and the affordances and constraints provided by materials and methodologies available to them (Glaveanu, 2015). They also used metacognition as they developed an awareness of their own ideas and mindsets. Again, "Monitoring Creative Activity" was the most frequently used strategy. This pattern was consistent across all four types perspectives studied (material, social, temporal, and ideational), showing that "Monitoring Creative Activity" may have played a role in developing awareness of these differences.

Metacognitive strategies occur as students synthesize differences. Glaveanu explained that "Actors" first internalized an understanding of the material affordances (and constraints) of their environment and the perspective of others, as described above (Glaveanu, 2015). Then "Actor(s)" resolved, synthesized, and generated new ideas that incorporated these social and material differences. Once these differences were internalized, they could "imaginatively construct new perspectives on their course of action which afford greater reflexivity and the emergence of novelty as they move between divergent and convergent thought" (Glaveanu, 2015, p. 165). Glaveanu drew from the work of Guilford and Torrance when alluding to "differences" as divergent thought while resolution/synthesis signaled convergent thinking. It seemed that metacognition may have facilitated this process.

As shown in Tables 7, the use of metacognitive skills frequently co-occurred with social, material and ideational differences. Table 8 shows that 69% of these differences were resolved or synthesized in the same thought units. Many indications of resolution also occurred in the

subsequent TU, but limitations in my use of the software prevented me from including this number. Co-occurrence tables and queries suggest the types of metacognition students used to develop an awareness of, consciously relate and synthesize these different perspectives (Glaveanu, 2015).

The aggregated data in Table 8 show that students used all of the metacognitive processes described by Schraw and Dennison except "Evaluation" as they synthesized the differences that arose in the dyad pairs. Students indicated "Monitoring Creative Activity" much more frequently than the other metacognitive elements, and this occurred most often when the "Actor(s)-Artifact" dyad was in play. Since co-occurrences were limited with the other dyads, I did not present this data. This data seems to suggest that metacognition helped regulate the synthesis of differences.

Manasa, like many students, indicated "Monitoring Creative Activity" as she internalized affordances. She noted an awareness of the need to synthesize differences between objects, people, and ideas before finding a way to externalize her thoughts. She summed this up when writing, "The purpose of the sorting exercise that I had deduced while weighing rocks and piling dollar bills was that anything can be approached from multiple perspectives. Unless we were the first to open the box and take the items out, we were faced with items that had already been sorted in some way by another group. I was not going to walk away from the table just because I agreed very much with the last group's method of sorting; the challenge was to first decipher this method, then come up with a different one." She acknowledged switching roles between "Actor" and "Audience" as her group approached the same subjects from multiple perspectives and externalized a variety of solutions. Realizing that this exercise emphasized the ability to approach the same subjects from multiple perspectives, she came to the conclusion that "Sorting,

similarly, has several aspects that are linked: the sorter, the act of sorting, and the sorted. Each component brings unique purpose and impact to "sorting" as a whole."

Externalizing a new course of action. After students constructed new perspectives, they took steps to externalize or actualize a course of action through the production of new artifacts, written or symbolic expressions of an idea, or performances that afforded greater utility, reflexivity or novelty (Glaveanu 2015). As Glaveanu explained, individuals acted on the differences (execution, implementation or performance) in ways that acknowledged, exploited the potential of, or attempted to reduce/bridge these differences (Glaveanu p.27). He referred to these actions as "External Creative Action." This brings us back to the co-occurrence data presented in Table 4 showing the different types of metacognition that occur with "External Creative Action," as students indicated externalizing their ideas (Glaveanu, 2015). Often, these processes occurred in an iterative cycle. As discussed above, queries showed that metacognitive processes frequently co-occurred in the same TU with both "Internal Creative Action" and "External Creative Action." This co-occurrence within the "Creative Action" triangle suggested that metacognition was involved in the externalization of creative thought (Armbruster, Hargrove, Valgeirsdottier). This interweaving of thought/action could have represented an iterative process between thought and action since one necessitated the other and they both occurred within the activity triangle. This could also have suggested that metacognition was essential in internalization/externalization process discussed by Vygotsky.

Metacognition helps students when grappling with affordances and constraints

Fundamental in both Robertson's curriculum and Glaveanu's framework (as well as field of creativity research) was the role that material and social environments played in facilitating or constraining the development of new perspectives, products and performances. As Robertson

explained, many exercises used material reality as their starting point with students sorting, connecting, manipulating, and deriving inspiration from objects or texts. The materials provided for each exercise, the new artifacts and methodologies created by students, the ideas of their instructors and peers, even the written instructions for each exercise provided both context and resources that facilitated or impeded creative action in each exercise. Therefore, it was not surprising that students indicated awareness of "Affordances" in most every Thought Unit. Because students mentioned "Affordances" with such regularity and consistency in each exercise, analyzing them quantitatively would have provided little new information, dimension or texture. Nevertheless, numerous patterns emerged that shed light on our study of metacognition in creativity. These are best illustrated by quotations from students' reflections.

Students mentioned using objects to facilitate thinking as they monitored their own creative thought and action. Kimberly described how "physical objects served as metaphorical anchors for our thoughts." Parker elaborated when writing that "the physical objects we were examining and manipulating in class were critical in fostering this type of abstract thought… Just as computers require some novel external input to achieve truly nondeterministic behavior, humans require external stimuli to assist in our original thinking…. And just as computers can take random seeds from any atmospheric noise, humans can turn *anything* into a source of inspiration, as evidenced by the diversity of connections generated in this exercise."

Many students reported that "materials took over." In Exercise #3, Jacob made the strategic decision to let the words/materials guide him. He wrote, "At first, I thought that this way of creating a story was inefficient, as it held me back from creating the story that I wanted to tell. But then I realized that all the alterations that I had to make had pushed me into an entirely unexpected direction. Soon enough, I had no planned course for where the story should go, but I

would rather find key words that would guide me." Similarly, Zach explained that "Phrases such as "without any pretense of disguise" or "bullets began to fly" were created with an innate direction and I simply allowed them to lead the way." Glaveanu explained this phenomenon when maintaining that material artifacts had "agency," with "intentions being inscribed into material objects by their makers and users, as well as their resistance to our doing" (Glaveanu, 2014, p. 88).

Even though Robertson designed these exercises that would highlight the effect of constraints on creative activity, "Constraints" (68 TUs) were mentioned much less frequently that "Affordances" (261 TUs). This was surprising because students reacted to constraints with passion and with a variety of perspectives. For many students, constraints (such as ambiguous instructions, space requirements, antiquated texts with limited words, boring images, and unfamiliar objects) were a great source of frustration, limiting their creative action. Yet for others, constraints became affordances. Parker wrote that, "…constraints can be catalysts for creativity. This apparent paradox can be explained by the simple idea that thinking outside the box is impossible without a box (or bucket) of some sort to think outside of. In fact, even if you limit yourself to staying inside the box, the end result may be much better than if you had begun by floating in a dark vacuum. I think the reason for this is that constraints are a form of inspiration."

After "Monitoring Creative Activity," Brent articulated his new awareness of constraints as a vehicle for enhancing creativity. He wrote that "…the sentences that my constraints guided me towards were rich and varied—more so than I could have hoped to write "freeform" without a significant effort. Strikingly, after writing under constraints I felt more creative. Writing normally, I felt like an uncaged bird in a blue sky after my warm-up. What star athletes take from

blood doping, we gathered by subjecting ourselves to innocent constraints." Similarly, Brian reflected that, "Since I was only limited to the words from the old novel, the story sounds like a stranger wrote it. I used diction that I would never think about using. However, it also allowed me to create a story I would have never imagined in the first place. In fact, it was the constraint itself (the words from the pages) that aided me in thinking of a story. The constraints in this exercise influenced my work heavily, but in terms of expression, I find that was up to me. Whether I have my full vocabulary to utilize or a limited set of words, how I manage to express myself is my choice… it is still my expression with the given constraints."

In Exercises #3 and #4, many students explored the idea that "mindset" or "attitude of mind" could be either an affordance or a constraint, with "the overall direction of thought processes dictated by our mindset, and our mindset(s) are always conditioned by experiences." Emily astutely noted that working with constraints was difficult, but also liberating. Even though everyone was working with the same set of tools, her mind and her way of thinking shaped the way she used the tools provided. This exercise led Ivy to address the constraints of her own mind. She maintained that, "conditioning is like a "default setting" and acts as a constraint which makes it difficult to adopt different mindsets." While monitoring her own creative activity, she asked herself, "What, then, are the implicit constraints I face in my own thinking when I am asked to conjure a story out of thin air with no additional requirement—or in that case, any sentences/statements that I make?...Is it really possible to consciously steer ourselves away from a mindset?? If not, then the mind itself becomes a constraint."

Throughout this series of exercises, a cycle of "chaining" occurred as students consciously used the new ideas, methodologies, artifacts, and performances that emerged during creative action as the foundation for subsequent problem-solving activities. Students reported

drawing from prior knowledge and preferences ("Knowledge of Cognition") to create their introductory artifacts in Exercise #1 (Journey to Here) and to sort objects in Exercise #2 (Knot that Sort). In turn, they used the new knowledge about sorting and pattern-making that they developed during the Exercise #2 (Knot that Sort) to sort words in Exercise #3 (Pulp Friction) and to make connections between unrelated objects in Exercise #12 (Object Connections). While "Monitoring Creative Activity," they developed a greater awareness of the impact of their own "Attitude of Mind" on creative output - especially in Exercise #4 (Boring Postcards). This cycle of "chaining" was demonstrated as students resorted each other's work, adopted similar frames of mind when writing captions for boring postcard, and utilized the most popular criteria when making abstract connections between unrelated objects.

While Table 4 provides the co-occurrence of aggregated data described above numerically, Figure 2 overlays students' reports of the metacognitive strategies that they used as they interacted with different mediators in a creative activity system. This visual representation enables us to see what types of metacognition students used when different elements of the activity system were in play and may suggest the utility of metacognition during creative action.

Similarities and differences across all five exercises

It would be too lengthy and cumbersome to study each of the fourteen exercises (or even the five exercises that I analyzed for this study) in depth, but it was interesting to note the similarities and differences across tasks. As Table 10 shows, results were fairly consistent across all five of the exercises that I analyzed. Each exercise included from 100-147 coded TUs. Students reported using five out of six metacognitive processes described by Schraw & Dennison across all five elements of each creative activity system. In each case, students reported "Monitoring Creative Activity" much more frequently that the other metacognitive strategies.

Some variance was shown in students' use of the other four metacognitive strategies depending on the task at hand, the structure of the activity, and the skills that Professor Robertson was trying to elicit. I describe some of the differences below. Data from the analysis of each exercise are included in Table 10.

