Reshaping Mathematical Identity by Valuing Creativity in Calculus

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“It is shocking to me that the creativity involved in math is often overlooked…A professor at my school is dedicated to integrating creativity in her coursework to ensure students are engaged and excited throughout the entire course. It was in her course that my interest into the topic of number theory grew.”

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 2015 Guidelines**
  - A successful major offers a program of courses to gradually and intentionally leads students from basic to advanced levels of critical and analytical thinking, **while encouraging creativity** and **excitement about mathematics.**
- Creativity ⇒ Gaining content knowledge (Leikin, 2014)
- Creativity is an important aspect of professional mathematicians' work (Borwein et al. 2014)

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 the Definition

- **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

Creativity Literature

- Considerable amount of literature on mathematical creativity at the primary and secondary levels (e.g., Silver, 1997; Lev-Zamir & Leikin, 2011).
  - However, very few studies at the undergraduate level
- Torrance (1966, 1978) created testing for creativity and giftedness in K-12 education
- Silver (1997) expanded three aspects of K-12 mathematical creativity
  - Flexibility - An ability to look at a problem from new perspective
  - Originality - Using an unexpected or unusual approach
  - Fluency - Applying ideas, tools of one area in a different area
- Leikin (2009) created a rubric for high school mathematical problem solving

How do we explicitly value and foster creativity in the mathematics classroom?

Development of the Rubric

- To answer this question, we created a rubric that serves as a formative assessment tool for creativity
- Originally developed as a tool for instructors, we now see it primarily as a tool for students (to promote meta-cognition)
- Multi-level development process:
  - Creativity rubric from AAC&U (Rhodes, 2010)
  - Leikin's (2009) Problem-Solving Rubric
  - Interview with mathematicians (Tang et al., 2015)
  - Constant alpha-testing on students' LiveScribe™ work
  - Feedback from past presentations

Creativity-in-Progress Rubric (CPR) on Proving

- Categories
  - Making Connections
  - Taking Risks

- Levels (Continuum)
  - Beginning
  - Developing
  - Advancing

Making Connections:
The ability to connect the proving task with definitions, theorems, multiple representations, and examples from the current course as well as possible experiences from previous courses.

Taking Risks:
The ability to actively attempt a proof, demonstrate flexibility in using multiple approaches or techniques, pose questions about reasoning within the attempts, and evaluate those attempts.

Properties of the Rubric

- It is NOT assessing "correctness" or "validity" of the final proof
- It is examining the full process of proof production
- It is NOT a rubric to label student's creativity!
- It makes explicit some aspects that may promote mathematical creativity

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CPR on Problem Solving: Reshaping Mathematical Identity by Valuing Creativity in Calculus

