Creativity in Mathematics Classroom Settings: Recognizing the Collective Level

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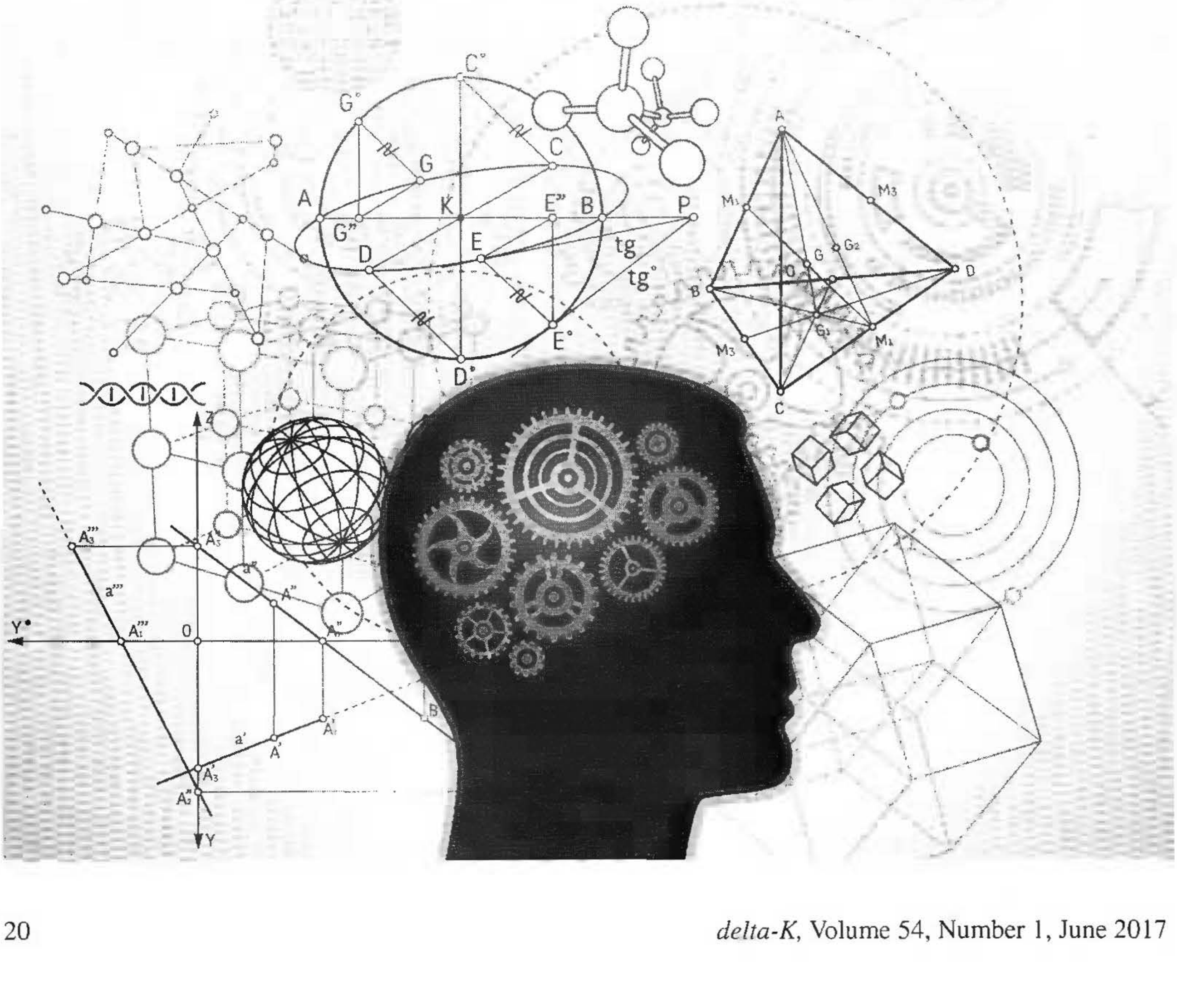
Introduction

Researchers see creativity as an essential life skill and recommend that it should be fostered by the education system (Burnard and White 2008; Craft 2000; Torrance 1988). For example, Burnard and White (2008) suggested that creativity is needed to meet the multiple needs of life in the 21st century, which calls for enhanced skills of adaptation, flexibility, initiative and the ability to use knowledge in different ways. A glance at the literature on both creativity and "education reform efforts" asserts that creativity in the classroom is not an added frill to be taken or left; on the contrary, it is an important thinking and acting skill that should be fostered. It is "now considered good for economies, good for society, good for communities and good for education" (Burnard and White 2008, 669). Friesen and Jardine (2009) argued that in today's globalized context, everyone needs robust, rigorous thinking abilities and skills—one of which is creativity—that not only the labour market increasingly calls for but also life in all its manifestations.