In Exercise #1 (My Journey to Here), 72 out of 116 TUs occurred during creative action. Students created a wide variety of "Artifacts" including mind maps, road maps, thumb prints musical compositions, and paper airplanes. They reported more frequent use and their reports of metacognitive strategy use varied more in this exercise than they did in the others. All reports of metacognition occurred when the "Actor(s)-Artifact" dyad was at play. Students engaged in "Planning" in 33% of these TUs, "Monitoring Creative Activity" in 37%, "Information Management Strategies" in 17%, "Knowledge of Cognition" in 9%, and "Correcting Comprehension" in 4% of these TUs. This makes sense because it was one of few exercises that explicitly challenged students to relate prior knowledge to current decisions and to represent this in the presentation of a "New Artifact," with no interaction with their "Audience. Emphasis on material rather than social differences is also fitting since they worked individually, at home when creating their "Artifact" and because they struggled with the constraint of representing their entire lives on a single sheet of paper. They had plenty of time to plan, they were unsure of what to expect, and they were nervous about making a good first impression so more use of "Planning" is understandable.

In Exercise #2 (Knot that Sort), 80 out of 147 TUs occurred during creative action. This exercise, more than any other, emphasized process over product as students worked together to sort miscellaneous objects according to subjective criteria. Even though students had to negotiate differences between people, objects and ideas in this exercise, they reported

"Monitoring Creative Activity" when the "Actor(s)-Artifact" dyad was in play much more frequently than they reported other codes (72% of TUs). The other metacognitive processes and dyads were reported with much less frequency. This was surprising. I had assumed that more metacognition would be reported in dyads that included "Audience" and "Social Differences" since students were both "Actors" and "Audience" to each other work, building from and resorting "Artifacts" that classmates had already completed using different criteria. Maybe students focused more on material objects (than potential tensions or differences with each other) because this was the first in-class exercise.

In Exercise #3 (Pulp Friction), 76 TUs out of 113 occurred during creative action. This appeared to be the most challenging exercise for most students. Students were very frustrated with the limited word choice, but out of duress they devised a variety of innovative strategies (multiple unsuccessful rewrites, developing word lists, spreadsheets and computer programs to sort words, simply letting the words guide them, waiting for the muse), and they composed a variety of compelling stories in spite of all-pervasive themes and rigorous constraints. Students reported "Monitoring Creative Activity" in 52% of TUs. Students engaged in more "Planning" (13%) "Correcting Comprehension" (12%), and use of "Information Management Strategies" (15%) (such as rereading the original text multiple times, selective focusing, and taking deliberate breaks to clear their minds) in this exercise than they did in others. Perhaps this was a result of rigorous constraints, the added challenge, and the fact that this was an in-home exercise focusing on product as well as process.

In Exercise #4 (Boring Postcards), 50 out of 100 TUs occurred during creative action. Students were asked to write ten different captions using different mindsets for the "boring postcards" that they selected. By chance, half of the students wrote captions first and identified

the mindsets that they used afterwards. While the other half deliberately adopted mindsets first and used them to develop ideas. Perhaps because this was a solo activity, students indicated "Monitoring Creative Activity" almost exclusively when the "Actor(s)-Artifact" dyad was in play (41 out of 48 TUs) and when grappling with "Material Differences." One interesting difference was that students used "Information Management Strategies" more in this exercise that in any other. Perhaps this was because students became aware of the impact that adopting different mindsets (irony, humor, cynical) had on their creative ideation and output as they consciously shifted focus and adopted different mindsets or perspective for each caption.

Understanding the type of metacognition used in these exercises suggested much about the interrelation between the elements of the activity system and the nature of the task. One would presume that the greater the complexity of a task, the more types and frequency of metacognition would be used. However, much to my surprise, results were fairly consistent across exercises regardless of the task, with only slight variations depending on the skill that Robertson was trying to emphasize. Metacognitive processes (especially "Monitoring Creative Activity" was used throughout each creative activity system, both within the "Creative Action" triangle as internal creative activity became externalized and when the dyads that mediated creative activity were at play. "Monitoring Creative Activity" was used most frequently when an "Artifact" was involved, especially if students were frustrated by constraints. If students had to interact directly with their "Audience" during the course of an activity, they would monitor their own understanding of interactions more frequently, especially if there were differences or tensions between themselves and others (i.e. competition). Students occasionally reported using "Knowledge of Cognition" during the early stages of creative action (to trigger prior knowledge so that they could plan). "Planning" was occasionally used, but usually with the more complex,

take-home exercises that permitted preparation, rather than fast-past, in-class exercises that emphasized quick thinking. Occasionally students mentioned "Using Information Strategies" to direct their attention during more complex problems or challenges. Often these were closely affiliated with "Monitoring Creative Activity," as one strategy informed the other. Because this curriculum focused more on process that product, students very rarely used "Correcting Comprehension." And they never used "Evaluation" because this this strategy occurred after creative action.

Research Question #3 – Where does Metacognition occur in the context of a problem-solving activity?

In this section, I illustrated students' use metacognition within the context of a creativity exercise. I began by describing Exercise #12 (Object Connections) as a creative activity system using Glaveanu's "Framework for Creativity." Then I analyzed co-occurrence and query data to show how, where and why students used metacognition during this activity. I also provided quotations from students to illustrate creative action from the perspectives of student "Actor(s)" in this activity system. This provided a rich context for delving deeper into the metacognitive processes used by students during creative action. Then I explored how metacognition might be included in Glaveanu's "Framework of Creativity." The "Constraints" of this thesis did not allow a full exploration of each exercise as an activity system.

I selected this exercise for several reasons. First of all, "making connections" was an overriding theme in Robertson's class. Out of a total of fourteen exercise, four provided students with the opportunity to practice making a variety of connections – connections between ideas, connections between snippets of conversations (symbols and meanings), connections between people, and finally connections between objects. As Professor Robertson explained, connection exercises enabled students to synthesize ideas, attitudes of mind, and solutions. This exercise

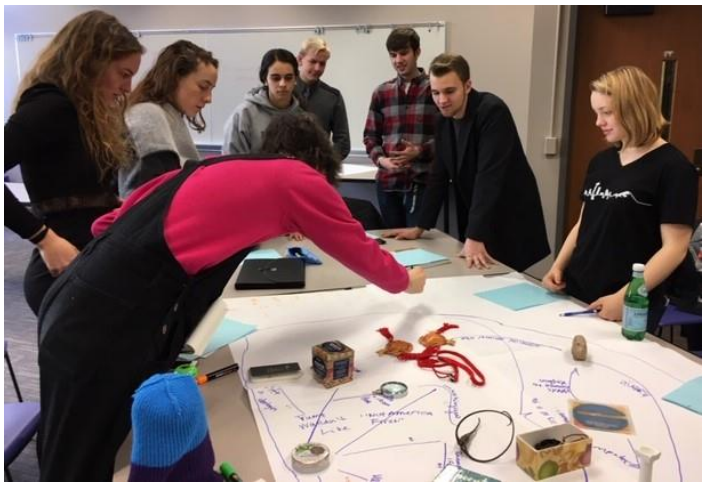
seemed particularly relevant to the theme of synthesizing differences, which was pervasive both in Glaveanu's work and in this curriculum.

Secondly, this exercise incorporated many of the ideas and practices that students used in previous exercises. As Ivy explained, "Drawing connections between objects on paper has been one of my favorite exercises because I think of it as a concrete way to tie everything we have learned about design thinking together. Some of the more obvious elements of this exercise include sorting (drawing a connection is the visual equivalent of sorting two objects into one category), constraints (there is only so much space we can use), and, of course, connectivity. Other exercises relate to this one in more subtle ways as well: the form of the objects is taken heavily into consideration when drawing connections, and empathy is especially necessary when we attempt to understand the connections others have drawn. The captions exercise, too, has a part in this exercise: by naming the connection, we are essentially captioning a category of objects from a specific frame of mind."

Lastly, this was the most complex exercise and best illustrated the interrelation between the elements in Glaveanu's activity system, as well and students' use of metacognition as they navigated differences during creative action. While some of the TUs in prior exercises were coded with multiple dyads, coding with all two or three dyad pairs occurred with much greater frequency in Exercise #12. This was because student "Actors" became "Audience" to the "Artifacts" that had been previously constructed by their classmates, and "New Artifacts" (the connections that students made) became "Affordances" in this exercise. In these instances, we had the opportunity to see creative action from the perspectives of both "Actors" and "Audience." They also had to negotiate a variety of "differences" in this exercise – material, social and ideational. This seemed like an indication of greater complexity and provided an

opportunity to see how students used metacognition as they interacted with all of the elements of the creative activity system to "acknowledge, exploit the potential of, or attempt to reduce/bridge" the social, material, and ideational "differences" that they encountered when solving these "wicked problems" (Glaveanu p.27).

Description of Exercise #12 as Creative Activity System



This exercise included two iterations. During Phase 1, students worked as a team with ten other classmates to generate unique connections between unrelated objects. The element of competition was added during Phase 2. This gave students the opportunity to see how interactions with other students (both collaborators and competitors) impacted their own creative action. Below I describe this exercise as a "Creative Activity System," using Glaveanu's definitions of the constitutive elements – "the five A's."

Actors and Audience. This exercise was a group activity with all participants playing multiple roles. In round one, students collaborated as a team of "Actors," helping each other make connections between a hodge-podge of unrelated objects and documenting their affiliations on paper. Student "Actors" also worked together to create the criteria that would be used to judge the "value" of connections. But before students could make their own new connections, they acted as "Audience," listening to the rationale of the classmates who made object connections before them. When creative action was over, and all connections and been made,

student “Actors” once again became “Audience” as they evaluated and voted on the best connections using the criteria that they had developed in the first round.

Creative Action. The class was divided into two teams of eleven students. In a warm-up iteration, the first student took an object (sight unseen) from a cardboard box and placed it on the butcher paper in the center of the table. Then each student took a turn selecting objects from the box, placing them next to object(s) on the butcher paper, and describing the 'connection' between their object and the other object(s) as quickly as possible. If the connection was with a single object, they placed the new object in line with the old. If the connection was between two or more objects, they placed the new object adjacent to them. Each student drew lines connecting the objects and labelled the connections. When each student had made a connection, the groups discussed the kinds of connections generated and developed a classification of the quality and value of connections that would be used in the next iteration. Robertson explained that “*poor connections”* were “simple, weak, bland, insipid, obvious and uninteresting. In other words, they don't contribute much to our culture of understanding.” Whereas, “*good connections”* were “complex, rich, multi-dimensional, subtle and expository. They reveal 'deeper' relationships (unlike the speed dating of the first iteration!) and enricher the associations among the collection of objects.” Students helped each other during this practice round and worked together to create better connections with each turn.

