Engaged Learning Through Creativity in Mathematics

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Abstract

This study examined the impact of a deliberate attempt to present creativity as a mathematical endeavor on students' conceptions about mathematics, attitudes toward learning mathematics, and approaches to mathematics. Course modules were developed as part of a grant-funded project on creativity in STEM education and implemented in a course for non-mathematics majors. Throughout the course, students engaged in hands-on, active learning of mathematics through discovery. The mathematical topics for the course were chosen based on their relevance to students' everyday lives and their suitability for encouraging creativity. Data were collected through surveys, focus group interviews, and written artifacts. In this paper, we describe the preliminary results of our study and offer implications for both research and teaching.

Keywords: Creativity, General Education Mathematics Courses, Instruction

Introduction

Creativity is often associated solely with the arts. An online search gives the following definition: "The use of the imagination or original ideas, especially in the production of an *artistic* work." (Oxford Dictionary Online, 2017; italics added). Although creativity is valued among mathematicians (Sriraman, 2004), undergraduate mathematics students do not consider creativity to be important to mathematics (Munakata & Vaidya, 2015). Our Creativity in Mathematics and Science Project, funded by the National Science Foundation, challenges these traditional notions of both creativity and mathematics. Through our project, we developed and implemented course modules that embraced creativity in mathematics for a general education mathematics course and assessed the impact of some innovative teaching methods on students' conceptions of STEM (science, technology engineering, and mathematics), their approaches to mathematics, and their understanding of what it means to "do math".

Problem statement

Our research explored the impact of a course that deliberately drew upon theories related to creativity in its development and implementation. Namely, we sought to uncover whether this course influenced students' conceptions about mathematics and their approaches to mathematics. The following were our research questions:

1.) Does a deliberate attempt to infuse the undergraduate curriculum with a focus on the creative process lead to changes to students' perceptions of mathematics and attitudes toward mathematics learning?

2.) What is the impact of this instructional strategy on students' creativity, especially as it concerns approaches to mathematics?

Relation of this work to the research literature

Recent discussions in undergraduate education have proposed active (Wieman, 2014), inquiry-based (Singer, Hilton, & Schweingruber, 2006), and problem-based learning (Freeman et al., 2014). In the STEM fields, especially, there has been a call to make instruction more relevant to students' needs (DeHaan, 2009), and to have it exemplify the work of scientists and mathematicians (NRC, 2000). All too often, undergraduate STEM education is relegated to learning through traditional, lecture-style instruction, with problems and laboratory experiences dictated by questions and exercises posed without regard to context (DeHaan, 2009). There is a need to shift learning away from the acquisition of facts and procedural knowledge and to environments that encourage innovation (Southwick, 2012). This runs parallel to the need to cultivate adaptive expertise in our students whereby they are exposed to opportunities to be flexible and adaptable in problem-solving situations (Cropley, 2015).

The discussion about effective mathematics instruction is particularly important when considering students in general education courses. The fact that these courses for non-majors are often students' terminal courses in mathematics--and that they are composed of students representing various disciplines and interests--adds to the complexity of the issue. Many universities offer courses in the application of mathematics, especially related to societal issues (such as voting) or everyday interests (such as sports and arts), while others focus on practical uses such as finite mathematics for finances. We decided to put aside the list of mathematical topics usually covered, and have the topics emerge naturally from the processes we sought to encourage in our students. That is, we first identified creative processes and learning objectives for the course, then developed content-based modules we believed encouraged these processes.

Our work set out to consider the impact of such a course on students and to use the results to inform further revisions to the course.

Conceptual framework

Our project draws from different works in creativity--from both psychology and education. As creativity is notoriously difficult to define, we chose to focus on the various traits of creativity identified by researchers (e.g., Amabile, 1996; Hadamard, 1954; Sternberg and Lubart, 1996). These traits include the ability to connect ideas, see similarities and differences, be flexible, have aesthetic taste, be unorthodox, be motivated, be inquisitive, and question norms. We also considered what others have noted as being essential to the work of mathematicians: divergent thinking, and the ability to identify new problems and contribute new knowledge (Nadjafikhah, Yaftian, & Shahrnaz, 2012). In the mathematics classroom, some have suggested problem posing as a way to encourage creativity (e.g, Silver, 1994). With the understanding that the difference between the nature of creativity of mathematicians and of students is chiefly that of degree and level (Hadamard, 1954), we sought to develop a mathematics course that centered around creativity.

Our course introduced students to topics in mathematics of relevance to their daily lives. The course aimed to expose students to the wonders of mathematics and covered various topics in discrete and continuous data modeling, fundamental aspects of Euclidean and non-Euclidean geometry, fractal geometry and probability theory. We took a hands-on approach to learning since we felt that mathematics is best understood by active learning methods such as doing problems, discussions and debates and even performing experiments rather than passively listening to a lecture. No formal textbook was prescribed; all necessarily materials were handed

out to the students in class or through our online system, as needed. The only prerequisite was a very elementary knowledge of mathematics which may be required for any college course.

Research methodology

This study was conducted at a state university in the Northeast US. The institution was recently designated as a Research III doctoral institution and enrolls a little over 20,000 students, including undergraduate, master's, and doctoral students. The university has historically enrolled large numbers of students who are first-time college attendees in their families, and prides itself on its diverse population of students, having the distinction of being a Hispanic Serving Institution.

The course, Contemporary Applied Mathematics, is one of three courses for students who are not STEM or education majors: it fulfills their mathematics general education requirement. The course was taught in Spring 2017 and enrolled 36 students. Three of the four authors developed the course and co-taught the course during the semester: one instructor was the lead, and the other two led certain classes and otherwise assisted or took notes on the course discussions. We met weekly to debrief about the most recent class meeting and to plan for future meetings.

