THE TEACHER'S ROLE IN FOSTERING COLLECTIVE CREATIVITY IN ELEMENTARY CLASSROOM SETTINGS

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In a research study designed to investigate the emergence of collective creativity in elementary classroom settings, and in which teachers' decision-making practices were analyzed alongside both the teachers' observed teaching practices in their classrooms and their students' problem solving actions, the first author developed four metaphors for collective mathematical creativity and linked the entailments of these metaphors to teachers' actions. In this paper, we discuss in detail these entailments and teacher actions, present a framework for collective creativity, and reflect on the implications for practice and further research.

Keywords: Elementary school education, Instructional activities and practices, Teacher beliefs

This paper is based on data collected by the first author in a research study designed to investigate the emergence of collective creativity in elementary classroom settings. In the study, teachers' decision-making practices were analyzed alongside both the teachers' observed teaching practices in their classrooms and their students' problem solving actions. Drawing on metaphors for collective mathematical creativity developed by the first author (Aljarrah, 2020; Aljarrah & Towers, 2019), and connecting teachers' responses to questions about their practice with both their observed teaching practices in their classrooms and their students' problem solving actions, in this paper we explore the entailments of the metaphors and their relationship to teachers' actions and present a framework for analyzing and understanding collective creativity in teaching and learning environments. We rely on data from interviews with the participating teachers, as well as examples of their students' mathematical activity. Elsewhere, we have presented detailed descriptions of the student actions and interactions that we claim showed evidence of the students' collective mathematical creativity (e.g., Aljarrah, 2020; Aljarrah & Towers, 2019, 2021, 2022). Here, we focus on the features of learning environments that foster such creativity.

Literature Review

Creativity—Individual and Collective

Researchers in the field of creativity have struggled to develop and sustain applicable pedagogical innovations that respond to the problem of fostering creativity within different contexts. In his discussion of the question, "How does a person learn to be creative?", Huebner (1967) saw that "the very question itself demands a definition of the word creative" (p. 134). While some see creativity as confined to special people, to particular arts-based activities, or to undisciplined play, Craft (2000) described it as "a state of mind in which all our intelligences are working together" (p. 38). The National Advisory Committee on Creative and Cultural Education (NACCCE, 1999) defined creativity as "imaginative activity fashioned so as to produce outcomes that are both original and of value" (p. 29). Another approach to creativity, which can be a good starting point for teachers who aim to teach for creativity, is Baer's (1997) conception of creativity as a continuum; that is, it is "not something that a person either has in abundance or lacks entirely" (p. 2). Very close to Baer's conception of creativity is Kaufman and

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Beghetto's four-c model of creativity (Beghetto & Kaufman, 2007; Kaufman & Beghetto, 2009). In their model, Kaufman and Beghetto described four types/levels of creativity: interpretative or mini-c creativity, every-day or little-c creativity, expert or pro-c creativity, and legendary or big-c creativity. They refer to everyday creativity as the creative actions of the non-expert. According to Beghetto and Kaufman (2011), little-c and mini-c creativity are more appropriate in the classroom context. For example, elementary students' ideas for a science experiment can be considered creative in the context of the elementary school. Beghetto and Kaufman (2011) argued that "a students' [sic] novel and personally meaningful insight or interpretations (which occur with great frequency while learning) are important sources of larger-c creative potential" (p. 98).

Regarding collective creativity, Sawyer (2003) asserted the improvised and collective nature of group creativity. For Sawyer, group creativity is: (1) unpredictable, in that each moment emerges from the preceding flow of the performance, (2) collective, in that members of the group influence each other from moment to moment, and (3) emergent, in that the group demonstrates properties greater than the sum of its individuals. Based on the above ideas, Aljarrah (2018) defined collective creative acts as particular kinds of "(co)actions and interactions of a group of curious learners while they are working collaboratively on an engaging problematic situation. Such acts, which may include (1) summing forces, (2) expanding possibilities, (3) divergent thinking, and (4) assembling things in new ways, trigger the new and the crucial to emerge and evolve" (p. 136).

The Teacher's Role in the Development of Students' Creativity

According to Silver (1997), the contemporary view of creativity "is closely related to deep, flexible knowledge in content domains; is often associated with long periods of work and reflection rather than rapid, exceptional insight; and is susceptible to instructional and experiential influences" (p. 75). This view led Silver to advocate for creativity-enriched instruction for all students. To achieve this goal, Silver (1997) suggested the use of problem posing and problem-solving activities to stimulate inquiry-based mathematics instruction, in which "the responsibility for problem formulation and solution is shared between teacher and students" (p. 77).

