Fostering Mathematical Creativity in a Classroom and its Effects

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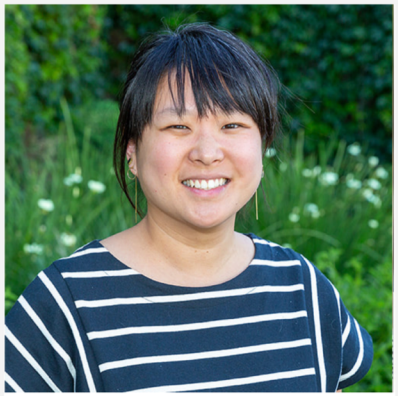
MATHEMATICS

Creativity Research Group



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Encouragement

- Tweet (#UTSACreativity, @msavic13), Facebook, Snapchat, MySpace, AOL IM…
- Take pictures
- Interact
- FUN!

Let's try something…

- Here are four numbers:

15, 20, 23, 25

- Which number is different from the other three? Why? (Think-pair-share activity)
- How many answers can you have?

Goal of "Talk"

Consider how to foster creativity in mathematics classrooms

Demonstrate the effects of students in creative settings

A big idea

WHAT IS MATHEMATICAL CREATIVITY?

Over 100 definitions (Mann, 2006)

A process of offering **new solutions** or insights that are **unexpected** for the student, **with respect to his/her mathematics background** or the problems s/he has seen before (Sriraman & Liljedahl, 2006)

Unpacking that statement

- **A process…**
  - Not necessarily a/the end product
- **…of offering new solutions or insights that are unexpected…**
  - Originality and surprise
- **…for the student, with respect to his/her mathematics background or the problems s/he has seen before.**
  - Relative to the student instead of to his/her peers or mathematics in general

Why creativity?

- World Economic Forum: Creativity is "one of the most important and in-demand skills in the next 5 years" (Schöning & Witcomb, 2017)
- MAA CUPM Guidelines (2015)
- Wolfram Alpha, Slater/Chegg, Artificial Intelligence (Wilson, Lennox, Hughes, & Brown, 2017)

Why Creativity?

- Creativity ⇒ Gain of content knowledge (Leikin, 2014)
- Creativity ⇒ Self-efficacy / Confidence (Regier & Savic, 2018)
- Creativity ⇒ Mathematical Identity (Omar et al., 2018)

How can we foster creativity?

- Tasks that give opportunities
- Instructors' practices and considerations
- Students' practices

How do we foster creativity?

- **Tasks that give opportunities**
- Instructors' practices and considerations
- Students' practices

How to make such tasks?

- Problem-posing (Silver, 1997; Kwon, Park & Park, 2006)
  - Giving people guidelines and letting people pose problems
- The "LEGO" approach
  - Giving people items (definitions, theorems, OR ACTUAL LEGOS) and allowing people to construct their own mathematics (or, in general, their own ideas)
- Lesson unplanning (Beghetto, 2017)
  - Working backwards from mathematical situations

What happens with such tasks?

- Power and authority of mathematics
- A person's freedom and (perhaps) identity
- Low entrance, high capacity

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Another Task

Is there an example in real-life of a perfect circle?

Items to consider

- I purposefully did not give an example, because…
- I had very open-ended prompts that were situated in the mathematics, because…
- I did not (or tried not) to place judgment on replies to my prompts, because…

Five principles

- Sriraman (2005) conjectured five principles for fostering mathematical creativity in K-12 classrooms:
  - Gestalt – Taking incubation breaks
  - Aesthetic – showing the beauty of math
  - Free Market – allowing people to take risks
  - Scholarly – building off of people's work
  - Uncertainty – being comfortable not knowing
- Seen in business situations (e.g., Amabile, 1996)

Self-efficacy

- One's beliefs about their own ability to accomplish a given task (Bandura, 1997)
- Highly predictive of general academic performance (Bouffard-Bouchard, Parent, and Larivée, 1991)
- **Better predictor of mathematical performance** than *mathematical ability* or *prior experience with mathematics* (Siegel, Galassi, & Ware, 1985; Pajares & Miller, 1994)

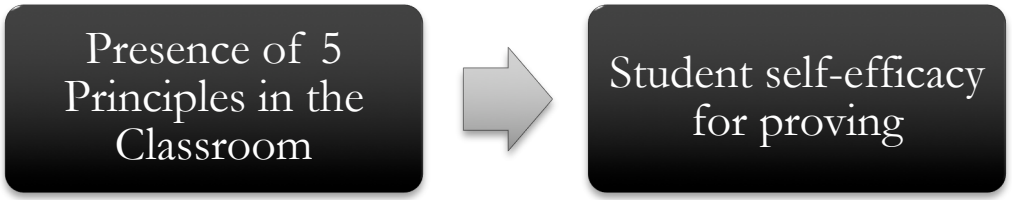
How do we gain self-efficacy?