Sawyer has done extensive work in the field of creativity, in particular identifying creativity as a collaborative emergent phenomenon (for example, Sawyer 1999, 2001, 2003, 2011). According to him, creativity is an emergent phenomenon that results "from the collective activity of social groups....



Although collaborative emergence results from the interactions of individuals, these phenomena cannot be understood by simply analysing the members of the group individually" (Sawyer 1999, 449).

As my concern here is classroom settings, it is important to point out that Vygotsky (2004) recognized the importance of the development of creativity in the process of constructing a human collective. For him, creativity should be conceived as essentially collective, and it is the pedagogue's responsibility "to create collaborative, imaginative, and ethical classroom communities that could empower and motivate teachers and students" (Knapp 2006, 108). These suggestions are congruent to both Davis's (2005) argument that "the classroom community can and should be understood as a learner—not a collection of learners, but a collective learner" (p 87), and Martin and Towers's (2003) suggestion to consider levels other than the individual at which mathematical understanding may emerge in classroom settings, namely, the collective.

As much as this glance at the literature explains the importance of creativity in education, it also includes implicit and explicit suggestions to go beyond the individualist view of creativity. These suggestions are supported by findings of studies which tried to combine collectivity and creativity. For example, a study of collective creativity in the workplace by Hargadon and Bechky (2006) considered collective creativity to emerge when the social interactions between individuals yielded new interpretations that could not be generated by an individual working alone. Moreover, Sanders (2001) argued that collective creativity can be very powerful and lead to more culturally relevant results than does individual creativity. In relation to collective creativity in mathematics, a study by Levenson (2011) found that working as a collective may actually encourage students to persevere and try new ideas. In addition, Sarmiento and Stahl (2008) found that creativity is often rooted in social interactions and that innovative creations should often be attributed to collectivities as a feature of their group cognition.

Creativity and Education

Huebner (1967) asked "how does a person learn to be creative?" According to him, "the very question itself demands a definition of the word creative" (p 134). Huebner put forward the possibility that creativity is not learned but is an aspect of human nature. Huebner argued that there is much theological thought that supports this idea. Therefore, "it would be more appropriate to ask what prevents creativity than to ask how one learns to be creative" (p 134). It may be possible that creativity is not confined to special people or to particular arts-based activities, nor is it undisciplined play. Craft (2000) described it as "a state of mind in which all our intelligences are working together [involving] seeing, thinking and innovating" (p 38), and the NACCCE report (1999) defines it as "imaginative activity fashioned so as to produce outcomes that are both original and of value" (p 29).

A brief tracking of the origins and uses of the word *creativity* in different cultures indicates that this word reflects a kind of biological fruitfulness, which means to bring something new into being. This definition is why most scholars in the field of creativity suggest newness and fruitfulness as two criteria for judging creativity. The richness of the word creativity, which can be seen through its multiple synonyms (for example, innovation, imagination, inspiration, novelty, originality, resourcefulness and so on), requires a kind of description that can reflect such richness.

In the field of mathematics education, Sinclair, Freitas and Ferrara (2013) used a sociocultural approach to frame creativity in a mathematics classroom. Their approach "emphasizes the social and material nature of creative acts" (p 239), and it does not conceive of creativity as a property or competency of children, but as emergent from their actions and doings. According to Sinclair, Freitas and Ferrara (2013), creative acts occur in the confluence of material agency, the people in the classroom agencies and the agency of the mathematical discipline, and they "collectively engender ... a new space, which enable[s] new forms of arguments to emerge" (p 251). Such acts introduce or catalyze the new, they are unusual, unexpected or unscripted, and they cannot be exhausted by existent meaning.