Levenson (2013) explored teachers' perceptions of the cognitive demands associated with tasks that have the potential to promote mathematical creativity. Teachers identified several cognitive demands: the ability of the task to connect separate mathematical topics, the possibility to promote "non-algorithmic and nonstandard thinking skills" (p. 285), and the employment of "mathematical thinking freely and flexibly with the help of the mathematical skills acquired during [one's] life" (p. 286). According to Levenson (2013), equally important to the choosing of the task is how the task will be implemented.

Lev-Zamir and Leikin (2013) investigated the relationship between teachers' declarative conceptions of creativity and their conceptions-in-action. Lev-Zamir and Leikin noted that although teachers' theoretical background in creativity is important, it is not enough; equally important is how they implement their understandings of creativity in the classroom.

Davies et al. (2014) conducted a systematic literature review to explore the teacher's role in promoting creativity, and ways in which teachers can be best supported to develop the skills and confidence to facilitate creative learning environments. Their findings revealed that teachers play an important role in creating learning environments that promote their students' creativity through "building positive relationships, modelling creative behaviour, longer-term curriculum planning, striking a balance between freedom and structure, allowing flexible use of space,

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understanding learners' needs and learning styles, creating opportunities for peer collaboration and assessment, and effective use of resources" (Davies et al., 2014, p. 39). It was also noted that to fulfill such requirements, teachers need to have positive attitudes towards creativity and the self-confidence to teach in particular ways. This is a daunting list of expected actions and competencies for teachers. In what follows we present, explore, and examine entailments of various metaphors for collective mathematical creativity that suggests ways forward for teachers wishing to develop these skills and foster collective mathematical creativity in the classroom.

Methods

The data described below were collected during a design-based research study exploring collective creativity in elementary mathematics learning environments (Aljarrah, 2018). Two mathematics teachers and 25 of their sixth-grade students in a Canadian school setting participated in the study. The core research questions for the study were:*1) What can be learned from the process of developing and refining an emergent definition of collective creativity for the elementary mathematics classroom? 2) Does collective creativity emerge in elementary mathematics classroom settings? 3) How can we foster collective creativity in elementary mathematics classroom settings, and what is the teacher's role in this endeavor? and 4) What use might the construct of collective creativity be to teachers of mathematics?*

As the study aimed to explore collective creativity, the design included having the researcher (the first author) gather and design mathematics problems that it was hoped would allow for student collaboration, engagement, and group work and bring these problems forward for enactment by the teachers in their classrooms and in researcher-led, small-group, task-based interviews with students outside scheduled class times. Additional materials such as the teachers' and researcher's planning documents, copies of students' work, documented observations of classroom activity, and video-recordings of interviews with the participating teachers and task-based interviews with students were also collected. The processes of analysis followed Pirie's (1996) advice to "sit, look, think, look again" (p. 556) supported by Powell et al.'s (2003) analytical model for studying the development of mathematical thinking, which consists of seven interacting, non-linear phases: (1) viewing the video data, (2) describing the video data, (3) identifying critical events, (4) transcribing, (5) coding, (6) constructing a storyline, and (7) composing a narrative (p. 413). Following Flanagan (1954), an event was considered to be critical if it was helpful in triggering and/or explaining the emergence of collective creativity in elementary mathematics learning environments. An initial literature review in the field of creativity led the first author to characterize the existing literature within the four metaphorical domains named earlier (see also Table 1). Analysis of critical events within the data collected during the study, together with conversations between the authors of this paper and reference to Towers and Proulx's (2013) framework for teaching actions and Davis' (2018) work on entailments of grounding metaphors led to the remaining elements of the entailments chart (see Table 1).