During the second round (Object Dominos Competition)**,** the element of competition was added. Students were charged with the task of making the most interesting connection, all the while building on each other’s ideas and externalizing internal creative ideation. In this iteration students developed 'interesting' & 'valuable' connections (using the classification system developed in the prior iteration). At the end, each group voted on the 'added value' that each

connection made to the evolving collection of objects (o = little or no added value, 5 = excellent added value). Students selected a "winner," the person whose connection was the 'most valuable' on the field. "Internal Creative Action" occurred as students came up with original ideas for connections between objects and when they created criteria for judging connections. "External Creative Action" included the physical connections between objects that students illustrated on the butcher paper.

It was interesting to note that the two groups approached this exercise differently. One group required that only one connection be made, while additional points were given to students who made particularly meaningful connections with more than one object. The second group required each object to be connected in some way to the other objects. The web of connections created by the second group was messier, but as a member of the first group maintained they "made just as many meaningful connections between pieces." In both cases, the group interaction was inspiring. Students helped each other draw and label, discussed how to assign an arbitrary value based on the strength of connections; this led to a fruitful conversation about the differences between computers and the human brain where they concluded that computes can only make abstractions if they programmed with the necessary parameters.

New Artifacts. In this exercise, "New Artifacts" included the methodologies and ideational connections students made between objects (the rationale for the connections they made), the elaborate "maps" linking one object to the next, the ranking system developed by small groups to judge the quality of each other's connections, and a performance element when "Actors" presented their rationale to the "Audience" in order to persuade them select their connection(s) as the "winner(s)." These artifacts come into being as a result of the ideation, incubation, insight, and externalized "Creative Action" of "Actors" who also served as members

of the "Audience." As such, the "New Artifacts" created in this activity system were more ideational than material, but included both. These "New Artifacts" were created through the interaction between all elements of the activity system.

Betz highlighted the performance element of this activity when she wrote, "More so than anything else, effective communication was key in helping the rest of the group understand the far-flung connections between the objects. There were a number of relatively strong connections that were so poorly explained, they were hardly worth grading. On the other hand, there were lots of connections which came alive in their description, and the presenter really made the audience relate to the connection between objects." This also illustrated the importance of an "Actor" being aware of his/her "Audience" – since the performance was often what often separated the winners from the losers, no matter how novel the finished product.

Affordances. Material affordances included a cardboard box filled with miscellaneous objects (listed below), butcher paper, white board, and colored markers. Students were both afforded and constrained by the mysterious objects they choose. The web of connections created by the students who preceded them also became both "Constraints" and "Affordances" for the "Creative Action" of each subsequent "Actor." "Actors" incorporated these "Affordances" into their own reasoning and extended them in novel, new connections, which became "Affordances" for the students who came after them. Interestingly, "Actors" also became "Social Affordances" because they created the preceding connections that each "Actor" had to build from and the criteria for judging each connection. In this case, "Actors" and "Audience" also worked together to create the criteria for success - a ranking system for judging "good" connections (very subjective in nature) on an objective scale; this "Artifact" became an "Affordance."

Zach described the complex relationship between “Affordances” and “Constraints” in this activity system. He explained that “The exercise itself seemed to be a task where boundaries were meant to be pushed and redefined. We were handed these quite physical constraints and, depending on the order you were placed in, only had a limited number of objects to connect it to. However, like our initial constraints exercise, the objects gave you something tangible to latch onto, something that allows ideas to branch off of and expand from that initial point.” As another student wrote in the final class publication, the constraint in this exercise was “arguably only the individuals and the scoring prowess of their peers.”

Summary of Results

As shown in Table 10, students generated one hundred and two reflections for this exercise, with fifty-one reflections occurring after creative action. Even though these “reflections-on-action” were a rich source of information, they were not tabulated in this study because they occurred after creative action. Results were best illustrated by the sheer number and variety of novel connections, the originality of the rationales developed for each connection, and the criteria used to determine the value of connections that the “Actors” in this activity system generated. As the results and quotations below show, metacognition was instrumental in the interrelationship between each element in the activity system that produced these results.

Some of the most highly-valued, novel connections developed by “Actors” in this activity system included: an intricate story about hunting in the woods to describe the connection between a plastic skull, a radio, and an old iPod (narrative connection); a roll of raffle tickets connected to box of sand and seashells because they reminded her of summers at “Seaside Oregon” (personal connection); a jar of dandelion seeds connected to a plaster colosseum pillar because this student “wishes for power” (metaphorical connection); a jar of coins was related to

a small US flag because capitalism and freedom went hand in hand (ideological connection); a dried seed pod and a picture of Van Gogh's flowers printed on a stationary box were connected because they both generated new growth (nature connection); a church diary is connected to things from different cultures (Japanese tea and French candies) because they all were things that Trump wouldn't like (political connection); coins (representing the invention of currency), a Greek column (new international power), and an old AOL CD all recorded history and represented change in era (historical connection).

The subjective value each group assigned to connections varied greatly. Some students made literal, physical or functional connections. But most students preferred deeper, more meaningful connections. In the final publication students explained that "Easy associations between objects were ignored in favor of deeper and more meaningful associations between objects… Universal connections between objects (round, shiny, big) became less important when competition motivated students to stand out in their analysis in some way or another – we wanted the connections to be challenging, engaging in some way. Our pre-learned dispositions of what connections are meaningful became increasingly valuable in competition – the connection between childhood memories, for example, were especially popular in multiple groups." Students often referred to "Knowledge of Cognition" as they wrote about consciously drawing from "pre-learned dispositions" when developing judging criteria. They also monitored their creative activity, and that of their classmates, as they evaluated connections. This related to the "Evaluation" component of metacognition, which occurred after creative action so was not coded.

Metacognition when dyad pairs are in play. As Table 10 and Figure 3 show, "Monitoring Creative Activity" was used much more frequently that the other processes. The

other metacognitive components were used, but they were reported infrequently during the course of creative action in spite of the complexity of this exercise. These results were surprising, given the interaction of elements and the range of metacognition reported by students in their reflections after-the-fact. Perhaps, there was little time to think about "Knowledge of Cognition," "Planning," "Implementing Information Management Strategies," and "Correcting Comprehension" during this exercise. Maybe students were so pre-occupied with creative action (rather than thought) that metacognition was not top of mind during this complex, fast-moving, competitive exercise. Perhaps, students felt little need to plan or correct mistakes since there were no right or wrong answers in this exercise. Subjective or personal reasons may also have led to these results - students were noticeably tired that day, they were in the middle of mid-terms and perplexed by yet another exercise on "making connections," so there were fewer TUs.

Exercise #12 was unique because 48% of TUs were coded with all three dyad pairs (compared to 1% in the other exercises), 29% contained two dyad pairs (across all three double-dyad configurations), and 99% co-occurred with "Monitoring Creative Activity." This suggested that students monitored creative activity more during complex interactions when two or more mediators of creative action were involved. Reports of metacognition were also spread more consistently across all three dyad pairs than in any other exercises, as shown in Table 10 and Figure 3. Both of these findings could be attributed to the design of this exercise where all three dyads were frequently at play as students engaged in creative activity. "Actors" interacted with "Audience" in the production of "New Artifacts." "Actors" were also "Audience," observing classmates "Artifacts." Students used more metacognition in the "Actor(s)-Audience" and the "Audience-Artifact" dyads than they did in the other exercises. Likewise, there were more reports of "Social Differences" in this exercise.

There were two explanations for this. Alternating between collaboration and competition, as well as between "Actor" and "Audience," brought the notion of "difference between self and other" to the forefront. Students had the opportunity to incorporate the ideas of others into their solution, and the element of competition generated greater awareness of metacognitive feelings (both motivational and inhibitory feelings).

This data, showing the use of metacognition when multiple dyads were at play, came to life when students described their experiences. Parker monitored creative activity when he wrote about the interrelation between "Actor(s)-Artifact" and "Actor(s)-Audience" while using "Affordances" to develop "New Artifacts." He reflected that, "In this exercise, we each contributed the connections we made between various items. Every person at the table exhibited a different methodology for making connections. I noticed that many students' connections built off of other students' connections, either by extending them or transforming them. In this sense, many of our connections connected certain connections and other connections. I find this interesting because we discussed in class how the physical objects we were examining and manipulating in class were critical in fostering this type of abstract thought." This reflection also showed his awareness of and the willingness to synthesize differences between students, objects, methodologies, ideas and connections (see below).

When "Monitoring Creative Activity," Ivy offered a concrete example of the way that "Actors" modified their own ideas by incorporating the different perspectives that they observed as "Audience" into their own "New Artifact." She explained that subsequent connections made by other students seemed to be gravitating toward the storytelling technique, as though they were "catering to a proven appetite for a certain way of making connections." She maintained that these story-like connections were different from the more intuitive connections made when there

was no competition. Simone had a similar take when she wrote that "Riley (the winner of our group) had the farthest stretch (and therefore most interesting) of connections, and entirely enticed the rest of us. During the practice round we all helped each other and fed off of one another's ideas." Though not coded as such because these observations came after creative action, these examples showed the conscious decision to adopt of a "winning" strategy; this involved "Monitoring Creative Activity," "Planning," and "Error Correction" as students adapted their strategies to accommodate "Audience" preferences.

Metacognition when synthesizing differences. Given the parameters for this exercise and the complexity (where "Actors" interfaced with and built off of each other's ideas to make novel connections between a plethora of unrelated objects), the need for "Monitoring Creative Activity" was not surprising. Students referred to this strategy in 64 out of 70 TUs as they grappled with social, material, temporal and ideational "differences."

"Monitoring Creative Activity" was indicated in 32 of the 34 TUs where students indicated "synthesis" of these differences. Monitoring what they learned when synthesizing differences (material, social and ideas), may have enabled students to become conscious of their own new learning. They indicated learning new ways of making connections that they hadn't thought of before (logical, physical or functional characteristics vs narrative, abstract, personal, metaphorical, subjective) and new understanding of what makes a "good connection" (personal, meaningful, depends on the context, a connection that leads to new connections, universal). Many students also articulated knowledge of how competition (social differences) affected them (forced them to make deeper connections or caused others to shut down). Some indicated new knowledge of how the method changed output (ideational differences) - the difference between being able to see all of the objects before making connections and having to make a quick

connection with a changing frame of reference when a random object was pulled out of a box. A couple of students also noted the utility of constraints in giving them something tangible to latch onto and branch off from. This conscious awareness enabled students to use these strategies in new situations. More than 50% of TUs showed students "Monitoring Creative Activity" while referencing both "Social Differences" and "Material Differences" in the same TU, as shown in the quotes below.

While they were not reported with great frequency, this exercise required all of the metacognitive skills identified by Schraw and Dennison (1994). They used "Knowledge of Cognition" as they drew from past experiences to create meaningful connections between objects. Much "Monitoring Creative Activity" occurred as students internalized and built on the ideas of their classmates. Students engaged in "Planning" as they made strategic decisions and communicated their ideas in compelling performances that would garner the votes of their "Audience." They also used "Monitoring Creative Activity" as they worked together to negotiate and synthesize ideational, material and social differences when generating a single set of criteria.

