Teachers' Actions that Foster Mathematical Creativity in Tertiary-Level Courses

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A process of offering new solutions or insights that are unexpected for the student with respect to their mathematics background or the problems they have seen before (Savic et al., 2017)

Mathematical Creativity

Fostering Creativity Literature

General Creativity

- Cropley (1998, 2018) – Nine principles of fostering creativity
- Soh (2000, 2015) – Creativity-Fostering Teaching Index
- Beghetto & Kaufman (2007) – Nurturing Creativity in the Classroom

Tertiary-Level of Mathematics

- Zazkis & Holton (2009)
  - Zaslavsky (1995) – open-ended
  - Shriki (2008) – new definitions
  - Leikin (2007, 2014) – MST
  - Watson & Mason (2005) - Examples

Sriraman's Five Principles for Maximizing Creativity

- **Gestalt**: Opportunities to engage in the four-stage creative process (Wallas, 1926; Hadamard, 1945)...Preparation, incubation, insight, verification
- **Aesthetic**: Teacher valuing solutions that utilize unusual proving techniques, come from diverse topics of mathematics, or make efficient or elegant solutions
- **Free Market**: Creating a classroom environment that allows students to freely input ideas, thoughts, and solutions

Sriraman's Five Principles for Maximizing Creativity

- **Scholarly**: creating a classroom environment "in which students are encouraged to debate and question the validity of… approaches to problems…, be encouraged to generalize the problem and/or the solution, as well as pose a class of analogous problems" (p. 28)
- **Uncertainty**: "Students be exposed to the uncertainty and the difficulty of creating mathematics" (p. 28)

Bridging Theory and Practice

- What pedagogical actions can instructors take to foster mathematical creativity?

Study Design

- Introduction-to-Proof Class (14 students) in Southwestern USA
- Seven students participated in semi-structured interviews
- Instructor (Dr. Eme) used the Creativity-in-Progress Rubric on Proving (Savic et al., 2017) to explicitly discuss mathematical creativity
- Instructor implemented an Inquiry-Based Learning pedagogy in the class

Coding Methods

Hypothesis Coding (Saldaña, 2013)

- Two members of the research team coded the interviews separately and then met to discuss their codes and a consensus on codes was reached
- The two members used leading questions based on the 5 principles to code the interviews.
  - Free Market: Did the course or instructor's actions/teaching promote students to take risks while presenting solutions? Did the course or instructor's actions/teaching create a safe environment for students to take risks?"

Gestalt--Teachers' Actions

- Allow for freedom of time and movement;
- Discuss explicitly that time, effort, and energy are needed to solve problems;
- Assign challenging problems and tasks.

Uncertainty-- Teachers' Actions

- Point out the difficulty and uncertainty of doing mathematics when students are working on challenging tasks;
- Provide affective support to students when they experience frustrations;
- Encourage perseverance;
- Expose students periodically to examples from history to explain that certain concepts took years/centuries to develop.

Aesthetic--Teachers' Actions

- Point out the elegance/novelty/beauty of certain solutions/approaches;
- Point out connections between disparate ideas in problem solving;
- Point out any atypical thinking/solutions;
- Point out simple solutions to complex problems.

Free Market & Scholarly--Teachers' Actions

- Encourage students to present their solutions and approaches;
- Encourage students to defend their solutions and approaches;
- Value students' contributions;
- Not penalize students for trying a different approach and failing;
- Encourage students to debate and discuss the teacher's approaches and the other students' approaches/presentations;
- Elaborate on how these discussions contribute to the process of knowledge building;
- Point out when a student builds on the work of another student;
- Encourage students to make generalizations;
- Allow students to problem-pose.

Teaching Actions

- **Option 1**

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- **Menu: handout**

- **Option 2**

Student Quote

- “I think a lot of it was the way the class was structured and Professor [Eme] gets a lot of credit for that. She very much threw us in there and said ‘sink or swim’. And you know it was ‘I’m here if you need a little guidance but you’re never gonna get an answer from me, so don’t even bother asking for an answer; you know it’s not about the answer it’s about the process.”