Findings

As we noted in the literature review section, Aljarrah's (2018) description of collective creativity is based on four metaphors (summing forces, expanding possibilities, divergent thinking, and assembling things in new ways), which were used to describe students' creative acts during problem-solving sessions inside and outside their classrooms. The summing forces metaphor was used to encompass the ways in which learners coordinate their efforts to enable

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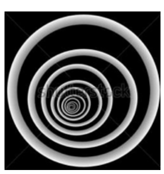
productive steering (Aljarrah, 2020) towards a mathematical understanding "that is not simply located in the actions of any one individual but in the collective engagement with the task posed" (Martin et al., 2006, p. 157). Expanding possibilities might be understood as broadening the learners' horizon by gaining new insights based on previous insights. It is a kind of stretching of the space of the possible as a result of the evolving and the growth of the learners' basic insights. Divergent thinking requires students to consider many potential pathways, look in many directions, journey outside a known content universe, go beyond the problem's clearly given conditions and information, and think outside-the-box (Aljarrah & Towers, 2019). And, finally, the assembling (things in new ways) metaphor implies looking for associations and making connections. It is a vision of creativity based on an assumption that many educative things are within the reach of learners in their learning environment.

Since our focus as educators is students' learning, a noteworthy question arose during the study: What do learning and teaching look like with(in) each metaphor of creativity? More precisely: If creative acts are summing forces, then what is learning and what is teaching? If creative acts are expanding possibilities, then what is learning and what is teaching? If creative acts are divergent thinking, then what is learning and what is teaching? If creative acts are assembling things in new ways, then what is learning and what is teaching?

In the following chart (Table 1), we present some entailments of the four metaphors of creativity generated during the research study. For each metaphor for collective mathematical creativity, the entailments include a visualization of the metaphor, the grounding metaphor on which the metaphor for creativity is built, and descriptors or metaphors that suggest the kind of learning and teaching anticipated for each way of thinking about mathematical creativity. Together, these entailments constitute the Collective Creativity Framework (CCF).

Table 1: The Collective Creativity Framework

Metaphors of Creativity	**Visualizing**	**Grounding Metaphor**	**Learning**	**Teaching**
Summing Forces		Sum of Forces	Productive Steering	Nudging
Expanding Possibilities		Inflating	Growth	Extending
Divergent Thinking		Multidirectionality	Widening Perception	Re-orienting Attention

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Assembling Things in New Ways		(De)construction	Assembling	Triggering Disintegration

Our exploration of the complexities of these entailments is still ongoing, so they are offered here mostly as a provocation and speculation about the kinds of learning and teaching actions that observers might see when one of the four metaphors for mathematical creativity is shaping the classroom activity. Nevertheless, we did see examples of these entailments in action in the data and we present some of those below. These examples are drawn from data featuring a group of three sixth-grade students (assigned the pseudonyms Mark, Kyle, and Zaid) working togther on the following problem (which was designed based on examples from Empson and Levi, 2011):

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.

Due to space limitations in this paper, we focus on addressing the entailments of only the first three metaphors of creativity, namely; summing forces, expanding possibilities, and divergent thinking.

Entailments of the Summing Forces Metaphor

The students began by familiarizing themselves with the problem. Mark was curious about John's part and commented, "But it is, [pause, 2 seconds] John barely gets any." Following this comment, Zaid asked, "Wait, but how much does Zac get?" Zaid's question initiated collective exploration and Mark suggested, "Just give him [i.e., Zac] a third," while Kyle responded to Zaid's wondering and Mark's suggestion by stating, "It is just whatever is left." Mark and Zaid agreed with him and stated, "Yeah, I guess so," and, "Okay, so, um" respectively.

Next, Mark suggested drawing the chocolate bar and on a shared piece of paper. He drew a rectangle and split it into quarters. Kyle then started to initiate a possible path to work on the task. "It does not say what Zac gets [pause 2 seconds] because we can do, like, John and Zac get twenty-five percent [each], and then, um, or sorry, no." Mark supported Kyle's suggestion by restating the given conditions of the problem: "Okay, Alex has to get twice what John got, and John's part cannot be more than one-fourth." Based on Mark's statement, Kyle refined his suggestion and stated with confidence, "Yes, like if John and Zac will get one-fourth [each], and then Alex gets, um, two-fourth—". Mark interrupted Kyle and stated, "Oh, yeah, it would work, yeah, because if John—". His statement seemed to not only represent a collective agreement, but also to express a collective aha moment when all the group felt as though the problem made sense. This, for example, can be seen through Mark's words, "Oh, yeah, it would work, yeah because if John" while he was reflecting on and reasoning an emerging pathway. Here, it is possible to hear their conversation as if just one person is speaking. This was evident in Kyle's words, when he interrupted Mark's statement and completed it by stating that "[because if John] gets twenty-five percent, Alex gets fifty percent, then there is twenty-five percent left from the bar, we just give that to Zac." It was evident that Zaid was also experiencing this collective aha

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moment, and he summarized the group's initial plan to proceed by stating, "I guess we just have to work with, um, Alex and John because Zac does not matter."