Zachary articulated this confluence of metacognitive strategies with elements of the activity system when he synthesized the differences between his own approach and that of others. "Knowledge of Cognition" and "Monitoring Creative Activity" led Zach to consider using a new "Information Management Strategy" for making more in-depth connections (ignoring constraints and working with an initial idea and following the thread of thought wherever it led him). This synthesis of ideas also involved "Correcting Comprehension" and "Evaluation," but they occurred after creative activity so they were not coded. He wrote, "In my opinion, I did not do so great. I think the most successful connections were the ones that were unafraid to make an indirect approach. They used their initial object as a starting point, following

the thread of thought wherever it took them. From there, they had an idea to work with and were able to circle back to a second object on the table with a much more in-depth connection. By doing so, they ignored the constraints associated with a one-dimensional direct connection and utilized what they had to foster their creativity. As a result, I feel their connections felt more organic. I get so stuck in the STEM mindset sometimes it gets frustrating. I am taught to just hunt for solutions when in actuality it seems creative exploration is the more fitting approach." As both "Actor" and "Audience," Zach grappled with differences between his ideas and the ideas of others as he ideated about the creative approaches that he could have taken to connect disparate objects.

Metacognition when negotiating "social differences" during competition. Students also noted "Monitoring Creative Activity" 26 times when grappling with differences between self and others. This co-occurrence occurred much more frequently in this exercise than other exercises, since the mission of this exercise was to understand and build from the connections that other classmates had made (this also occurred in Exercise #2, where students also built off of others' ideas). Furthermore, students' awareness of the differences between self and other may have been accentuated by the juxtaposition between a collaborative, team-oriented round followed by a round of competition. This may have impacted the degree of risk they were willing to take when making connections between unrelated objects.

Students reacted to competition in a variety of ways, all involving the use of metacognition. While "Monitoring Creative Action," some students noted feeling motivated by the "light-hearted element of competition in a safe classroom environment." Others shut down in the face of competition. Several students mentioned drawing from prior knowledge of a strategy called "coopertition" that they learned in Robotics competitions. This strategy promoted

cooperation within a framework of competition, using the most off-the-wall ideas of other classmates as a platform for their own creativity.

Amelia reflected on the effects of collaboration and competition on creative ideation and externalization. While "Monitoring Creative Activity" she noted, "I really liked this exercise until the competition started. I thought that making the connections between objects was fun and engaging, but the competition aspect made me feel uncomfortable. During the competition rounds, I felt more vulnerable, like people were judging me (which they literally were). While I think this pressure had some positive impact on the quality of my responses because I tried harder, the negative impact was greater because I felt more nervous and was less willing to take risks in my suggestions. Furthermore, the people around me were in contest with me and thus did not aid my responses."

Kimberly, who acknowledged having much prior experience with "coopertition," reflected on these nuances with full knowledge of her own tendency to speak up when there is no competition ("Knowledge of Cognition"). She was also consciously aware of "Monitoring Creative Activity" as she assessed whether she was meeting her goals and when verbalizing new strategies. As a result of this awareness, she consciously planned and adopted strategies in response to the added element of competition. She reflected that "I thought of connections between others' objects that I would have spoken up about had it not been a competition. I felt that some level of richness within the network was missing due to unspoken connections. At the same time, adding competitive pressure forced me to push myself further in terms of the connections I made between my object and others.' I repeatedly asked myself "and what else?" and "is that enough?" and "what else does that remind me of." In being more directed (for lack of a better term) about searching my mind for solutions, I may not have made off-the-wall

"stretch" connections as easily (a drawback to the competitive approach), but I also didn't spend as much time thinking through obvious connections like shape and color."

Metacognition when synthesizing conundrums (ideational differences). After ideating, monitoring and reflecting upon their own creative activity and that of others, "Actors" discussed, agreed upon, and generated a list of 25 different sorting preferences that they would use for evaluating the subjective "value" of classmates' connections on a scale from 0-5. Then they externalized their ideas by drafting elaborate matrices in their notebooks and on the whiteboard (creating order out of chaos, as Amelia mentioned). One student articulated her thought process when writing that, " Making connections like "round" and "blue" is very valuable because it allows one to connect objects with desired qualities, and is globally applicable (literally, too, the world fits into both of those), but connections like "birth of an era" are more entertaining to think through, and reveal more about the people making the connection."

It was helpful to see where students used metacognitive skills within the context of creative action. With this as my objective, I described Exercise #12 (Object Connections) as an activity system where all "five A's identified by Glaveanu– Actor(s), Audience, Artifacts, Action, and Affordances – acted in interrelation. "Actors" internalized affordances, synthesized differences, and externalized new ideation through an impressive variety of truly unique solutions. The exercise illustrated the frequency with which (as well as where and when), students used the metacognitive skills identified by Schraw and Dennison (1994) during creative action. While fewer metacognitive skills were used due to the fast-paced, open-ended nature of this exercise, students reported "Monitoring Creative Action" with much more frequently in this exercise. This was especially apparent in the simultaneous co-occurrence of this strategy with

multiple dyad pairs. This also occurred when "Actors" synthesized the difference between objects, people, and ideas. Thirdly, this occurred within the Creative Action triangle as student moved from internal creative action (ideation, incubation, insight) to externalizing these ideas through the creation of new material artifacts (novel connections), methodologies (criteria for attributing "value'), and performances (explaining obscure connections and persuading classmates that theirs' is the best). One conclusion could be that students monitored their creative activity more during complex tasks – tasks where greater interaction between the elements of the activity system was required to synthesize more social, material, temporal and ideational differences.

While Table 10 provides the co-occurrence data described above numerically, Figure 3 overlays students' reports of the metacognitive strategies that they used as they interacted with different mediators in a creative activity system. This enables us to see what types of metacognition students used when different elements of the activity system were in play and may suggest the utility of metacognition during creative action.

DISCUSSION

In this study, I examined the relationship between metacognition and creativity as students completed a series of exercises designed to cultivate creativity. Based on an extensive review of literature, classroom observations and analysis of data from student reflections, I have come to agree with the findings of many scholars that metacognition plays an important role in the creative process. Students in this study indicated using an array of metacognitive skills; they demonstrated knowledge of their own cognition, monitored, and regulated creative activity as they completed each creativity exercise. A model that captures the complex interrelationships between metacognition and creative activity system could further our understanding of how, when, and why to use these strategies when solving complex, open-ended problems.

By comparing data from two analytical frameworks analyzing metacognition and creative activity, I found that students used metacognitive processes (particularly "Monitoring Creative Activity") throughout creative activity systems – to process interactions between each dyad pair, within creative triangle, and when generating and using affordances from the environment. "Monitoring Creative Activity" seemed to oversee the whole process - providing students with an overall understanding of their own knowledge, monitoring creative activity, and helping them direct creative thought and action (Hargrove, 2011, p. 11). "Monitoring Creative Activity" also enabled students to develop conscious awareness of, shift between, synthesize and externalize the differences they perceived between themselves and others, materials object, methodologies and ideas (Glaveanu, 2015). As students illustrated in their written reflections, by developing an awareness of these differences and of the processes they were using, they could determine what worked and what didn't work. Then they could utilize this knowledge to consciously choose the most effective strategies, methods and tools (Valgeirdottir and Onarhaim, p. 215).

Glaveanu explained that creativity research "confronts researchers with enormous complexity (Glaveanu, 2014, p. 86). I found this statement to be true when observing students in this class, reading the reflections that they wrote about creativity exercises, and studying the literature. Reducing the study of creativity to persons, products, or a single process failed to capture the iterative nature of creativity, the interdependence of elements in the sociocultural/material context of this class, and the ongoing transformation that occurred over time. Static studies, definitions and models resulted in "methodological reductionism," as Glaveanu explained. But I discovered many new realizations and challenges when using a more comprehensive systems framework of creativity to capture the types of metacognition used during creative action. Some of these insights are described below.

The first lesson I learned is "that more is not better" when it comes data. At first, I was reluctant to limit the scope of my study to just five exercises. Each exercise was designed with such whimsy and wit with the goal of cultivating specific design strategies and attitudes of mind. And each resulted in such a plethora of creative solutions and depth of student reflection, that I hesitated to eliminate a single thought unit that might help illuminate the range of metacognitive strategies that students use in creative activity systems. However, I soon realized that analyzing data from all fourteen exercises would be too time-consuming and unwieldy. So I decided to choose five exercises (corresponding roughly to each element in the activity system). My intent was to choose a variety of foundational exercises (different tasks, artifacts, "attitudes of mind," and group configurations) that would generate a range of metacognitive strategies, all aligning neatly in different dyad pairs. This would enable me to see patterns in the type of metacognition students used with when different mediators/dyads were in play and during different types of tasks.

Much to my surprise, the data were very consistent across all exercises regardless of the task. Results showed that students used five out of the six metacognitive skills identified by Schraw and Dennison (adapted for creative work) as they interacted with all five elements of Glaveanu's Framework of Creativity to produce new artifacts, methodologies and performance. All metacognitive processes were used throughout each creative activity systems, but students used "Monitoring Creative Activity" much more than any other strategy. And they did so much more frequently when interacting with "Artifacts" than they did when interacting with "Audience" - regardless of the task. Students also seemed to use "Monitoring Creative Activity" most when the "Actor(s)-Audience" dyad was in play as they developed awareness of, synthesized and externalized differences (regardless of whether the difference was material, social, temporal, and ideational). All of these elements (both metacognitive and creative) seemed to be transformed in the process, while students monitored and regulated their creative thought and action.

Rarely did students report planning, using information management strategies, or correcting comprehension errors during the course of these activities. This suggests that "Monitoring Creative Action" is an essential process when "Actor(s)" and "Artifacts" mediate "Creative Action." This strategy seemed to be the driver of creative action both between mediators and within the "Creative Action" triangle, allowing "Actors" to understand and regulate their own cognition so that they could bridge differences between "self and others, symbols and objects, and past/present/future."

Adding metacognition to Glaveanu's framework allowed me to explore the relationship between metacognition and "creativity in action" in depth, but I discovered several misalignments in these two frameworks. This led me to question the benefits of adding

metacognition, as described by Schraw & Dennison, to Glaveanu's model. Glaveanu seemed to use a wider lens that Schraw & Dennison. Therefore, it was difficult to capture the metacognitive processes that monitored and regulated creative activity within the "Creative Action" triangle. Glaveanu's framework was designed to capture the interrelationship between three mediators of creative action – Actors, Audience and Artifacts – as they transform social and material affordances. Students reported using the metacognitive components described by Schraw & Dennison to monitor and regulate interactions between these three mediators, but they also seemed to emphasize the use of metacognition to monitor and regulate the processes that occurred within the triangle. Glaveanu referenced internal (ideation, incubation, insight) and external (execution, implementation, performance) as reciprocal processes that occur during creative action, but he did not elucidate or address how these processes occurred within the "Creative Action" triangle.

