“I’ve Gotten Better in Areas I Didn’t Associate with Communication”: Exploring Undergraduate Peer Mentors’ Creativity in Mathematical Task Development

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Education in the United States suffers from a lack of integrated and applied learning approaches that support the effective communication of mathematical ideas and real-world problem solving skills. Despite more than 50 years of research on curricular and policy reforms in mathematics education (Berry et al., 2014), there has been little change in the typical mathematics classroom for student learners. As a response, researchers have increased the calls for interdisciplinary perspectives on learning, especially in the disciplines of mathematics and science. Nasir et al. (2021) argue for an expansive view of learning which “engages a multiplicity of cultural repertoires of practice,” citing Gutiérrez & Rogoff (2003); and they offer a perspective on learning which leverages the “multiple representations and ways of knowing” across settings (Nasir et al., 2021, p. 562). This expanded view of learning, which highlights the various dimensions and pathways to knowing, challenges the normative views that plague a majority of narratives on learning mathematics.

While professional mathematicians tend to engage in a host of creative processes through peer collaboration (Byers, 2020; Sriraman, 2009), undergraduate students learning mathematics, especially those in developmental or “remedial” courses, are often subjected to a “banking model” of education (Freire, 1996; Larnell, 2016). In the banking model of education, teachers are the sole possessors and communicators of knowledge, and students are represented as empty containers into which teachers deposit knowledge. In this model, the ideas of effective peer collaboration are flattened to one-dimensional practices that include, as examples, students checking to see if they have the same answers as a peer or rushing through a longer list of tasks. The banking model of education accurately describes both the history and development of school mathematics, and it emphasizes the memorization of facts and a repetition of processes that ultimately stifles communication, creativity, and critical thinking.

In response to the banking model of education, Freire (1996) proposed a “problem-posing education” to highlight the importance of dialogue, critical thinking, and a mutual exchange of knowledge between teachers (or mentors) and students. In Freire’s conception, dialogue-based learning relies on a breakdown of traditional hierarchies in mathematics classrooms, and encourages mutual interactions and co-investigation. His focus on critical consciousness and student empowerment reframes learners as active subjects in their education rather than passive recipients. In his focus on real-world relevance, Freire centers on learning practices that are rooted in culture, student backgrounds, their individual experiences and circumstances, which embracing high expectations and cultural relevance as noted by Ladson-Billings (1995).

As the research on creativity in mathematics education expands (Leikin & Pitta-Pantazi, 2013; Mann, 2006; Sriraman, 2009), there are a host of intersections that should be highlighted in studies of creativity in mathematics and in Freire’s conception of problem-posing education. One important intersection across both of these frameworks is an emphasis on *process* over *product*, where the processes of inquiry and exploration are valued as much, if not more than, arriving at a single correct answer. While the banking model of education thrives on products of assimilation in both form and technique, a problem-posing education asks learners to be creative as they challenge the status quo, and the normative way of approaching problems. Although Freire (1996) approaches problem-posing education in a broader scope, setting up one of the seminal framework for liberatory education, the focus on creativity further encourages the development of interdisciplinary connections across different domains of knowledge. The intersection of creativity and problem-posing perspectives encourages the different actors in learners’ networks, such as peer mentors, to break tradition and find creative means that can help support mathematical learning.

Research in undergraduate mathematics education is constantly evolving to make better sense of the impact of various social systems in mathematical learning spaces, and a growing body of work emphasizes creative approaches to learning and teaching mathematics. In this work, peer collaboration has emerged as a powerful strategy to support student academic development, particularly in relation to the development of more advanced problem-solving skills. While the extant research on undergraduate mathematics has traditionally focused on classroom environments, curricular changes, and academic outcomes that relate to student belonging, for example, there is a notable gap in our understanding of the creative processes peer leaders engage in as they develop and refine their mentoring strategies.

In this article, I offer a conceptual framework that situates the extant research on peer networks (Gamlath, 2022; Walker, 2006) and mathematical creativity (Elgrably & Leikin, 2021; Leikin & Pitta-Pantazi, 2013; Mann, 2006) within Freire’s (1996) conceptions of open-ended exploration and problem generation in his model of problem-posing education. Using this framework, I describe a set of non-verbal (written, visual) and verbal (speaking, presenting) active processes through which undergraduate peer mentors improved their communication strategies in the collaborative development of a set of mathematical tasks. Specifically, I answer the following research questions: (a) How do mathematics peer mentors develop and utilize creative non-verbal and verbal communication strategies to support their peers’ learning of first year college algebra? (b) In what ways does the process of developing creative tasks for mathematics learning contribute to mathematics peer mentors’ own understanding of mathematical concepts and their ability to center creative explanations as opposed to rote or “traditional” forms of mathematical learning?

This study of undergraduate peer mentors’ creativity in mathematical task development, situated at a small liberal arts college in the United States, illustrates the multiple ways that creativity, problem-posing education, and peer mentoring interact to advance students’ communication strategies in mathematics and their developmental approaches to understanding algebraic concepts. I argue that the support undergraduate peer mentors provide, especially to first-year students, can be stunted by a host of “traditional” mathematical practices that mimic the banking model of education and limit peer mentors’ ability to focus on the needs of their peers. The study findings demonstrate how a move to open-ended mathematical exploration and problem-posing practices in the training and development of peer mentors, based in the traditions of Freire’s (1996) problem-posing education, opens peer mentors up to a broader set of strategies that improve their mathematical communication and creativity (Elgrably & Leikin, 2021). This article makes two key contributions: first, the research on creativity in mathematics is expanded to integrate and honor Freire’s long standing conceptions of problem-posing education, which has implications for a smoother integration of work across secondary and post-secondary mathematics. Second, this article presents nuances on peer mentoring in mathematics that extend beyond traditional notions of peer tutoring and the teaching assistant to incorporates factors that relate to the intersecting cultural, social, and context-based components of teaching and learning mathematics (Ladson-Billings, 2014; Nasir et al., 2021; Tate, 1995).