Turning now to examine the teaching that occasioned this learning, we note that an important aspect is the setting up of a learning environment within which it is possible to prompt, promote, and sustain effective interactions between all the agencies in the learning environment including the program of study, the people in the classroom, and the materials and tools. The choice of problem was a significant teaching act that nudged these students into a place where they were challenged, but at an appropriate mathematical level. According to one of the participant teachers, "the problem is inviting to all students at their own levels. Each brings their particular backgrounds and experiences to share their perspectives on the problem."

Group size was also considered by the teachers in this study to be an important teaching decision. Both participant teachers indicated that they prefer to divide the class into small groups (2-3 students in each group). One of the teachers noted, "I prefer the small groups. The bigger the group the less that gets done. Much more time is wasted with larger groupings." According to her, small groups allow students to share their ideas freely, and to ask questions comfortably: "Students have to be able to explain their understanding to their classmates so that they get the strategy being suggested. Kids are better at asking questions in small group settings and saying, 'I do not get it.'" The teacher also added that, "Often the students work with who they are comfortable with, which is often someone at their own level of comprehension. Elsewhere, Martin et al. (2006) have also recognized that "although [students] bring identifiable personal contributions to the collective action, it is through the coacting of these that collective understanding emerges and grows" (p. 157). In our example, students' productive steering toward "better" mathematical ideas and thoughts—that appear to be helpful for the group in developing a solution to the problem—"is not determined by all the individuals having the same understanding" (Martin et al., 2006, p. 157). Instead, and as seen in the above extract, it was a result of the summing of their diverse and different understandings and thoughts.

Another critical strategy to nudge the students towards effective collaboration and productive steering from the very beginning of their problem-solving activity was restricting the group to one shared document upon which to pool their ideas. Also noted as a strategy to promote collective mathematical understanding (Martin et al., 2006), here we acknowledge this strategy as a useful way to promote the kind of learning we identify as productive steering through its capacity to nudge students to collaborate. With one shared document, students can simultaneously see the developing problem-solving strategy and, if each has a writing tool, can equally contribute to the gathering of data for the problem or the steering of the solution.

Entailments of the Expanding Possibilities Metaphor

The entailment for learning for the Expanding Possibilities metaphor is Growth. In the following part of the excerpt, there are many occasions where students engage actively and collectively in processes that help them in growing their initial knowledge, thoughts, and strategies. As the problem solving progressed, Kyle summarized their different basic options for splitting the chocolate bar: "Okay, so, so we have our ninths, and we have our eighths, now sevenths, sixths, and fifths, yeah, these are our options." Zaid stressed the idea that "it goes on forever." Mark agreed with him and at that point, the task of the students expanded from finding as many ways as they could to divide the chocolate bar into three pieces to proving that the process of dividing the chocolate bar would go on forever.

The group collectively then developed the idea of "realistic" parts of the chocolate bar (the fractional parts they were considering—tenths, ninths, eighths, sevenths, sixths, and fifths) and

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“technical” parts (that could be divided forever). They then used quarters as a generator for an infinite series of options. On their working sheet they wrote, “last section always divided by four once you reach the last realistic idea.” For example, one of their options was to give John two-ninths, Alex four ninths, and Zac three-ninths. They then expanded this “realistic” option. Kyle suggested, “As long as John always gets half of what Alex gets, Zac does not really matter.” For them, since Zac does not really matter you can take one of his parts and divide it into four equal-sized sections, give one to John, two to Alex, and then divide the last section into four again; give one to John, two to Alex, and then keep zooming in to the last section and do the same thing an infinite number of times. According to them, this idea can be applied to all realistic options (i.e., the tenths, ninths, eighths, sevenths, sixths, and fifths).

Here we want to focus on the teacher’s role as a participant in the learning endeavour who is responsible to make “judgments about when and how to intervene” (Martin & Towers, 2011, p. 275). Teachers’ actions within the collective have the potential to either prompt or hinder the emergence of creative acts in mathematics learning environments. For example, while Mark, Kyle, and Zaid were discussing the possibility that the process of dividing the chocolate bar between the three children could go on forever, the first author suggested that they try to arrange the different possibilities in a table. After the first author’s suggestion, Mark changed his mind and stated that, “*I do not think it can go forever. We cannot go more than one-fourth and we cannot go less than one-tenth*.” On reflection, it is obvious that the intervention from the first author, while intended to extend the learning, actually shut down the growth of the students’ thinking, blocked the emerging, collective structure, and directed the group to a misleading path. Realizing this, the first author decided to step back and watch for another opportunity to intervene for the purpose of furthering the evolving structure of mathematical thinking and understanding. As Martin and Towers (2011) note, “the teacher must continually listen to, and re-connect with, the improvisational actions of students, possessing a sophisticated capacity to step back until the collective action calls him or her forth” (p. 275).

