EXPLORATION OF UNDERGRADUATE STUDENTS' AND MATHEMATICIANS' PERSPECTIVES ON CREATIVITY

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Background Literature

- Definition of Creativity
  - Mann (2005) stated that there are over 100 definitions of mathematical creativity
- How do you even try to find what the definition of creativity is?

Background Literature

- By interviewing mathematicians!
- Claparède and Flournoy (1902)
- Hadamard (1945)
- Sriraman (2009)
- Borwein et al. (2014)

Background Literature

- Product (Runco and Jaeger, 2012) vs. Process (Balka, 1974; Torrance, 1966)
  - Pelczer and Rodriguez (2011) pointed out that "it is important that when judging the creativity of a student we pay attention also to the process by which he[/she] arrived to the results and not only to the final problem" (p. 394)

Background Literature

- Relative vs. Absolute Creativity (Vygotsky, 1982; 1984)
  - This definition acknowledges that students "have moments of creativity that may, or may not, result in the creation of a product they may, or may not, be either useful or novel" (Liljedahl, 2013, p. 256).
- Difference between K-12 and Mathematicians' Creativity (Sriraman, 2005)
- Many research has been done on K-12 mathematical creativity

Research "Needs"

- Due to the previous literature, there are still needs to
  - understand mathematicians' perspectives of creativity in teaching and learning of mathematics in the undergraduate level, and
  - investigate the mathematical creativity of undergraduates.
- We attempt to answer both by interviews and coding interviews using a Creativity-in-Progress Rubric (CPR) on Proving.

Methods – Interviews

- Interviewed 6 mathematicians in two different universities (X, Midwest R1 and Y, West R2)
  - Diverse in research area
  - One female, Five males
- Interviewed 8 undergraduate students from a discrete mathematics course at University X
  - Two females, Six males
  - Diverse in grade, ethnicity and race

Methods – Interviews

- Mathematicians
  - Asked a set of questions such as "How do you define mathematical creativity in proving?" and "How do you teach mathematical creativity in undergraduate courses?"
  - Given a set of mathematical creativity definitions to comment on
  - Given a set of three proofs (from Birky et al., 2011) of the theorem, "If $n \geq 3, then\ n^3 \geq (n+1)^2$.

Methods – Interviews

- Undergraduate students
  - Asked a set of questions such as "How do you define mathematical creativity in proving?" and "How do you think mathematical creativity in undergraduate courses should be taught or graded?"
  - Given a set of three proofs (from Birky et al., 2011) of the theorem, "If $n \geq 3$, then $n^3 \geq (n+1)^2$.

Methods – CPR

- The CPR on Proving (Savic et al. 2014) has three different categories:
  - Making connections - demonstrating links between multiple representations and/or ideas from the student's current and/or previous course(s).
  - Taking risks - approaching a proof and demonstrate flexibility in using different or multiple approaches.
  - Creating ideas - developing original mathematical ideas that are either pertinent to the proof or can be proven.

Methods – Coding

- Two of the researchers coded transcripts separately using the CPR on Proving categories
- The two researchers came to an agreement on the coding
- They then presented it to the rest of the group for mutual full agreement

Results - Mathematicians

- Making Connections
  - Somehow your mind has to spread out a little bit to see connections, connections to other theorems you could use . . . That's creativity also. – Dr. A
  - I think when students realize that they can solve these problems with things that are not just in this section. It can be from some other part of the course. Be somewhat creative. You are encouraged to use everything you know. – Dr. LS

Results - Mathematicians

- Taking Risks
  - [Y]ou're saying, “there is this problem, and I'm going to try this approach. And this approach, I don't even know what the next step should be.” So I think the creativity part of it affects the proof differently. – Dr. B
  - I think the creativity comes in thinking about which technique to use, what is it that you’re going to do next. You are trying to figure something out. – Dr. D

Results - Mathematicians

- Creating Ideas
  - So I was working on that and there was an implication that the colleague had proved, A implies B. And it occurred to me...is the converse true? Does B also imply A? … And then I proved it. And that was a great moment. Because it was some new discovery. But the actual creative moment was not the carrying out, … [b]ut having the idea was the spark. … It's that initial moment that is the creative part – Dr. A
  - [Proofs 2 and 3 from Birky et al. (2011)] are both non-routine thinking. I like both of them. I'm not sure if I would be able to come up with any of those two proofs because it requires some unexpected ideas. – Dr. DA

Results - Students

- Making Connections
  - I would have tried to do something similar based on other things we'd proved like this. – S10
  - The creativity would be using the rules that I can hold, tangible rules that are easily, relatively easily proven – S15

Results - Students

- Taking Risks
  - Creativity in math would mostly be trial and error… – S28
  - So you have a proof to do – there's sometimes, you know, tons of different ways to do it, and to be creative is when, you know, you don't just use the simple one necessarily, but uh – uh think of something else. – S11
  - Most people would think induction, but they're like "okay, I'll try to think of another way" – S16

Results - Students

- Creating Ideas
  - Another aspect of being creative is that you have a theorem and then there's different things – different implications of that theorem you can think about… all the what if's. When you go down those roads, that's being creative. – S11
  - Creative [sic] comes down to finding certain ideas to take the uh statement of a uh theorem or a conjecture and just coming up with a strange way to take it down to the solution. – S14

Results

	Creativity Category		
Mathematician	Making Connections	Taking Risks	Creating Ideas
Dr. A	4		3
Dr. B	1	3	6
Dr. C	4		3
Dr. DA	4	1	10
Dr. LS	6	2	3
Dr. D	4	4	2
Total	23	10	27
Percentage	38	17	45

Results

Student	Making Connections	Taking Risks	Creating Ideas
5		3	4
10	1	1	4
11	1	6	6
14			9
15	3	2	8
16		2	2
26			
28	1	3	8
Total	6	17	41
Percentage	9	27	64

Discussion

Percentages	Making Connections	Taking Risks	Creating Ideas
Mathematicians	38	17	45
Students	9	27	64

- Least percentages indicate where mathematicians and students rarely think of when pondering creativity
- Many students and mathematicians believe that "creating ideas" is a sufficient definition, which agrees with the literature (Hadamard, 1945)

Teaching Implications

- Possible teaching implications
  - Talking explicitly about what it means to be creative
  - Emphasize that “making connections” is also a part of mathematical creativity

Future Research

- Teaching discrete mathematics with the CPR on Proving in future classes
- Expanding to other classes

Thank you!

- Anyone interested in any of the project can email us at

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