Four primary sources of self-efficacy information (Bandura, 1997):

1. **Enactive experiences**: One's own success in accomplishing a given task.
2. **Vicarious influences:** Observation and self-comparison of someone else's competencies
3. **Verbal persuasion:** Direct verbal appraisal of one's ability by someone else
4. **Physiological reactions:**
    - feelings of strength and stamina (Positive)
    - Physical/emotional stress or fatigue (Negative)

Research Question

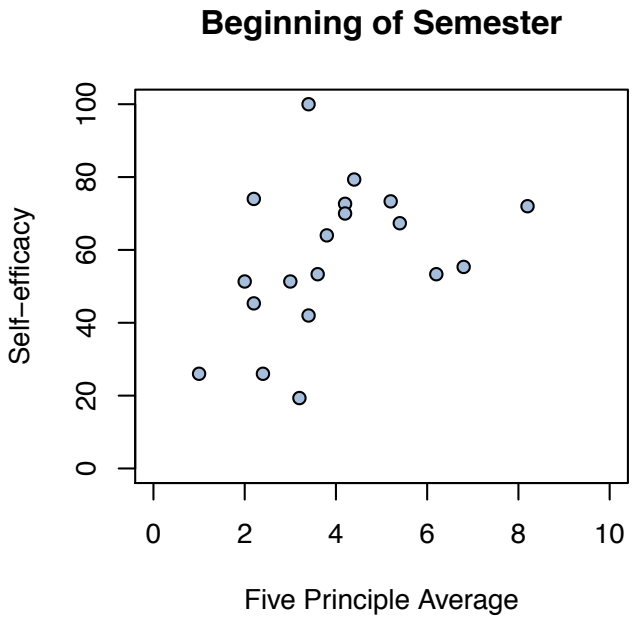
- How does classroom presence of Sriraman's (2005) **five principles for maximizing creativity** impact **student self-efficacy for proving**?

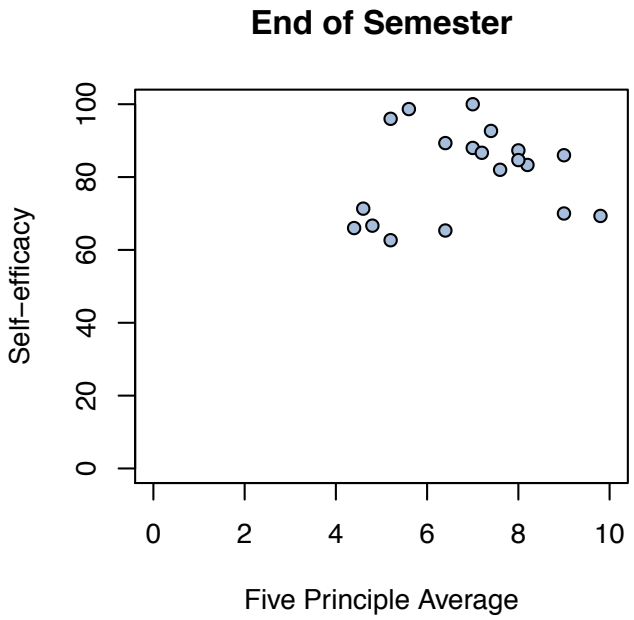


Methods

- 2 Discrete Math classes utilizing Inquiry teaching at a Large Midwest Research 1 University
- Summer 2017 – Dr. A – 20 students
  - Observations: video taped 2 weeks of class (50 min, 5x/week)
  - Online surveys: 8 students
  - Interviews: 2 student
- **Fall 2017 – Dr. Z – 32 students**
  - Observation: video taped every class (50 min, 3x/week)
  - **Online surveys: 22 students (pre- and post-semester)**
  - **Student interviews: 4 students**