I tried to adjust for this by distinguishing between "Internal Creative Action" (ideation, incubation, insight) and "External Creative Action" (execution, implementation, or performance). This gave me a glimpse into the metacognitive processes that occurred inside the triangle, but this analysis seemed like a stretch – like "fitting a square peg into a round hole." Students indicated "Monitoring Creative Action" much more frequently and consistently within this triangle (with both internal and external creative action) than any other processes regardless of the type of task. This suggested that "Monitoring Creative Activity" was fundamental as students reflected upon their own ideation, incubated ideas, and developed insight. It also appeared to be essential as students transformed internal creative action into externalized representations including artifacts, methodologies and performances. It was also interesting to note, that students reported monitoring internal creative action (thoughts) more than external

creative action (artifacts) even though we commonly associate and measure creativity by looking at externalized "products."

This points to temporal inconsistencies between the two analytical frameworks that I selected. While Glaveanu's framework emphasized the interrelationship between "Actor(s)," "Audience," and "Artifact" *during* creative action, Schraw and Dennison's MIA described components that occur before, during and after a learning episode. For example, in the MIA "Planning" occurred before learning, whereas this process seemed to occur during ideation in Glaveanu's framework. "Evaluation" of both strategy-use and the quality of output is an essential component of both metacognition and reflection (and provides much indispensable feedback which informs future creative action), but I could not code this component because Schraw and Dennison maintained that "Evaluation" occurred *after* the completion of a creative act – not during.

Students were instructed to "act first, think later" or "try, discuss, and reflect" during each creativity exercise. Reflection comprised half of each exercise and was an essential component in each creativity system enabling students to assimilate, integrate, and synthesize understanding. This was evidenced by the fact that I obtained 578 Thought Units (TUs) from students' written reflections, with the word "reflect" occurring 113 times and "reflection" occurring 82 times across exercises. Metacognition seems to be a form of reflection, and reflection seems to occur throughout all components of metacognition both consciously and unconsciously, as implied in the writings of Vygotsky, Dewey, Schon, and others. Yet reflection, by name, was not included in Schraw & Dennison's model.

Students demonstrated much rich reflection before, during, and after the completion of each exercise (43%, or 249 out of 578 TUs). Such retrospective "reflection-*on*-action" would

have contributed to our understanding (and was essential in students' ongoing development as they continued to synthesize thinking after completing an exercise), but Glaveanu's framework only captured "reflection-*in*-action." Glaveanu acknowledged "continuity of action" and the assimilation of "New Artifacts" as affordances for future activity, but his model was designed to study "creativity in the making" through the study of in-the-moment interrelations between "Actor(s)," "Audience," and "Artifact" in specific "relational spaces" or situated contexts during - not before or after - creative action (Glaveanu, 2014, pp. 87-89). In order to maintain consistency with the analytical framework that I selected, I decided not to analyze reflections that came after creative action. But much was lost in this omission. Whether this is a limitation of Glaveanu's framework or a limitation in the design of my study remains to be told.

More fundamental perhaps, is the fact that the MIA was designed to study comprehension during reading and writing. Even though metacognition has been found to be domain-general and applicable to creativity, the language that Schraw & Dennison used to define metacognitive components was inconsistent with the strategies, processes, and definitions used to describe creative action. I attempted to redefine metacognitive processes in a way that encompassed creative activity, as Bruch (1988) did in her frequently cited study on meta-creativity, but this required a leap of logic which may not be defensible. This led to coding challenges and may also have resulted in some coding inconsistencies. Maybe a framework for "process awareness," such as that proposed by Valgeirsdottier & Onarheim (2017) specifically for the study of creativity, would have been more applicable and generalizable than the MIA.

It was challenging to wrangle all of the themes that I observed into a bite-sized thesis. Studying any one theme in isolation and out of context failed to capture the essence of this class, its participants, and the complex process of creativity. Adding the metacognitive components

described by Schraw & Dennison to Glaveanu's framework seemed consistent with Robertson's view of creativity as a "form of action," an "iterative process," a "synthesis" that requires reflection. The addition of metacognition also seemed to expand Glaveanu's conceptualization by describing some of the drivers that he alluded to in "perspective taking" and his conceptualization of creativity as an ecological, developmental system. Even though the analytical frameworks that I used were not in perfect alignment, this study enabled me to explore deeply, to pull many facets from Robertson's class into a cohesive model, and to develop new insight in synthesizing social, material, and ideational differences through creative interaction.

Areas for further research

This project brought many avenues for future research to mind. Professor Robertson incorporated reflection and studio design practices into his curriculum, it may be beneficial to incorporate specific metacognitive strategies and principles from Learning Sciences into each exercise more deliberately and explicitly. A revised framework of creative action that includes metacognition might enable us to determine when to incorporate metacognition into such a curriculum most effectively. Perhaps we could also develop regulatory checklists and strategy evaluation matrices such as those suggested by Schraw (1998) to improve students' knowledge of cognition, creative strategy use, and construction of new knowledge by evaluating how, when and why to use design "attitudes of mind" to solve open-ended problems (Schraw, 1998, p. 120). Cultivating an understanding of the relationship between metacognition and creativity could help students manage their own creative thought processes more strategically while developing both skill sets.

Given the current thrust to teach collaboration and communication skills, it would be interesting to study these exercises from the perspective of socially shared regulation of learning

(SSRL). This seems consistent with the interactive nature of Robert's class; the interrelation between "Actor(s)," "Audience," and social "Affordances" described by Glaveanu, and students' reflections about the value of class discussions. In one of my first iterations of research I coded the socially-shared, other-regulated, and self-regulated learning in each exercise (and found many incidents of each throughout), but I decided to omit this thread because it did not relate directly to Schraw & Dennison's framework. The study of SSRL could relate to further study of collaborative and distributed creativity.

On a final note, I have been eager to survey this esteemed group of students to find out whether they have been able to transfer the skills that they learned in this class to other academic environments. The answer to this question might suggest more areas for research. I believe that through creative action, collaboration, reflection, and synthesis we can transform our differences (just as students did in these creativity exercises) and find innovative solutions to the "wicked" problems we must face.

Limitations of this study

The participants in this study came from diverse backgrounds and were pursuing a variety of professions and academic interests; however, they were all Honors Students from the University of Washington – diverse in some ways but relatively homogenous in age, race, general cognitive ability, and level of motivation. The results and conclusions are limited to this demographic and level of education. Further research would be needed to determine whether findings can be generalized across educational and demographic levels.

Written reflections are highly subjective, self-reports of personal experiences; therefore, they are subject to participant bias with the potential for respondents to inflate or deflate observations, experiences and assessment. Furthermore, coding and analysis are subject to

different interpretations, inconsistency and bias on the part of the researcher. Therefore, it would be difficult to replicate and generalize the results of this study internally or to other populations.

REFERENCES

Armbruster, B.B. (1989), Metacognition in Creativity. In J.A. Glover, R.R. Ronning, and C.R. Reynolds (Eds.), *Handbook of creativity* (pp. 177-182). New York: Plenum Press.

Assunta, Z. M., Turrini, G., & Miazza, D. (January 01, 2006). "ADDIZIONARIO": A new tool for learning between metacognition and creativity. *Informatica, 30,* 4, 399-405.

Baer, J., & Kaufman, J. C. (2012). Being Creative Inside and Outside the Classroom. The Netherlands: Sense Publishers.

Bransford J. D., Brown A. L., Cocking R. R., editors. (2000). *How People Learn: Brain, Mind, Experience, and School.* Washington, DC: National Academies Press.

Braten, Ivar. (1991). Vygotsky as Precursor to Metacognitive Theory: II. Vygotsky as Metacognitivist. *Scandinavian Journal of Educational Research, 35*(4), 305-20.

Bråten, I. (1991). Vygotsky as precursor to metacognitive theory ; 1 : The concept of metacognition and its roots. *Scandinavian Journal of Educational Research, 35,* 179-192.

Bruch, C.B. (1988). Metacreativity: Awareness of thoughts and feelings during creative experiences. *The Journal of Creative Behavior*, **22**, 112–122.

Costa, A., & Kallick, Bena. (2000). *Discovering & exploring habits of mind* (Habits of mind ; bk. 1). Alexandria, Va.: Association for Supervision and Curriculum Development.

DeHaan, R. L. (2009). Teaching Creativity and Inventive Problem Solving in Science. *CBE Life Sciences Education*, *8*(3), 172–181. doi:10.1187/cbe.08-12-0081

Feldhusen, J. F. (1995). Creativity: A knowledge base, metacognitive skills, and personality Factors. *Journal of Creative Behavior,* 29, 255–268.

Feldhusen, J. F., & Goh, B. E. (1995). Assessing and accessing creativity: An integrative review of theory, research, and development. *Creativity Research Journal*, 8, 231–248.

Flavell, J. (1979). Metacognition and cognitive monitoring: A new area of cognitive-Developmental inquiry. *American Psychologist*, 34, 906–911.

Glăveanu, V., & Candland, Douglas K. (2013). Rewriting the Language of Creativity: The Five A's Framework. *Review of General Psychology*, *17*(1), 69-81.

Glăveanu, V. (2014). *Distributed creativity : Thinking outside the box of the creative individual* (SpringerBriefs in psychology). Cham: Springer.

Glaveanu, Vlad Petre. (2015). Creativity as a Sociocultural Act. *Journal of Creative Behavior*, *49*(3), 165-180.

Glăveanu, 2017a Glăveanu V.P., Creativity in perspective: A socio-cultural and critical account, *Journal of Constructivist Psychology*, online first.

Hacker, D. J., Graesser, A.C., & Dunlosky, J., (Eds.). (1998). *Metacognition in educational theory and practice*. "Smart problem solving: How metacognition helps." By Davidson, J. E., & Sternberg, R. (pp. 47–69). Mahwah, NJ: Lawrence Erlbaum.

Hargrove, Ryan. (2011). Fostering creativity in the design studio: A framework towards effective pedagogical practices. *Art, Design & Communication in Higher Education 10*(1), 7-31.

Hargrove, R. A. (2013). Assessing the long-term impact of a metacognitive approach to creative skill development. *International Journal of Technology and Design Education*, *23*(3), 489-517.

Hargrove, R., & Nietfeld, J. (2015). The Impact of Metacognitive Instruction on Creative Problem Solving. *The Journal of Experimental Education, 83*(3), 291-318, DOI: 10.1080/00220973.2013.876604

Herrenkohl, L., & Mertl, Véronique. (2010). *How students come to be, know, and do a case for a broad view of learning* (Learning in doing: social, cognitive and computational perspectives). Cambridge ; New York: Cambridge University Press.

Kaufman, J. C., & Beghetto, R. A. (July 01, 2013). In Praise of Clark Kent: Creative Metacognition and the Importance of Teaching Kids When (Not) to Be Creative. *Roeper Review, 35,* 3, 155-165.