CPR on Problem Solving

MAKING CONNECTIONS

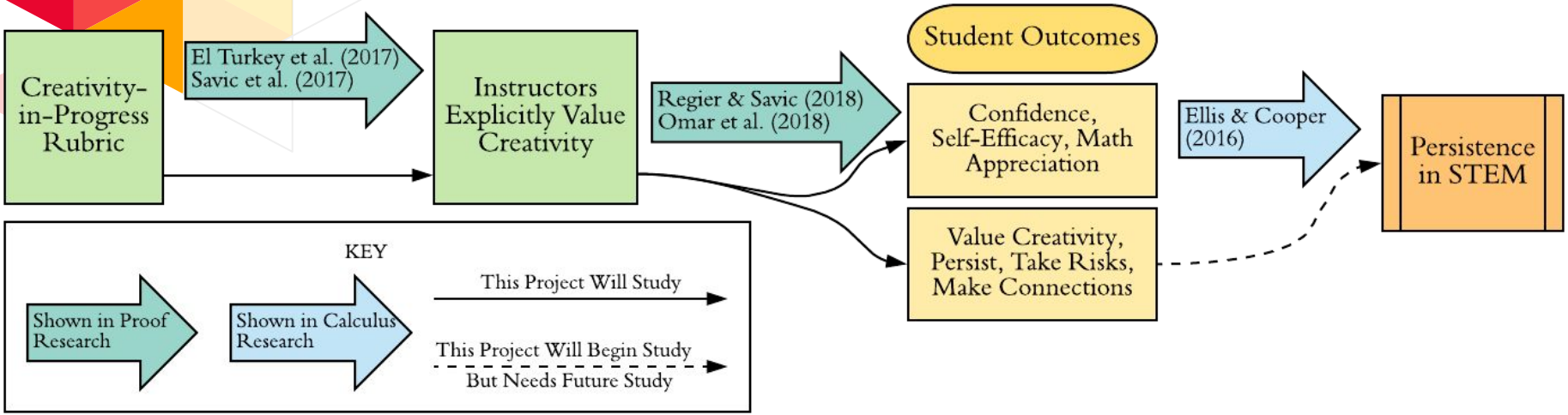
	Beginning	Developing	Advancing
Between Definitions/Formulas/ Theorems	Recognizes some relevant definitions/formulas/theorems from the course with no attempts to connect them in a solution	Recognizes some relevant definitions/formulas/theorems from the course and attempts to connect them in a solution	Uses relevant definitions/formulas/theorems from the course or other resources outside the course in a solution
NA ☐			
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
NA ☐			
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 those examples
NA ☐			
Between Solutions	Attempts to connect multiple solutions to each other	Connects multiple solutions to each other	Connects multiple solutions to each other and generalizes common properties
NA ☐			

CPR on Problem Solving

TAKING RISKS

	Beginning	Developing	Advancing
Tools and Tricks[2]	Uses a tool or trick that is usual for the course or the student	Uses a tool or trick that is partly unusual[3] for the course or the student	Creates a tool or trick that is unusual for the course or the student
NA ☐			
Flexibility[4]	Introduces one solution path	Introduces more than one solution path	Uses more than one solution path
NA ☐			
Posing Questions	Recognizes there should be a question asked, but does not pose a question[5]	Poses questions clarifying a step within a solution	Poses questions about reasoning within a solution
NA ☐			
Evaluation of Solution Attempt	Checks surface-level[6] features of a solution attempt	Checks an entire solution attempt for reasoning	Revises or validates an entire solution attempt for reasoning
NA ☐			