Self-efficacy vs. Principles Average (n=22)





pre-post T-test:

Self-efficacy
p-value = 3.626e-05

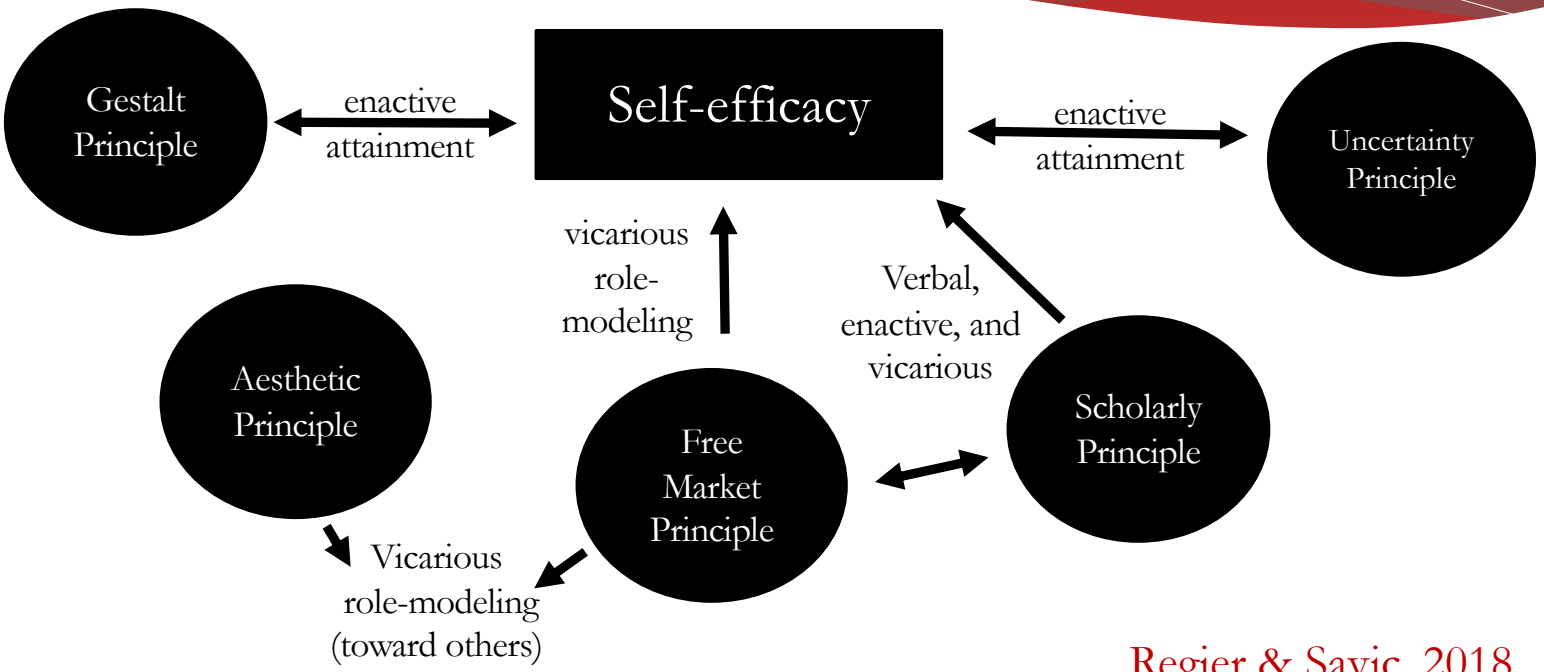
Principle Average
p-value = 8.973e-07

Scholarly + Free Market -> Vicarious Role-Modeling

I: What in class contributed to your building confidence?

Fannie: The general environment of everyone not being afraid to fail. Just generally understanding that **my peers weren't going to judge me for doing something wrong** was really refreshing. And definitely having that **time to work with other people was really important, because everyone kind of had their own perspective or their own different take on the problem**.. like there are **multiple different ways that were correct like solve it, but like someone next to you might of had like a different idea about it that's just as correct as yours.**

Potential Implications



Regier & Savic, 2018

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- **Students' practices**

Students' Perspectives

- Metacognition (Schoenfeld, 1992)
  - Definition of creativity as a process, and people realizing that process
  - "Creative actions might benefit from meta-cognitive skills and vice versa, regarding the knowledge of one's own cognition and the regulation of the creative process" (Katz and Stupel, 2015, p. 69)
- How were you thinking when you answered the number problem? The perfect circle question?