Lave, J., & Wenger, Etienne. (1991). *Situated learning: Legitimate peripheral participation* (Learning in doing). Cambridge [England] ; New York: Cambridge University Press.

Leverenz, C. (2014). Design Thinking and the Wicked Problem of Teaching Writing. *Computers and Composition, 33,* 1-12.

Moran, S., & John-Steiner, V. (2003). Creativity in the Making: Vygotsky's Contemporary Contribution to the Dialectic of Development and Creativity. In *Creativity and Development* (p. Creativity and Development, Chapter 3). Oxford University Press.

Moshman, David. (2018). Metacognitive Theories Revisited. *Educational Psychology Review, 30*(2), 599-606.

National Research Council. Washington, DC: National Academies Press; 2007. Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future, Committee on Science, Engineering and Public Policy.

Pesut, D. J. (1990). Creative Thinking as a Self-Regulatory Metacognitive Process-A Model for Education, Training and Further Research. *The Journal of Creative Behavior, 24*(2), 105-110.

Piirto, J. (2011). Creativity for 21st Century Skills: Personality, Motivation, Study, and Talent. In *Creativity for 21st Century Skills: How to Embed Creativity into the Curriculum* (pp. 1-12). Rotterdam: Sense.

Puryear, Jeb S. (2014). Inside the Creative Sifter: Recognizing Metacognition in Creativity Development. *Journal of Creative Behavior, 50*(4), 321-332.

Puryear, JS. Metacognition as a Moderator of Creative Ideation and Creative Production. *Creativity Research Journal.* 27, 4, 334-341, Oct. 2015. ISSN: 10400419.

Rittel, H., & Webber, W. (1973). Dilemmas in a general theory of planning. *Policy Sciences, 4*(2), 155-169.

Rhodes, M. (1961). An Analysis of Creativity. *The Phi Delta Kappan, 42*(7), 305-310.

Robertson, I., Herrenkohl, L., Tasker, T., "Cultivating Design Based Thinking Using Studio Pedagogy"

Rodgers, Carol. (2002). Defining Reflection: Another Look at John Dewey and Reflective Thinking. *Teachers College Record, 104*(4), 842-66.

Sanz de Acedo Lizarraga, M. L., & Sanz de Acedo Baquedano, M. T. (2013). How creative potential is related to metacognition. *European Journal of Education and Psychology, 6*(2).

Sawyer, R., DeZutter, S., Smith, Jeffrey K., Smith, Lisa F., & Kaufman, James C. (2009). Distributed Creativity: How Collective Creations Emerge From Collaboration. *Psychology of Aesthetics, Creativity, and the Arts, 3*(2), 81-92.Schraw, & Dennison. (1994). Assessing Metacognitive Awareness. *Contemporary Educational Psychology, 19*(4), 460-475.

Schraw, G. (March 01, 1998). Promoting General Metacognitive Awareness. *Instructional Science, 26,* 113-25.

Schraw, G., & Moshman, D. (1995). Metacognitive theories. *Educational Psychology Review, 7*(4), 351-371.

Seely-Brown, J. (2006). New Learning Environments for the 21st Century: exploring the edge. *Change.* September/October 2006. Heldref Publications.

Sternberg, R. J., & Lubart, T. I. (1996). Investing in creativity. *American Psychologist*, 51, 677–k688

Valgeirsdóttir, D., & Onarheim, B. (2017). Metacognition in Creativity: Process Awareness Used to Facilitate the Creative Process. In *Analyzing Design Thinking: Studies of Cross Cultural Co-Creation* CRC Press.

Vygotsky, L.S. (1978). *Mind in society: The development of higher psychological processes.* Cambridge, MA: Harvard University Press.

Wallach, M. A., & Kogan, N. (1965). *Modes of thinking in young children*. New York: Holt, Rinehart and Winston

Yancey, K. (1998). *Reflection in the writing classroom*. Logan, UT: Utah State University Press.

www.inc.com/business-insider/worlds-top-10-problems-according-millennials-world-economic-forum-global-shapers-survey-2017.html

www.battelleforkids.org

Table 1

Frequency of Thought Units (TUs) indicating students' interaction with elements of Glaveanu's "Framework of Creativity" during each creativity exercise studied

Frequency of codes	Ex #1 (72 TUs)	Ex #2 (80 TUs)	Ex #3 (76 TUs)	Ex #4 (50 TUs)	Ex #12 (52 TUs)	Total (330 TUs)
Actor(s)-Artifact	61	65	67	49	37	279
Actor(s)-Audience	11	13	0	3	17	44
Audience-Artifact	16	35	3	5	29	88
Total	88	113	70	57	83	411
Int. Creative Action	55	71	54	45	43	268
Ext Creative Action	25	47	58	27	18	175
Affordances	58	78	42	42	41	261
Constraints	7	3	47	9	2	68

Table 2

Frequency of Thought Units (TUs) indicating students' use of the metacognitive components described in Schraw & Dennison's "Metacognitive Awareness Inventory" during each creativity exercise studied

Frequency of codes	Ex #1 (72 TUs)	Ex #2 (80 TUs)	Ex #3 (76 TUs)	Ex #4 (50 TUs)	Ex #12 (52 TUs)	Total (330 TUs)
Knowledge of Cognition	2	10	10	1	2	30
Planning	26	7	14	9	2	58
Monitor Creative Activity	32	72	51	41	40	236
Information Mgt. Strategy	13	2	15	9	0	39
Correct Error Comprehension	4	4	12	1	1	22
Total	82	95	102	61	45	385

Table 3

Frequency of Thought Units (TUs) indicating students' reports of "differences" in each of the five creativity exercises studied

Frequency of codes	Ex #1 (72 TUs)	Ex #2 (80 TUs)	Ex #3 (76 TUs)	Ex #4 (50 TUs)	Ex #12 (52 TUs)	Total (330 TUs)
Material	18	52	62	44	36	212
Social	15	33	5	6	28	87
Temporal	5	0	0	1	2	8
Ideational	12	13	19	10	3	57
Synthesis	31	52	50	38	33	204

Table 4

Co-occurrence of components in Schraw & Dennison's MIA and the elements of Glaveanu's "Framework of Creativity" indicated in the same TU (aggregated from all five creativity exercises studied)

Creative Activity System	Know About Cogn	Planning	Monitor Creative Activity	Info Mgt Strategy	Correct Comp. Errors	Eval.	Total
Actor(s)-Artifact	26	55	208	38	20	0	347
Actor(s)-Audience	2	4	39	2	3	0	50
Audience-Artifact	4	8	83	2	6	0	103
Actor(s)-Artifact Audience-Artifact	4	8	71	2	5	0	90
Actor(s)-Audience Audience-Artifact	2	3	31	1	3	0	40
Actor(s)-Artifact Actor(s)-Audience	2	4	29	3	3	0	41
Actor(s)-Artifact Actor(s)-Audience Audience-Artifact	2	3	16	1	2	0	24
Int Create. Action	23	55	206	29	14	0	327
Ext Create. Action	11	22	138	29	16	0	216
Int | Ext Cr Action	4	19	108	19	9	0	159
Affordances	22	46	197	36	17	0	318
Constraints	11	11	46	8	5	0	81

Table 5

Co-occurrence of metacognitive components indicated in the same TU (aggregated from all five exercises)

Creative Activity System	Know. About Cogn.	Planning	Monitor Creative Activity	Info. Mgt. Strategy	Correct Comp. Errors	Total
Knowledge of Cognition (30)	0	5	15	2	0	22
Planning (58)	5	0	17	2	3	27
Monitor Creative Activity (236	15	17	0	22	9	63
Info Mgt Strat (39)	2	2	22	0	1	27
Correct Comp Errors (22)	0	3	9	1	0	13
Evaluation (0)	0	0	0	0	0	0
Total	22	27	63	27	13	152

Table 6

Co-occurrences between "differences" and dyad pairs (aggregated from five exercises)

Differences	Actor(s)-Artifact	Actor(s)-Audience	Audience-Artifact	Actor(s)-Artifact | Audi-Artifact	Actor(s)-Artifact | Audi-Artifact | Actor(s)-Audience
Material (212 total)	201	28	65	60	24
Social (87 total)	73	32	66	56	23
Temporal (8 total)	8	3	3	3	3
Ideational (57 total)	124	23	14	14	3
Total	406	86	148	133	53

Table 7

Co-occurrence of "differences" and the type of metacognitive indicated in the same TU (aggregated from all five exercises)

Differences	Knowledge About Cognition	Planning	Monitoring Creative Activity	Information Management Strategy	Correcting Compreh. Errors	Totals
Material	21	34	167	26	18	266
Social	3	9	80	4	6	102
Temporal	0	1	7	4	0	12
Ideational	6	14	46	6	6	78
Total	30	58	300	40	30	458

Table 8

Students' indications that "differences" were "synthesized" co-occurring with metacognition in the same TU (queries of data aggregated from all five exercises)

Differences	Knowledge About Cognition	Planning	Monitoring Creative Activity	Information Management Strategy	Correcting Compreh. Errors	Totals
Material	10	18	132	22	17	199
Social	0	3	62	3	6	74
Temporal	0	0	6	3	0	9
Ideational	1	4	20	5	5	35
Total	11	25	220	33	28	317

Table 9

Students' indications that "differences" were "synthesized" co-occurring with metacognition in the same TU in the "Actor(s)-Artifact" dyad (queries of data aggregated from all five exercises)

Differences	Knowledge About Cognition	Planning	Monitoring Creative Activity	Information Management Strategy	Correcting Compreh. Errors	Totals
Material	8	18	125	22	17	190
Social	0	3	53	3	5	64
Temporal	0	0	6	3	0	9
Ideational	1	3	19	5	0	33
Total	9	24	203	33	27	296

Table 10

Co-occurrence of elements in each "Creative Activity System" and the metacognitive components described by Schraw & Dennison (1994), broken out by creativity exercise

Co-occurences between creative thought/action and metacognition (each exercise)	Knowledge About Cognition	Planning	Monitoring Creative Activity	Implement Info Mgt Strategy	Correct Comprehension Errors	Total
EXERCISE #1						
Actor(s)-Artifact (new product)	7	26	29	13	3	78
Actor(s)-Audience(s)	1	3	9	0	1	14
Audience-Artifact	1	5	13	0	1	20
Totals	9	34	51	13	5	112
Social Differences	1	5	11	1	2	20
Material/Symbolic Differences	4	10	6	2	2	24
Temporal Differences	0	0	5	3	0	8
Totals	5	15	22	6	4	52
Conundrum/Challenge	1	4	10	2	1	18
Resolution/Realization/Synthesis	1	10	18	7	4	40
External Creative Action	1	6	15	9	1	32
Internal Creative Action	6	26	27	9	4	72
M/S/C affordance used to create new artifact	6	20	29	13	4	72
Constraints impeding/facilitiating creativity	2	5	1	2	0	10
EXERCISE #2						
Actor(s)-Artifact (new product)	9	7	57	2	4	79
Actor(s)-Audience(s)	0	1	12	0	1	14
Audience-Artifact	1	2	34	0	4	41
Totals	10	10	103	2	9	134
Social Differences	0	2	32	0	3	37
Material/Symbolic Differences	7	5	48	2	4	66
Temporal Differences	0	0	0	0	0	0
Totals	7	7	80	2	7	103
Conundrum/Challenge	2	3	10	0	1	16
Resolution/Realization/Synthesis	7	3	48	2	4	64
External Creative Action	6	4	43	2	3	58
Internal Creative Action	6	7	65	2	4	84
M/S/C affordance used to create new artifact	10	7	70	2	4	93
Constraints impeding/facilitiating creativity	0	0	2	0	0	2