Since this was a general education course for non-science and math majors, the class represented diverse majors from outside science and mathematics including the arts and humanities. Few of these students, if any, had experience with the kinds of mathematical topics that were being discussed and few had seen mathematics presented quite in the hands-on and open-ended form that we adopted.

We employed both quantitative and qualitative research methodologies. Data were collected from the 35 students (21 female, 14 male) who consented to participating in the study. We collected data through semi-structured focus group interviews, surveys, journals, class assignments and two well-known measures of creativity (Guilford, 1958; Torrance, 1965). For the quantitative measures, we compared pre- and post-test gains against a those of a comparison group. This paper will focus on the results of the qualitative data—namely, the focus group interviews, reflective journals, and classroom artifacts. We have completed analysis of the interviews (of 12 students) and are expecting to complete analysis of the journals and written artifacts (from all 35 consenting students) in the next month.

Seven semi-structured group interviews were conducted with 12 students during the last two weeks of the course. The interviews were audio taped and transcribed. The purpose of the interviews was to collect information on the students' attitudes, beliefs, and opinions about the creativity course. The interviews were coded into seven initial categories and later broken down into subcategories. (Please see Table 1.)

During the interviews, students most often discussed the instructional and teaching strategies (n=106 times) employed by the instructors of the course. Overwhelmingly, these excerpts distinguished differences between traditional instruction of mathematics and science and the instruction in the creativity course. Students often described specific instructional activities they completed during the course (n=72) and discussed how the course influenced their thinking and learning of mathematics (n=67).

Table 1. Subcategories of the Main Themes

Theme	Subcategories
Mentions Specific Activities	Alignment Among Curricular Materials

	Connections to Personal Life and Knowledge Non-typical Problems Thinking Differently Working as a Community
Discusses Instructional/Teaching Strategies	Teaching How to Think Atypical Answers Instructor Qualities Active Learning Discussing Ideas Unfinished Problems Flexibility Vision for Education
Discusses Their Ways of Thinking or Learning	Depth of Understanding Discussing Ideas Confidence and Stress Thinking Differently
Discusses Creativity	Surprise Math Can Be Creative Value of Creative Approach
Mentions Future Aspirations	Helpful for Their Career Choice Applicability to Multiple Majors Transfer to Their Everyday Lives
Conceptions About Mathematics	Confidence Broadens Thinking Challenges Past Beliefs
Other	Connection to Other Disciplines Frustration: not given final answer/unfinished Procedural vs Conceptual Knowledge Standardized Tests Enjoyable Grading

The following offers descriptions with exemplar excerpts for some of the subcategories:

Teaching How to Think

Students pointed out that the instructors encouraged students to think mathematically. Therefore, they created a culture where students were not taught what to think, but were active participants in their learning. An excerpt from Mia highlights the contrast between the creativity course and her experiences in the past:

> I think it's really different from like a lot of the courses I've taken um, just because they don't teach in like a conventional way. You know, like, in every other math course I've ever taken it's been like you learn the theory and then like you learn um, they give you like examples, and then you do the homework, and then you take a test. And like it's just like one week doing that whole thing, and this is kind of teaching you the theories but not like I don't, it's hard to explain, with the numbers and stuff in it. So, it's teaching you the way of thinking, I guess, without making it seem as difficult. If that makes sense.

Discussing Creativity

There were two subcategories for students discussing creativity: surprise that math can be creative and value of the creative approach. For example, Ann stated, "I think it's different because it's the first class I've taken that tells you that math can be creative instead of just logical. You needed it for practical things, not creativity." Many students had initial thoughts of creativity as art, photography, film, or other endeavors not generally associated with science or mathematics. In general, students believed mathematics to be rule-based, logical, and formula-driven, so they were surprised when they were encouraged to be creative.

Students found that an emphasis on creative approaches stimulated new ideas, allowing them to look at things differently and be less afraid to try something different. They claimed that the creative activities helped them remember what they had learned. Many remarked that younger learners tend to get more creative opportunities in math, but that diminishes in middle and high school. Corey further explained:

> They are more pushing creativity than like getting a solid right answer using the right formula...I've taken Calc so always have to memorize things always have to get the right answer in order for me to get credit. So it is definitely different. Because as long as you are being creative, like supporting how are you getting an answer, it is acceptable...But once you get going and like you said, be creative and thought out of the box helps me become more creative. Because I am very like, I have been learned to go straight forward, use these problems, get the right answer and you're done. Whereas now it's pushing me to like think outside the box and that's not something I am used to.

Implications for Teaching Practice and Further Research

This study was based on a first attempt at implementing our newly developed course modules. Our plan is to revise our modules based on our results and implement them once more in several sections of the general education course. The results of our pilot study thus far, however, have indicated changes to students' conceptions about mathematics. The study has potential to inform the curriculum of other mathematics courses for non-majors. Namely, the preliminary results indicate that a deliberate attempt to encourage creative thinking among students can influence their confidence, broaden their thinking about mathematics, and even guide their career choices. These traits are especially relevant for non-mathematics majors, who will most likely not take additional mathematics courses.

We are currently implementing the course modules in a similar course (for non-mathematics majors) at our local community college and also in a first-year seminar course for mathematics majors at our institution. The aim of the implementation in the latter course is to expose students to a new way of thinking about mathematics as they begin undertaking the mathematics course sequence. Our continuing research is expected to further elucidate the impact of our instructional strategy on various populations of undergraduate students.

Discussion Questions

1. What is the place of mathematics content in a course that promotes creative approaches to mathematics (and other disciplines)?
2. How can mathematics courses for majors embrace creativity?
3. How do you assess creative approaches to mathematics?
4. What research would help practitioners consider this teaching innovation?

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