CPR on Proving

- Creativity-in-Progress Rubric (CPR) on Proving (Savic et al., 2016; Karakok et al., 2016)
- Focused on fostering creativity in the proving process
- Two major categories:
  - Making Connections
  - Taking Risks
- Created with the intention as a research tool, then teaching tool, and now a student/teaching tool
- Implementations: El Turkey et al., (2018); Omar et al. (2018)

CPR on Proving

MAKING CONNECTIONS:

	Beginning	**Developing**	**Advancing**
Between Definitions/Theorems	Recognizes some relevant definitions/theorems from the course or textbook with no attempts to connect them in their proving	Recognizes some relevant definitions/theorems from the course and attempts to connect them in their proving	Implements relevant definitions/theorems from the course and/or other resources outside the course in their proving
Between Representations[1]	Provides a representation with no attempts to connect it to another representation	Provides multiple representations and recognizes connections between representations	Provides multiple representations and uses connections between different representations
Between Examples	Generates one or two specific examples with no attempt to connect them	Generates one or two specific examples and recognizes a connection between them	Generates several specific examples and uses the key idea synthesized from their generation

CPR on Proving

TAKING RISKS:

	Beginning	**Developing**	**Advancing**
Tools and Tricks[2]	Uses a tool or trick that is algorithmic or conventional for the course or the student	Uses a tool or trick that is model-based or partly unconventional[3] for the course or the student	Creates a tool or trick that is unconventional for the course or the student
Flexibility[4]	Begins a proof attempt (or more than one proof attempt), but uses only one approach	Acknowledges and/or uses more than one proving approach, but only draws on one proof technique	Uses more than one proof technique
Posing Questions	Recognizes there should be a question asked, but does not pose a question[5]	Poses questions clarifying a statement of a definition or theorem	Poses questions about reasoning within a proof
Evaluation of Proof Attempt	Examines surface-level[6] features of a proof attempt	Examines an entire proof attempt for logical or structural flow	Examines and *revises* an entire proof attempt for logical or structural flow

Use of the CPR on Proving

- Omar et al. (2018) lecture-based combinatorics course
- 5 assignments
  - 3 routine skill problems (10 points each)
  - 1 portfolio problem (60 points)
- Portfolio Problem:
  - Scratch work (10 points)
  - 3-page (min) Reflection using CPR (35 points)
  - Summary of Results (15 points)

Example of portfolio problem

- Let $n \geq 1$ be an integer. Determine the number of walks in the plane with n steps, starting from (0, 0), with steps of type (0, 1), (0, -1), or (1, 0), given the condition that any such walk cannot intersect itself. Any generalizations if the directions you can move are altered? (Generating functions might help.)

Benefits Visible in Work

- Encouraging Experimentation
- Encouraging Multiple Perspectives
- Balancing Flexibility and Perseverance

Benefits in Problem Solving

- Yeah. I think, I think it [the CPR on Proving] kind of opened my eyes to how I approach problems and gave me kind of ideas for how I want to approach them. You know if I got stuck, I would be like 'OK, I have, I might maybe try' you know, like if I got stuck I'd like try to like either make the connections between examples or make the connections between representations, ...**and the reflection process kind of, over time, helped to refine my problem solving strategies** so I kind of knew when I was spit balling, getting lost and kind of knew when I should probably keep attempting an idea because it was hopefully gonna pan out.

Benefits in Math Identity

- "This was a really hard project for me... I was really proud of myself though. I personally thought up of an idea (the parity of the tilings), and used that to create a cool conjecture. **Even though that conjecture turned out to have been done already, I felt like I made a solid step toward what a career research mathematician would do.**"

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Conclusion

What will you consider about mathematical creativity that you did not know previously?

What did you take out of this talk that you will implement in your tomorrow or in the next twenty years?

Impressions

It must not be forgotten that the basic law of children's creativity is that its value lies not in its results, not in the product of creation, but in the process itself. **It is not important what children create, but that they do create, that they exercise and implement their creative imagination.** (Vygotsky L. S., 2004, p. 72)

THANK YOU UTSA!

Thanks to Carolyn Luna for asking me to talk.
Thanks to you for attending.

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