Co-occurences between creative thought/action and metacognition (each exercise)	Knowledge About Cognition	Planning	Monitoring Creative Activity	Implement Info Mgt Strategy	Correct Comprehension Errors	Total
EXERCISE #3						
Actor(s)-Artifact (new product)	7	12	47	14	11	91
Actor(s)-Audience(s)	0	0	0	0	0	0
Audience-Artifact	1	1	3	0	0	5
Totals	8	13	50	14	11	96
Social Differences	1	2	5	0	0	8
Material/Symbolic Differences	9	9	43	13	10	84
Temporal Differences	0	0	0	0	0	0
Totals	10	11	48	13	10	92
Conundrum/Challenge	3	5	14	3	4	29
Resolution/Realization/Synthesis	3	4	36	12	10	65
External Creative Action	4	5	43	14	10	76
Internal Creative Action	8	12	36	9	5	70
M/S/C affordance used to create new artifact	3	8	26	13	7	57
Constraints impeding/facilitiating creativity	9	6	32	5	5	57
EXERCISE #4						
Actor(s)-Artifact (new product)	1	9	41	9	1	61
Actor(s)-Audience(s)	0	0	2	2	0	4
Audience-Artifact	0	0	5	2	0	7
Totals	1	9	48	13	1	72
Social Differences	0	0	6	3	0	9
Material/Symbolic Differences	1	9	36	9	1	56
Temporal Differences	0	0	1	1	0	2
Totals	1	9	43	13	1	67
Conundrum/Challenge	0	1	9	1	0	11
Resolution/Realization/Synthesis	1	9	30	8	1	49
External Creative Action	0	7	20	4	1	32
Internal Creative Action	1	8	38	9	0	56
M/S/C affordance used to create new artifact	1	9	34	8	1	53
Constraints impeding/facilitiating creativity	0	0	9	1	0	10

Co-occurences between creative thought/action and metacognition (each exercise)	Knowledge About Cognition	Planning	Monitoring Creative Activity	Implement Info Mgt Strategy	Correct Comprehension Errors	Total
EXERCISE #12						
Actor(s)-Artifact (new product)	2	1	34	0	1	38
Actor(s)-Audience(s)	1	0	16	0	1	18
Audience-Artifact	1	0	28	0	1	30
Totals	4	1	78	0	3	86
Social Differences	1	0	26	0	1	28
Material/Symbolic Differences	0	1	34	0	1	36
Temporal Differences	0	1	1	0	0	2
Totals	1	2	61	0	2	66
Conundrum/Challenge	0	1	3	0	0	4
Resolution/Realization/Synthesis	0	1	32	0	1	34
External Creative Action	0	0	17	0	1	18
Internal Creative Action	2	2	40	0	1	45
M/S/C affordance used to create new artifact	2	2	38	0	1	43
Constraints impeding/facilitiating creativity	0	0	2	0	0	2

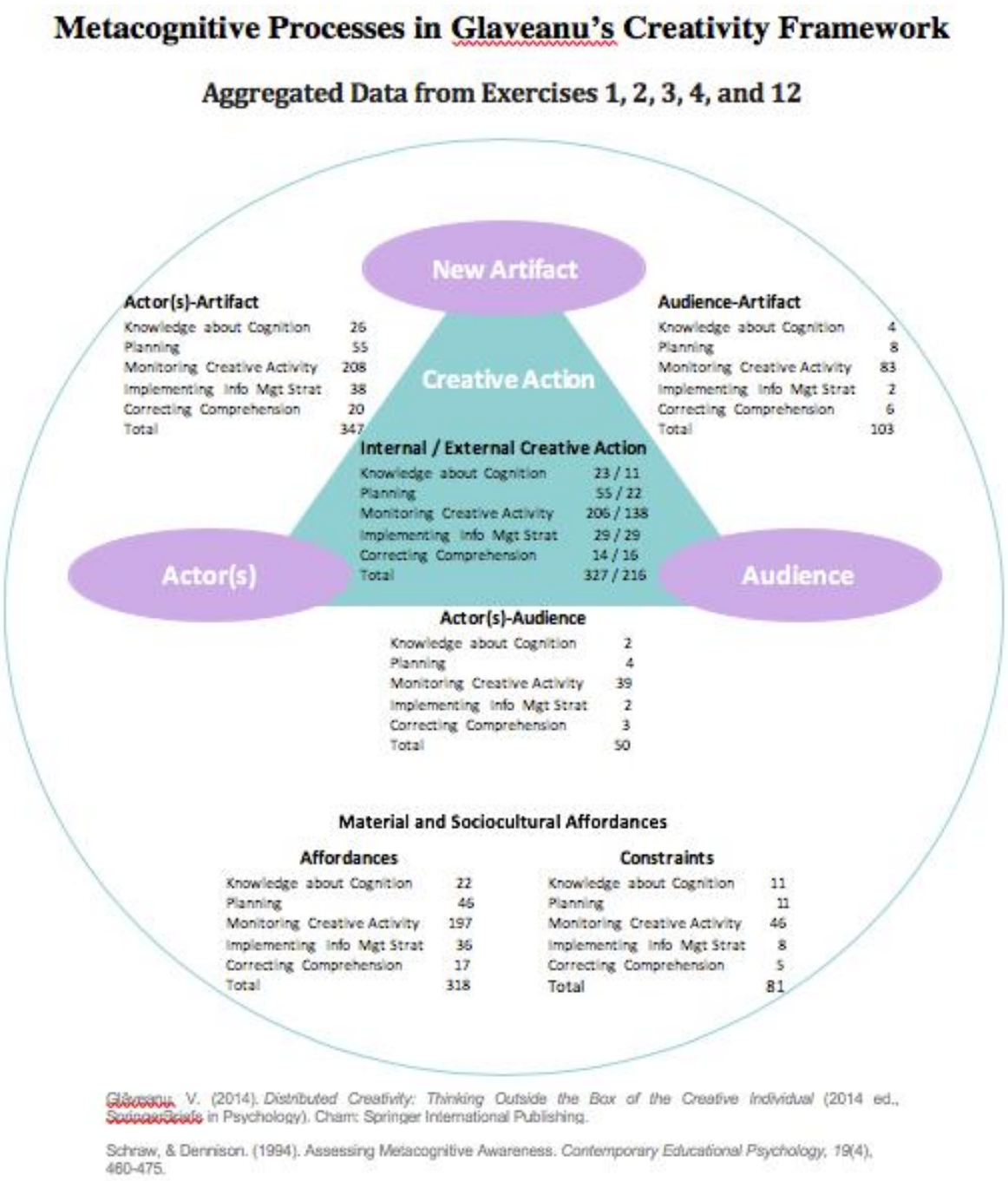


Figure 2. This figure shows the metacognitive processes that students indicated using as they completed five creativity exercises (out of 330 reflection-in-action). Metacognitive processes are aligned next to the elements that are at play in a depiction of a creative activity system (Glaveanu, 2013; Schraw & Dennison, 1994).

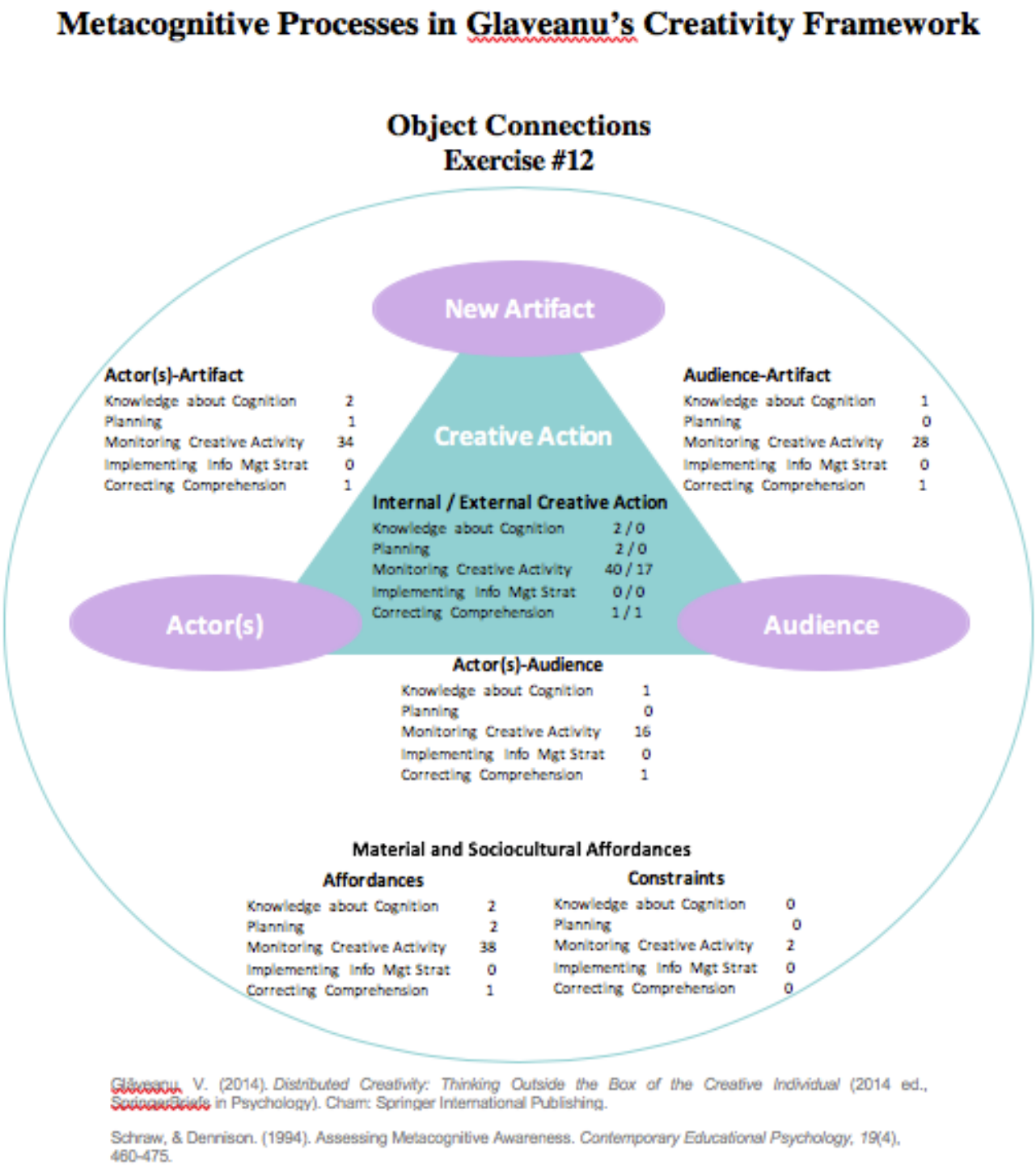


Figure 3. This figure shows the metacognitive processes that students indicated using as they completed Exercise #12 (Object Connections) (52 reflections-in-action). Metacognitive processes are aligned next to the elements that are at play in a depiction of a creative activity system (Glaveanu, 2013; Schraw & Dennison, 1994).