Collectivity and Education

Gathering together, as a collective of all our diversities, stories and perspectives, lays the ground for effective problem solving, which also requires creative collaboration. Although diversity may increase the difficulty of collaborating, it also can make our experiences richer, worthier and more memorable. It "increases the creativity and wisdom of solutions" (Gray 1989, 13), and it "increases acceptance and support for creative ideas" (Isaksen 1994, 2). According to van Osch and Avital (2010), collectivity "refers to the collective and collaborative engagement of a group of people (i.e., a community) with shared interests or goals in meaningful actions" (p 5). It is a kind of a learning collective in which the focus on "the activities and insights of the collective [does not] mean to erase or to minimize the activities or insights of individuals" (Davis and Simmt 2003, 147). On the contrary, working collectively can "make space for, and support the development of, individual student's ideas" (p 147), and offer opportunities for all of the participants to be more creative (Davis, Sumara and Luce-Kapler 2008). Davis (2012) assumed that individual and collective knowing are inseparable, interrelated and interwoven.

It might be important to start to think how we can—those who gather together in the classroom; teachers and students—start "thinking the world together" (Jardine, Clifford and Friesen 2003). The starting point in this great, imaginative and exciting adventure lies, as Pratt (2006) explained it, in "the willingness of the teacher to be re-positioned, not as knower but as a significant participant" (p 93). Such a participatory approach to teaching, triggers the emergence of "collective, momentary, situated knowledge" (p 93), and this is how the knowledge is collectively created. Pratt (2006) stated that "experiences, interpretations, learning, teaching, epistemologies, all of these are dynamic negotiations that occur in-between, neither yours nor mine, yet both of ours" (p 94).

Some informing studies embraced the collective process in mathematics education (for example, Martin and Towers 2003, 2009; Martin, Towers and Pirie 2006). For example, Martin and Towers (2003) suggested that students' collaborative work and "improvisational performances" in mathematics trigger the emergence and the evolving of collective mathematical understanding. According to them, collective mathematical understanding "is a phenomenon that emerges and exists in collective action and interaction" (p 251). Martin, Towers and Pirie (2006) described collective mathematical understanding as an emergent and gradually growing phenomenon, which cannot be traced to the individual learners, but emerges from their coactions as a collective. By coactions, Martin, Towers and Pirie (2006) refer to specific kinds of mathematical actions that are carried out by the members of a group, and that, at the same time, are "dependent and contingent upon the actions of the others in the group. [They] can only be meaningfully interpreted in light of, and with careful reference to, the interdependent actions of the others in the group" (p 156).

Martin, Towers and Pirie (2006) described doing and understanding mathematics as "a creative process, and thus believe that because mathematical understanding can grow at both the individual and the collective level (and will be different in the two contexts) it is necessary to consider it at both levels" (p 176). Through coacting, the mathematical ideas and actions "stemming from an individual learner, become taken up, built on, developed, reworked, and elaborated by others, and thus emerge as shared understandings for and across the group, rather than remaining located within any one individual" (p 157).

Collective Creativity in Classroom Settings

A dominant and an unresolved challenge in studying creativity in classroom settings is to find a well-established definition that is widely accepted and applicable in such settings. According to Torrance (1988), although there have been many attempts to define creativity, it still defies a precise definition. According to him, it seems unseen, nonverbal and unconscious, but it also involves every sense and extrasensory perception. Despite such claims about creativity, when we want to study creativity, and/or educate for creativity, it seems unavoidable to approximate a description as a framework. While trying to do this, it is important to keep in mind that creativity in real life exists in many different forms (Tardif and Sternberg 1988). Therefore, I believe that it will be more appropriate to describe creativity in classroom settings based on the actions and doings of the classroom community while they are working on worthwhile problematic situations, ones that require a learner or a group of learners "to develop a more productive way of thinking about [them]" (Lesh and Zawojewski 2007, 782).

Based on a brief review of the literature about creativity in different contexts and at different levels, I found that although scholars in pedagogy, mathematics education and teacher education have generated a solid literature base promoting learning for individual creativity, the fostering of individual creativity and characterizing mathematical creativity (Leikin 2009; Silver 1997; Sriraman 2009), only a few of the current approaches to creativity are suited to the distributed and collective enterprise of the classroom (Levenson 2011; Sinclair, de Freitas and Ferrara 2013). This does not mean that earlier accounts are wrong or unfruitful; on the contrary they provide food for thought concerning creativity in mathematics education. They may, however, be incomplete, given that they mostly restrict themselves to one path, vision, description or experience of creativity. Because of such incompleteness "people seem to be talking past each other" (Klein 2013, 108).