This article contains three primary sections that begin with an overview of the conceptual framework for the study. In this first section, I describe three intersecting frameworks that connect Freire’s (1996) outline of problem-posing education with the emerging literature on mathematical creativity (Mann, 2006). Five areas are outlined at this intersection:

# Conceptual Framework

A major thorough line of research in mathematics education focuses on the development of communication practices and dispositions that support learning within and beyond traditional classroom settings (Clark et al., 2014). Communication practices can be examined in a variety of ways. However, with the development of new technologies and culturally situated teaching and learning practices, examining students’ verbal (speaking, presenting) and non-verbal (written, visual) practices presents a broad scope towards understanding decision making strategies.

Mathematics peer mentors (MPMs) in undergraduate settings – serving in a dual role as both teacher and student – present important cases for further inquiry into how individuals negotiate their pedagogical practices in relation to their mathematical communication goals. Moreover, MPMs provide insight into tutoring and other student leader developmental practice for mathematics programs and, more broadly, departments and divisions in the computational sciences. This paper describes the results of a two-year study focused on undergraduate student leaders’ communication practices and mathematical dispositions as they prepared to communicate various topics to their peers in both formal and informal settings.

Mathematical dispositions are explored as a complex set of context-based variables, which are ascribed to markers that range in both feature and value. While a host of dispositions have been examined in empirical studies to account for the extensive methods that purport how such dispositions are developed amongst those teaching and learning mathematics, this paper examines similar questions by framing peer leadership in mathematics (e.g., tutors, peer-led and team-based teaching, etc.) as representative of the tension between teaching and learning to teach. The values exhibited by peer leaders, as well as their related negotiation strategies when put into practice, can be explored through multiple domains, such as one’s responses to challenges, the view of self as a mathematical thinker and doer, and also their self-efficacy.

Understanding the various contexts in which communication practices and dispositions are developed has become an important hallmark of both pre-service teacher and student leader preparation in mathematical spaces. This article takes a developmental approach to examine how student leaders, mostly from non-mathematical majors or backgrounds, negotiate decisions. In order to identify and frame the various connections between individual dispositions, peer-led and team-based learning, and communication practices in undergraduate mathematics, we drew on perspectives and frameworks from a variety of disciplines outside of mathematics education. By crossing disciplinary boundaries, we were able to examine various aspects of leaders’ self-development and that of their peers within and outside of traditional learning contexts, as would be normally offered by faculty in the form of lectures or in office hours.

# Methods and Data

The methods and data will go here.

# Study Findings

## Non-verbal strategies

## Verbal strategies

## Types of mathematical matter

In assessing MPMs strategies, a secondary framework was identified that contributed to an extra layer of analysis of the study results On top of assessing MPMs’ creativity, the type of “mathematical matter,” or the context of the content included in mathematical problems assessed as a part of the mathematical task development exercises, was conceptualized.

| Mathematical matter type | Description | Example 1 | Example 2 |
| --- | --- | --- | --- |
| Typical Matter (TM) | Typical matter is content which is generally expected in common explanations. |  |  |
| Everyday Matter (EM) | EM is content that is broad in scope and is generally not based on understanding a particular frame or context. |  |  |
| Contextual Matter (CM) | CM is content that is narrow in scope and is based on understanding a specific context and references. |  |  |

## Skill building

There were a host of mathematical topical areas that peer mentors used in their engagements with each other and in the development of mathematical tasks. These topical areas were the core priorities across the course learning plan, and they were distributed on a course plan by the number of weeks for any given set of topics. The MPMs used this document to complete a set of self-assessments through the course of the program and to collaboratively select and distribute topics and timelines for the mathematical task development exercises.

### Self-assessments

Each peer mentor conducted a self-assessment across each of the topical areas over the course of the semester.

### Peer assessments

Based on the lowest scored items on their self-assessments, MPMs developed short presentations for a single topical area or as a transition from one topical area to the next. In the latter scenario, an assumption was made that the prior knowledge in the “lower” topical area was developed enough to begin an introduction to the “higher” topical area that generally follows the concepts in terms of introduction. For example, in working with polynomials, students can be introduced to the coefficients of a binomial expansion in multiple ways. Some of these methods are general enough to be followed with little prior knowledge whereas more “technical” (formal definitions and theorems) introductions may require some specific prior knoweledge; these prior knoweldge bases were identified as the “lower” topical areas. Thus, peers were asked to assess each others’ presentations based on either a single or a set of topical areas.

#### Peer quantitative assessments

Table X presents a summary of the quantitative resutls for the peer assessments. In a scale survey, peers assessed each other on a set of communication skills across each of the types of mathematical matter.

## Network relations

The network relations are provided to help the reader visualize the different groupings around students’ topical areas for the mathematical task development exercises.

## Creativity in task development

As discussed earlier, the main intervention for the was the MPM task development exercise. This exercise contained a different set of objectives that were examined for differences within and outside of topical areas.

# Discussion and conclusion

When MPMs were provided with an opportunity to expand their ideas of what was considered “mathematical,” they were more likely to source knowledge from each of the three types of mathematical matter: everyday matter (EM), technical matter (TM), or personal matter (PM). Prior to these provisions being introduced, MPMs were likely to focus on TM and did not attempt to build on EM or PM.

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