Entailments of the Divergent Thinking Metaphor

In this section we show how the group’s divergent thinking evolved while they were trying to find a *mathematical* way to show that the process of dividing the chocolate bar can go on forever. Kyle reflected on and expanded his initial suggestion: “Okay, so, so we have our ninths, and we have our eighths, now sevenths, sixths, and fifths, yeah, these are our options,” and noted, “there is a way in between them.” His statement that “there is a way in between [any two realistic possibilities]” indicates a moment where the group went beyond the stated conditions of the problem and started to think outside of its content universe. At this point, the first author intervened subtly by reorienting the group’s attention to a tool that might help them think mathematically about their idea—the number line. Mark then initiated a new conversation about using the number line and decimals to explain why, *“mathematically,”* the process of dividing the chocolate bar could *“go on forever”*:

Mark: You could, you could also put it in decimals.

Zaid: But, I mean if you did decimal fractions then you can do anywhere from here [while pointing to a point on the number line that represents 0.1] to all the way to [while pointing to a point on the number line that represents 0.25]—

Mark: Look, if you did zero point two five to zero point one— [while he was drawing a line segment to represent a part of the number line with 0.1 and 0.25 as its endpoints].

Zaid: And, twenty-five hundredths, and umm.

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Mark: Yeah.
Zaid: If you used the decimal fractions there will be a loooooot.
Mark: If you did this that is endless. You could do—
Zaid: Oh, yeah endless, because you could just keep adding like … point one, point one, point one, point one, point one, point one, one, one, one, one, one, one, one, one, one… [writing 0.1000000000000001 on their shared piece of paper]…
Mark: Exactly, for decimals it is endless.
Zaid: Yeah, okay.
Kyle: Yeah.
Mark: If you take two numbers, there is an endless list of numbers between them, even if it is one and two.
Kyle: Okay, um, we got it.

The intervention by the first author (offering a new tool with which to think) exemplifies the kind of re-orienting of attention that leads to a widening of the learner's perception about the problem and consequently to divergent thinking, the third of the metaphors for collective mathematical creativity. The students were familiar with the number line, of course, but it wasn't in play until proposed by the first author at a moment when the students had an idea about the space "between" the numbers they were considering but seemed not to have a concrete way to widen their perception of what this space between might contain. Reorienting their attention to something they knew about already but weren't capitalizing on was the teaching action that propelled them forward to think in divergent ways about the problem.

Discussion and Implications

The entailments of the metaphors for collective mathematical creativity that we have presented in the Collective Creativity Framework are significant ways to understand the underpinnings of effective creative learning in mathematics classroom settings, within which the teacher's role is understood as facilitating and scaffolding to provide "the student with room for the creative action required for learning" (Martin & Towers, 2011, p. 253). Davies et al. (2014), though, note a dearth of research that details how teachers can be supported in enhancing their practice to support such student creativity. Our work offers a framework for teachers to reflect on the opportunities they are offering to students to express their creativity through one of Aljarrah's (2018) four metaphors, and from there to glimpse, through the entailments chart that underpins the CCF, the teaching strategies that might enhance that creative activity in the classroom.

Davies et al. (2014) did note the importance of professional development that provides opportunities for reflection on practice and peer dialogue, and in addition reported that "external partnerships, especially with creative professionals, were seen to be beneficial as [they] led to co-creation of knowledge and exploration of conceptualisations of creativity" (p. 39). Our work shows how teachers can be supported in deepening opportunities for students to engage in collective mathematical creativity through the establishment of a partnership between classroom teachers and researchers with a shared goal of enhancing student experience and fostering mathematical creativity.

The design-based research model adopted for this project also provides opportunities for teachers to be introduced to new theoretical concepts (such as collective mathematical creativity), new forms of math problems (such as ones specifically designed to afford collective

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action), and alternative pedagogical structures, while at the same time providing researchers with authentic opportunities to interact with learners and teachers and to develop practice-informed theory.

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