Based on both an interpretive review of the literature on creativity and collectivity and many problem-solving sessions with groups of learners, I perceive collective creative acts as the actions, coactions and interactions of a group of curious learners, while they are working on an engaging problematic situation. Such acts, which may include (1) overcoming obstacles, (2) divergent thinking, (3) assembling things in new ways, (4) route-finding, (5) expanding possibilities, (6) collaborative emergence and (7) originating, trigger the new and the crucial to emerge and evolve (Martin and Towers 2003, 2009, 2011; Martin, Towers and Pirie 2006; Sinclair, de Freitas and Ferrara 2013).

I based my description of collective mathematical creativity on three elements: (1) an assumption that creativity is not a property or competency of children, but rather is an emergent from their collaborative actions and doings (Martin, Towers and Pirie 2006; Sawyer 2003; Sinclair, de Freitas and Ferrara 2013), (2) the origins and uses of the word creativity that reflect a kind of biological fruitfulness, which means to bring something new and crucial into being and (3) as suggested in the seven metaphors above, that can be used to describe the experience of creativity as it emerges in classroom contexts (Klein 2013). This is an attempt to add to our understanding of this phenomenon, and consequently to transform our practice as educators by thinking about how to create and offer genuine classroom opportunities for students to exercise creativity; opportunities that have the potential to transform the classroom into a space of expanding possibilities.

My suggested description of collective mathematical creativity indicates that the starting point to trigger collective creativity in mathematics learning environments is to create and offer genuine classroom opportunities for students to practise collective creativity: opportunities that encourage students to do what real mathematicians do. According to the NCTM (2000), to enrich students' mathematical experiences, deepen their knowledge, and enhance their opportunities and options for shaping their futures, we need to promote their understanding and applying of mathematics, and to engage them in what Davis (1996) named the mathematical, which he used to refer to "inquiry which has allowed our mathematics to emerge. It involves a noticing of sameness, pattern and regularity amid one's explorations. It involves comparing, ordering, creating, and naming" (p 93). And, it involves a dialogical conversation about, and "an active and intersubjective questioning of the world" (p 94).

As I noted before, doing and understanding mathematics are usually described as creative acts (Martin, Towers and Pirie 2006). To do mathematics, according to King (1992), means to produce mathematics that is new and significant. Herein, creativity is not the final end product that results from students' interactions and coactions while they are working on a mathematical task; rather creativity is located in the coactions and interactions themselves that result in what might be considered as new and significant to, at least, the local classroom community.

Martin, Towers and Pirie (2006) offered some suggestions regarding tasks that have the potential to prompt mathematical doing and understanding. For example, they should be open-ended tasks that allow for a variety of responses and invite a variety of paths, and they should be at an appropriate mathematical level. In addition, such tasks should encourage students to use different mathematical processes (problem solving, reasoning, communicating, connecting and representing) to deepen their mathematical understanding and apply their mathematical knowledge (NCTM 2000). In other words, mathematical tasks should be rich, approachable and encourage mathematical inquiry (Davis 1996).

I think it is important to include an example of a task that may encourage students' mathematical sensibilities and mathematics to emerge, interact and evolve. The task was used in a recent research study of collective creativity in elementary mathematics classroom settings. The participants were two mathematics teachers in a Canadian school setting, and their sixth-grade students in the academic year 2015/16. The task was introduced to a group of three sixth grade students (S1, S2 and S3) in an interview setting with the author. The task states that "three children, Alex, Zac and John, shared a chocolate bar. Explain in as many ways as you can how those children may divide the chocolate bar into three pieces such that Alex will get twice what John got, and John's part is no more than one-fourth of the original bar and no less than one-tenth of it." Herein, I am including accounts drawn from a 25-minute problem-solving session with the three students. These accounts are included here to exemplify just two of the seven metaphors of creativity (namely, overcoming obstacles and expanding possibilities). In addition, a brief description of each of the seven metaphors is included.