Uncertainty-- Teachers' Actions

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- Encourage perseverance;
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Students' Quotes

- "I think also the feedback that Dr. [Eme] would give us on our homework. Cause we would turn it in and we would be able to have multiple submissions of our homework to make sure that we would get the proof right."
- "We had one proof that I worked on pretty much all semester... It appeared on our first exam and then it appeared later on in the course and I just worked on it throughout because I wasn't finding a solution... it drove me a little bit crazy... [I] did it probably a hundred times. Finally, I ended up proving it and when professor [Eme] had reviewed it, she told me that there were nine different ways to prove it and this is not one of them, but it's true and it works, and it's phenomenal. And it was very exciting. It was a creative moment. It took me months to get there but I got there and it was very exciting."

Gestalt--Teachers' Actions

- *Allow for freedom of time and movement;
- Discuss explicitly that time, effort, and energy are needed to solve problems;
- *Assign challenging problems and tasks.

Students' Quotes

- "I think really the structure of the course is what helped to expand on my mathematical creativity when I thought I didn't have any. So, um, and you know the structure of the course meaning, you know the group discussions, the group talks, um the presentations were a pretty big deal."
- "So I think when she … gave us like that reflection of like what it means to be creative, we kind of, she kind of just like told us like 'No proof is gonna be exactly the same. Like none of your proofs are actually gonna be the same as each other and you guys are all gonna come up with different ideas'. And she kind of like helped us, like she never like hindered those ideas. She was like 'Oh, well maybe it can work like this. Maybe it can work like that. You just have to like see'."

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- Point out when a student builds on the work of another student;
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- Allow students to problem-pose.

Student Quote

- “There’s one guy in particular who had a way of coming up with these tricks that just made proofs very efficient. Instead of having ten lines, he would have three and it would be fully proved. And it was really neat.....It was wonderful watching his work.”

Aesthetic--Teachers' Actions

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Discussion

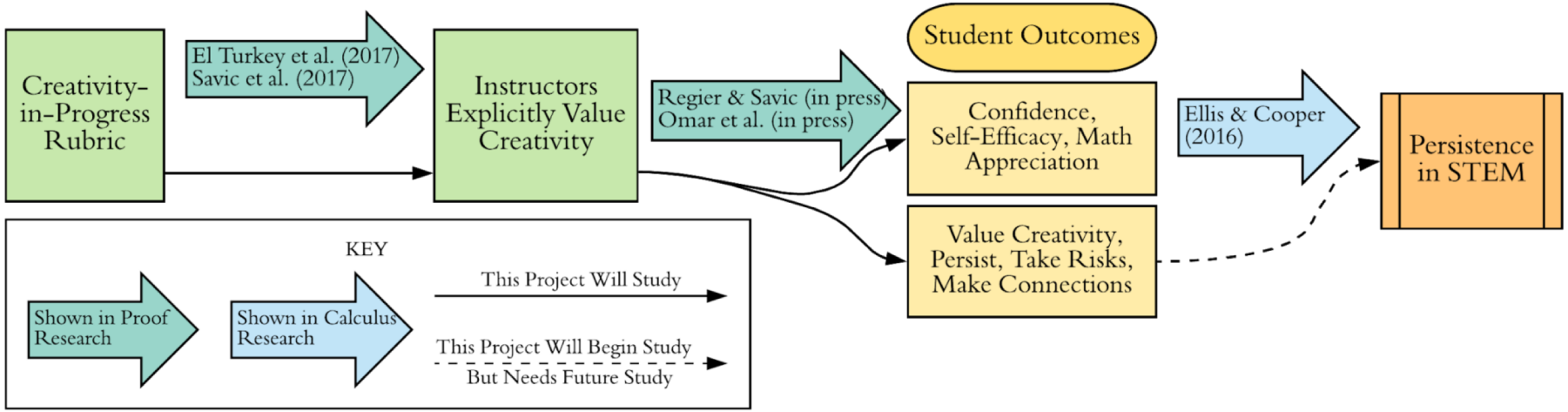
- Dr. Eme, in our coding, did not perform all 20 teacher actions
- These teacher actions alone are not enough to foster creativity
  - Creativity-based tasks

Future Research

- Which actions are most/least important? Is there some minimal spanning set of teacher actions?
  - Is there a least number of practices that one could implement and still see similar results to the classroom presented here?

- What are the effects of creativity-fostering on students?
  - Regier & Savic (2019) – Growth in Self-efficacy
  - NSF Grant (#1836369, #1836371) on Creativity in Calculus and Math Identity

Creativity in Calculus



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Thank you!

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