Welcome Question

- What does it mean to be creative in math?
- When do you feel you were/are creative in proof process?

How can we (or should we) assess undergraduate students' creativity?

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Outline

- Background Literature
- Research Questions
- Methodology
- Results
- Future Research

Background Literature

- Mann (2006) stated, "in seeking to facilitate the development of talented young mathematicians, neglecting to recognize creativity may drive the creatively talented underground or, worse yet, cause them to give up the study of mathematics altogether" (p. 239)
- Studies of K-12 Creativity (e.g., Silver, 1997; Leikin & Lev, 2013)
- Sriraman (2009) interviewed mathematicians on creativity (particularly the insight stage) in their own research
- Sriraman (2005) stated that K-12 creativity is naturally different than creativity from mathematicians
- Zazkis and Holton (2009) discussed creativity in undergraduate mathematics using problems in many different content areas

Research Questions

- How do mathematicians define creativity in mathematics?
- What is creativity with regards to the proving process?
- Can we (or should we) value and/or assess undergraduate students' creativity in proof?

Methodology

- Conducted interviews with 6 research mathematicians
  - 3 males, 1 female from one university
  - 2 males from another university
  - Different mathematical backgrounds (Algebra, Analysis, Differential Equations)
  - Varying in years of experience
- Two parts:
  - Open-ended interview questions
  - An task-based activity assessing creativity in proof

Sample Interview Questions

- What does it mean to be creative in math?
- When do you feel you were/are creative in proof process?
- Do you think students' need to be or should be creative?
- Do you require or expect your students to be creative?

Definitions of Creativity

According to the mathematicians, creativity in mathematics is

- Flexibility (Silver, 1997) - An ability to look at a problem from new perspective
- Originality (Silver, 1997) - Using an unexpected or unusual approach
- Fluency (Silver, 1997) - Applying ideas, tools of one area in a different area
- Insight (Wallas, 1926; Savic, 2012) - A spark in the creation of mathematics

Definitions of Creativity, cont.

- I think the definition of creativity is approaching a problem from a different perspective or with different tools. (Dr. E)
- it is an ability to see something from a new perspective, and ability to interpret things in a new way instead of start moving in the new direction. It is primarily to look at things differently. (Dr. F)
- "[S]ome kind of idea or approach that no one ever thought of before." (Dr. C)
- "Which trick to use at which juncture." (Dr. D)

Creativity in Proving

- Coming up with novel ideas
  - "[Creativity] usually happens when you understand what is going on, sort of the revelation moment." (Dr. F)
- Pinpointing the key idea
  - "Somehow able to pinpoint the key idea, so that's part of the creative process. What do I need to do in order to make that step so the rest of it is downhill?" (Dr. B)
- Errors or mistakes in approaching the proof
  - "If it did happen [the idea being incorrect], then it is creative in some sense because exploring a wrong answer helps." (Dr. A)

Can we expect students to be creative?

- For two mathematicians, it is dependent on the course
  - "I don't think [students in Calculus] want to be very creative. My impression is, they just like to learn this, they don't want to become mathematicians; they don't want any fun or joy or anything…Upper level classes it is different. They should get to see something, the spirit of math, it's a big part of math." (Dr. A)
- For two different mathematicians, courage is necessary for students to be creative
  - "One of the big barriers that I see with students is if they can't see how whole thing's going to go from start to finish, they have hard time just jumping in and trying." (Dr. D)

Can we expect students to be creative? (cont.)

- One mathematician believes in giving partial credit for creativity in an incorrect student proof.
  - "I've seen some wrong solutions of students that I still feel creative…I give a lot of partial credits for that." (Dr. E)
- Alternately, another mathematician regards validity higher than creativity.
  - "Although, if I were to grade them, I would grade the correct boring proof higher than the original proof that has an error…But, I would put a note saying that I like your originality." (Dr. F)

Three Proofs

- Please take a moment to glance at the three proofs on the handout.
- What is creative about the proofs, and which one is more creative?
- The mathematicians utilized a creative thinking rubric from the AAC&U's assessment on students' essay writing (Rhodes, 2010)

Evaluation of Creativity in the Three Proofs

- Proof 1 – not necessarily creative
- Proof 2 – creative
- Proof 3 – creative

Evaluation of Creativity in the Three Proofs, cont.

- Three mathematicians stated that the first proof would be perfect if the goal of the section was to learn proof by induction.
  - "I would be happy to get that answer (proof 1) from my students when I teach induction." (Dr. E)
- However, one mathematician believed that, although the other two proofs were more creative, they would not be useful.
  - "These are very clever and it's enjoyable to read it and it's a kind of thing you could publish in a column of a magazine or something because it's so much fun. But it doesn't help you much as a working mathematician." (Dr. A)

Evaluation of Creativity in the Three Proofs, cont.

- Three mathematicians wanted to see the students' proving processes behind each of the proofs to utilize more rubric categories
  - I: Would you think that more of these rubric categories could be found in the process behind each of these?
    A: Sure.
    I: ok and how?
    A: how?
    I: Yeah.
    A: you'd need more data than that, you need to look at [the proving process] and analyze it . . And generalize things that you see people doing over and over again.

Ideas on How to Teach Creativity in a Proofs Course

- Group proving in the course
- Reducing the amount of questions in class dealing with computation
- Partial credit and emphasis on creative aspects
- "Big" Projects
- Limitations
  - Creativity on demand is a difficult venture, especially when new material is placed in a test
  - Courses must cover the material, leaving little time for a discussion about creativity in proving

Conclusion

- Creativity is important to mathematicians in their profession.
- In proving, creativity involves finding those "new ideas/ perspectives/connections."
- In the classroom, creativity may be valued, but it is extremely difficult, either because of the curriculum [Calculus], or because of time and content constraints
- Creativity can be found by comparing proofs, but more importantly in the proving process

Future Research

- Utilizing the mathematicians' comments while grading creativity with the AAC&U rubric, coupled with a mathematics creativity rubric (Leikin, 2009), we would like to create our own creative proving rubric.
- With Dr. Gail Tang, we are currently creating a transition-to-proof course with many questions requiring creative solutions (e.g., Zazkis and Holton, 2009).
- For research purposes, we will assess students' creativity using our new rubric.

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THANK YOU ALL!

- Questions/Comments?
- If we cannot answer a question today, or if you have an idea, please feel free to email us at savic@ou.edu or gulden.karakok@unco.edu.