Overcoming Obstacles

This metaphor suggests that the spark of creativity glimmers when we are addressed by a worthwhile problematic situation. Consequently, many scholars in the field of mathematics education describe problem solving as a form of creativity (Mann 2006; Silver 1997; Sriraman 2009). According to Silver (1997), problem-solving and problem-posing tasks can be used to foster creativity. Such tasks include less structured, open-ended problems that permit the generation of multiple goals and multiple solutions. The first obstacle that the participant group confronted was "where to start, and how to proceed."

"But it is [Pause 2 seconds] John barely gets any," S1 commented after S3 finished reading the problem. "Wait, but how much does Zac get?" S3 asked. His question initiated kind of collective overcoming obstacles activities. "Let's just give him a third," S1 suggested. "It is just whatever's left," S2 responded to S3's question and S1's suggestion. After a brief conversation S1 suggested to "Draw the chocolate bar," and on a shared piece of paper, he drew a rectangle and split it into four equal-sized pieces (quarters) to represent the chocolate bar. The three students engaged in a conversation while they were working collectively on their shared representation of the chocolate bar. S1 summed up the group's suggestions by stating that "Oh, yeah, it would work, yeah because if John," S2 interrupted and completed S1's statement "gets 25 per cent, Alex gets 50 per cent, then there is 25 per cent left from the bar, we just give that to Zac." S3 noted that "I guess we just have to work with, Alex and John because Zac doesn't matter."

The group agreed on S3's comment. To this end, the group was collectively engaged in overcoming obstacles activities. They tried to understand the problem and to consider the conditions of it. They listen respectfully to each other, and respond thoughtfully to the wonderings and suggestions that emerge through the conversation.

Divergent Thinking

According to Webster's online dictionary, divergent thinking is creative thinking that may follow many lines of thought and tends to generate original solutions to problems. There are four key components of divergent thinking which can be considered components of creativity; these are fluency, flexibility, originality and elaboration. Herein, our group's divergent thinking started with S2's question "OK, so how many other ways can we do this?"

Assembling Things in New Ways

Creativity includes using what we have creatively, which, in turn, may require finding connections, combining ideas and information, and assembling things in new ways. Klein (2013) argued that our discoveries and our solutions to different problems are all based on the idea of combining and recombining pieces of information to produce new ideas or to understand anew. Within the same paradigm, insight may eventually be gained by engaging with several events to discover a pattern or other relationship.

Route-Finding

Koestler (1964) argued that "the creative act is not an act of creation in the sense of the Old Testament. It does not create something out of nothing: it uncovers, selects, re-shuffles, combines and synthesizes already exciting facts, ideas, faculties, skills" (p 120). This vision of creativity is very close to Craft's (2003) "little c creativity," which may be understood as navigating new pathways, manoeuvring, charting a new path, discovering, uncovering or tracing. Students in the participant group were curiously engaged in processes of negotiating, selecting, combining and synthesizing different ideas and information to find their routes around the problem.

Expanding Possibilities

To be creative, according to Norris (2012), means "to be in a state of openness to the unknown, a place of possibilities, a place that a playful environment fosters" (p 300). Craft (2000) argued that one of the engines for little-c creativity (everyday creativity) is possibility, that is, using imagination, asking questions and playing. Craft described "possibility thinking" as "refusing to be stumped by circumstances, but being imaginative in order to find a way around a problem or in order to make sense of a puzzle" (p 3).

The group's starting point for building on, and expanding of their different suggestions and ideas was S1's wondering, "We cannot have three ninths?" S2 commented, "No, we cannot have three-ninths because then it won't be split into three." S1 interrupted S2's comment and completed it by stating that "because Alex would have six, John has three, and there is nothing left for Zac." S3 wondered, "Zac and Alex don't have to be equal, right?" S1 replied, "No, but." Accordingly, S3 interrupted S1 and noted that "so, Zac can have a tiny little piece [Pause 2 seconds] as long as Alex is twice as much as John." S1 completed S3's comment by stating that "as long as Alex is twice as much as John, and John is no more than one-fourth and no less than one-tenth, Zac can get as much as he wants or little as he needs." After a brief conversation, S1 argued that "I don't think it can go forever. We cannot go more than one-fourth and we cannot go less than one-tenth." But S3 didn't agree with him, and he believed that "technically, if you just kept on zooming in, slicing like into three, then zooming in to the last section depressing into three that goes on forever then, it goes on forever." Later, S1 agreed with him and suggested that "you can also do the opposite way by expanding [Pause 2 seconds], well, no, expanding will work too but it would stop, but this zooming in will go on forever." S2 agreed with them and summarized their different basic options: "OK, so we have our ninths, and we have our eighths, now sevenths, sixths and fifths, yeah, these are our options for that."