Appendix A: Codes, definitions and examples.

Deductive Codes from Glaveanu's "Framework of Creativity"	**Definition of Code**	**Example of TU**
Actor(s)-Artifacts	Coded when student "Actor" reports engaging with "New Artifact" including material objects, words, symbols, methods, or presentation in response to an exercise prompt.	"I used the paper as a way to capture words instead of expanding it into a signifier in itself."
Audience-Artifacts	Coded either when student "Actor" notes observing classmates' "Artifacts" during the process of their own creative action (not after), or when the awareness of "Audience" influences students "Actors" ideas/actions.	"Knowing that others will be watching me present my "art"—and they will be reading this reflection, too!—made it a lot more nerve-wracking than drawing poorly-drawn stick figures, connecting them with colorful arrows, and telling my own story actually were. Although the assignment was not graded, the pressure was on: I was making my debut, and first impressions were very difficult to reverse. How could I present a mixture of just the desirable amounts of creativity, quirkiness, humor, and intellect?"
Actor(s)-Audience	Coded when student "Actor" notes a conscious awareness of, collaboration or negotiation with their "Audience" during creative action. Places creative action "in the relationship space created by an "Actor" and the social environment," indicating that "creators and "Audiences" are both agents and observers of creative action as it unfolds over time" (Glaveanu, 2014, p. 37-38)	"The more time I spent developing my ideas, the more I realized how much my work is usually shaped by the perceived expectations of my professors and peers and how little it usually depends on expectations and standards of my own. "
Internal Creative Action	Coded when student notes ideation, incubation or insight during creative action.	"As I thought about what to include, the patterns of behavior I normally associated with my life began to solidify into a causal chain. My decision to become a vegetarian stemmed from my love and respect for nature, my familial love for my cross-country team is a result of an apathetic family relationship at home, and my continuous doodling is a reminder to me of the simple pleasures in life."
External Creative Action	Coded when student notes execution, implementation, or performance during creative action.	"For me, I organized the collections very objectively. For example, when I organized the currency, I sorted them into country of origin, and then sorted those piles by color. I found tables with objects that could be sorted objectively to be the easiest to sort such as the table to shells, or the table of fossils."

Internal | External Creative Action	Coded when student indicate both "Internal Creative Action" (ideation, incubation, insight) and "External Creative Action" (execution, implementation, or performance) in the same TU.	"To avoid being too biased by the original use of the words, I typed up the text and wrote a quick Python script to sort the words alphabetically and eliminate duplicates. The resulting word list as a whole still felt tainted by the original choice of vocabulary, but after wrestling with it for a bit, I was able to better separate out the diamonds in the rough and express a wider range of emotions than was present in the original pages."
Affordances	Coded when student indicates that people or objects in their environment guide, facilitate, or constrain creative action. Illustrates the interdependence between creators and a social/cultural/material world.	"As far as how I thought about my captions, the first thing I did was think about the magazine that I regularly read: The New Yorker. In this magazine there are little cartoons on the last page that readers can send in funny captions for in order for their caption to posted in the next week's issue. I always loved reading these and forming my own captions in my head. The only difference now was that instead of a thought-provoking cartoon, I had a boring postcard. So, I guess most of my approach towards my captions was comedic, making them as if they might win a contest."
Deductive Codes from Schraw & Dennison's "Metacognitive Awareness Inventory"	**Definition of Code**	**Example of TU**
Knowledge of Metacognition	Coded when student indicates explicit awareness of knowledge base, memory or repertoire of strategies; procedural knowledge of how to use strategies; or conditional knowledge of when, where, and why to use strategies.	"This specific assignment went nicely with what I learned from the honors class I took last quarter, Stories of Knowledge, Knowledge of Stories with Jeanette Bushnell. We often talked about Native storytelling and how the mind isn't necessarily organized chronologically and Native language and stories reflect the true spider-web nature of our brains. I tried to apply this to my piece (which came out looking a lot like a spider web) rather than draw a series of events and arrows, because life is not really a straight path." "I found that throughout the sorting process**,** I was drawn to tables with more uniform objects. I was drawn to tables with similar things, that upon closer inspection could be divided by individual characteristics. I think this reflects my technical mind. I prefer to draw concrete conclusions than

		general abstract ones. In the same manner, I prefer to focus on detailed, engineering diagrams rather than landscapes. I was drawn to the money table because all the money had the commonality of being money, but it had many other similarities (color, size, country, number, value) by which to group it."
Planning	Coded when students report thinking about what they want to accomplish and how to do so BEFORE creative action. Includes planning, goal setting, previewing materials, reading instructions carefully, selecting appropriate strategies, organizing action steps, identifying obstacles, allocating resources.	"I was not very good at drawing, so that was off the table. I was also not very motivated to write an essay at the moment. This limited my options a lot, and it took many minutes of brainstorming to finally come to the conclusion that I should do a word cloud. Doing a word cloud meant that I had to put the most prominent things in my life in the biggest font, following with less prominent things in smaller font."
Use of Information Management Strategies	Coded when students indicate deliberate use of information management strategies and skills DURING a creativity exercise to control cognition and to process information more efficiently. Includes slowing down, selective focusing, breaking problem down into smaller tasks, making diagrams, creating examples, organizing, elaborating, summarizing.	"There were some I labeled as too straight forward and didn't spend much time looking over them. Some I deemed as futile after spending several minutes analyzing them for any identifying characteristics. When I came across a collection of objects that I ranked between these two poles (not too boring, but not impossible), I took extra time to try to find the most efficient way of sorting them."
Monitoring Comprehension	Coded when students indicate assessing their own learning or strategy use DURING a creativity exercise. Includes observing, acknowledging, evaluating, assessing, measuring progress, or interpreting the learning, creative action, ideas or strategies.	"Overall, I thought the assignment was difficult because it interrupted my flow of ideas and obviously limited the verbiage that I could use. This forced me to be very methodical about my word choice and really analyze if a word was essential or even available for me to use. Which I think was one of the objectives or "points" to the assignment. I also struggled with the fact that the vocabulary available was not what I imagined writing and therefore, I think it was much more difficult to get to the point of my story; I definitely would have used different word choice."
Correcting Comprehension	Coded when students report using strategies to correct comprehension, strategy or performance errors DURING a creativity exercise. Includes asking for help, change strategies, re-evaluate assumptions and understanding, reread or review info if something isn't clear.	"I initially started the assignment by reading the pages and cataloging the words in a spreadsheet. I found this process to be very time intensive and not efficient enough for my liking. Instead I opted to skim the pages and refer to them to ensure I was using the correct vocabulary. I also found this to

		be time intensive. Even after doing this assignment, I'm still unsure about how I would go about it the second time around."
Codes used when students note differences	**Definition of Code**	**Example of TU**
Social Differences	Coded when students report differences between their own thoughts/actions and the thoughts/actions of other "Actors" or "Audience" as they solve creativity exercises.	"I really liked this exercise until the competition started. I thought that making the connections between objects was fun and engaging, but the competition aspect made me feel uncomfortable. During the competition rounds, I felt more vulnerable, like people were judging me (which they literally were)." "While I think this pressure had some positive impact on the quality of my responses because I tried harder, the negative impact was greater because I felt more nervous and was less willing to take risks in my suggestions. Furthermore, the people around me were in contest with me and thus did not aid my responses."
Material Differences	Coded when students report challenges with the materials objects, symbols, words or methodologies provided for an exercise or available to them in the context of creative action.	"My group had a table with various knick-knacks that appeared to have been collected from travels. Some of the materials were less conspicuous (a letter, some random coins), and others were obvious souvenirs or items indicative of foreign travels. We originally thought about sorting everything by shape or color, especially with enough random items that didn't really fit the travel theme. Eventually, we decided to do a map, plotting as many items as we could."
Temporal Differences	Coded when students report differences between memories or past experiences, current action, and/or their anticipation of the consequences of their creative action.	"For me, this exercise was an attempt to organize and structuralize this vague continuum that was my past and my life. In the moment, it is hard for me to pinpoint the exact source of my emotions but when I draw upon my current knowledge and experiences it allows me to sort of brush away some of the ambiguity and uncertainty present in my past and truly assess what it meant to me retrospectively." "This is a process that began long before this assignment, but I feel this exercise brought a new level of self-awareness to the process itself. In

		understanding how my life revolves around these core passions, desires, and convictions I find something tangible to hold on to in this ambiguous world."
Conundrums	Coded when student refers to ambiguity, paradox, confusion, complexity, challenge, or frustration when completing creativity exercises.	"One of the most difficult parts of this exercise for me was working on a group of items for several minutes, going to another station, then coming back to find my work taken apart. I know that this was the point of the exercise, but I tend to get overly attached to things that I have created no matter the quality or lack thereof. This was most present in the way I organized the group of different color rocks." "I was proud of the way I sorted the items because I felt that I stepped away from my typically highly structured method of sorting, creating a range of different color gradients across the table. It was sad to see my work taken apart, but it helps me become more comfortable with the designing process and specifically the stage of ideation when many ideas can get thrown out before the product is produced."
Constraints	Coded when students mention being limited or constrained by the materials, the instructions, or their own beliefs.	"The exercise itself seemed to be a task where boundaries were meant to be pushed and redefined. We were handed these quite physical constraints and, depending on the order you were placed in, only had a limited number of objects to connect it to. However, like our initial constraints exercise, the objects gave you something tangible to latch onto, something that allows ideas to branch off of and expand from that initial point."
Synthesis	Coded when students indicate that they have resolved or synthesized the differences listed above.	"For example, my personal favorite table included a "random" collection of Chinese stamps, star-gazing guides, miniature clogs, and a single Styrofoam peanut. To me, it felt only natural to form a story of adventure out of these mismatched relics. A tale of travel to all corners of the globe, of countless nights beneath cold, cloudless skies, and of the process of getting so lost and alone that inevitably one found oneself."