Collaborative Emergence

Imagination and play can be considered improvisational practices, because they involve uncertainty and unpredictability and because they are unscripted. Through the practice of improvisation, creativity may also be a collaborative emergence. Sawyer (1999) conceived of creativity as an emergent phenomenon that results "from the collective activity of social groups. Although collaborative emergence results from the interactions of individuals, these phenomena cannot be understood by simply analysing the members of the group individually" (p 449).

The previous accounts show us that the same characteristics that Martin and Towers (2009) aligned to improvisational coactions are applied to the mathematical inquiry of the participant group. These are:

1. No one person driving: "as the students work together and collaborate, no one student is able to lead the group to a solution" (p 13).
2. An interweaving of partial fragments of suggestions and representations: "the group, through offering fragments of [different possibilities especially concerning John's and Alex's parts], coact to make and develop confidence in a new [emerging possibilities]" (p 14).
3. Listening to the group mind: During students' coacting and interacting, there were "several places where innovations are offered (often in fairly incoherent fragments) and where, by listening to the group mind, the group is able to pick up on ideas and interweave the fragments to build a collective [ideas and solutions]" (p 15).
4. Collectively building on the better idea: "when an image is challenged and an innovation offered, a coacting group must collectively determine whether the innovation is to be accepted into the emerging performance. They achieve this by listening to the group mind" (p 15).

According to Sawyer (2003), improvisation "exaggerates the key characteristics of all group creativity: process, unpredictability, intersubjectivity, complex communication, and emergence" (p 5). And this exaggeration is completely demonstrated by the previous accounts of the participant group. The group coactions and interactions triggered and sustained the emergence of "new ideas, suggestions, connections, paths, processes, etc."

Originating, or Making Something New

The word creativity, both in its origins and in most of its varied uses, reflects a kind of newness, originality or novelty. In addition, the new thing that is brought into being is seen as something valuable, fruitful, effective, appropriate and so on. For the purpose of describing creativity in classroom settings, both Baer (1997) and Starko (2009) suggested that a product or idea is original to the degree that it is original to the creator, and it is appropriate if it meets some goal, purpose or criteria within a sociocultural context.

Students in the participant group demonstrated evidence of newness and appropriateness of their actions and doings. Apparently, students were engaged in the task for its own sake. I didn't offer them any kind of extrinsic motivations to participate or to engage in doing the tasks. The previous brief accounts from the problem-solving session with my participant group show many indications of new and effective things emerging during the flow. Flow is a notion used by Csikszentmihalyi (1990) to refer to the state of being completely involved in an activity for its own sake.

Concluding Remarks

These brief accounts (few minute conversations) show us the richness, the collective and the emergent nature of students' conversation. Here, I would like to advise the reader that there was no intervention from anyone other than the three students during the session. The problem-solving session with this group of students can best be described as a free yet constrained mathematical inquiry. The task was open-ended with two constraints. Students' thoughtful, and sometimes playful, arguments, talks and negotiations show us the conversational and dialogical nature of mathematical inquiry (Davis 1996). Observing such a group of students while they were working on some mathematical tasks afforded me invaluable opportunities to understand what it really means to do and understand mathematics. Students were free to make decisions, work on the task, experiment, move, talk, mingle, play, and accept or reject. Adding some constraints to the task didn't hinder the task; rather they made it more interesting, challenging and intrinsically engaging.

Despite the good work in the field of mathematical creativity, it remains unclear how it might look in a classroom setting. Herein, I presented a description of mathematical creative acts based on seven metaphors. In addition, I introduced a brief description of each metaphor. Two metaphors were exemplified by some observations from a problem-solving session with a group of sixth grade students. This paper is an attempt to describe mathematical creativity as it may emerge in mathematics learning environments. The metaphors can be considered design principles to support teachers' efforts in creating and offering genuine classroom opportunities for their students to exercise creativity—opportunities that have the potential to transform the classroom into a space of expanding possibility.

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