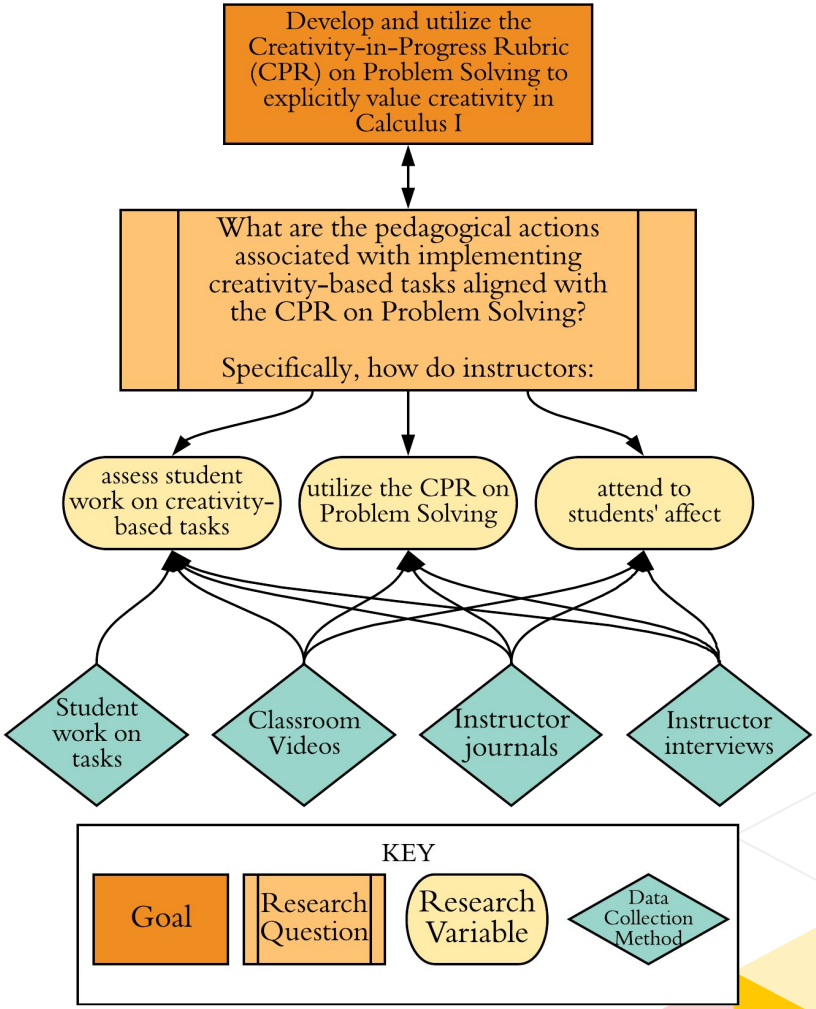
Logic Model

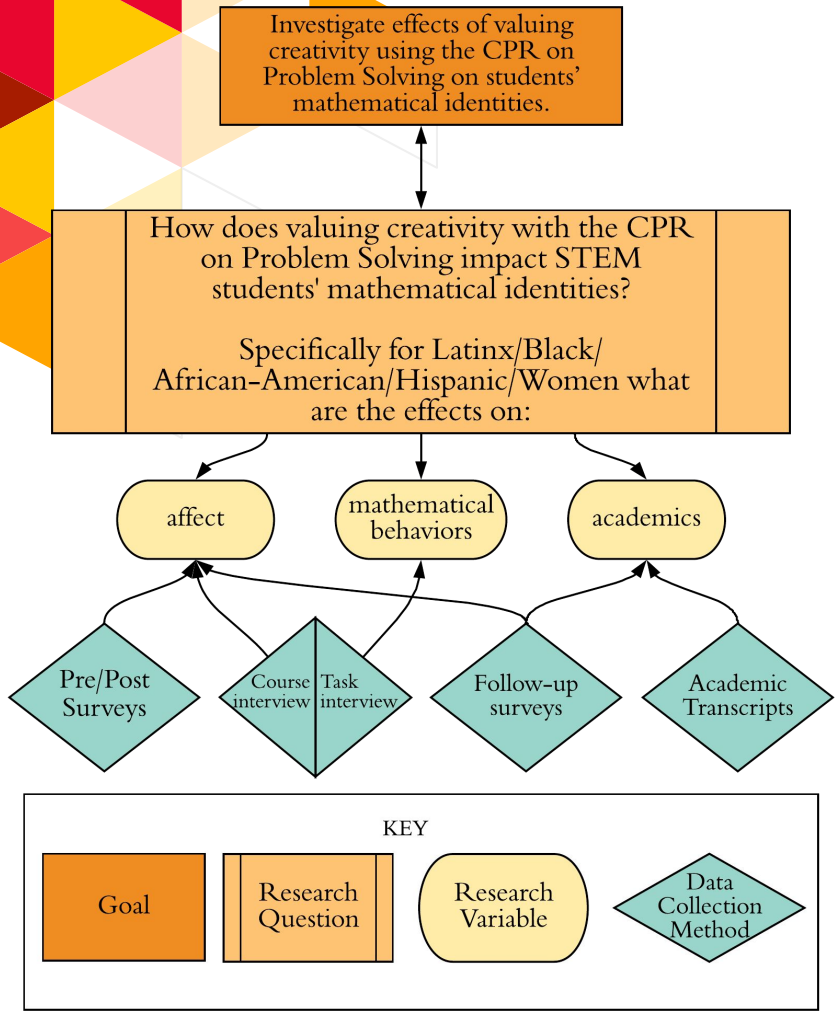

Creativity-in-Progress Rubric
El Turkey et al. (2017)
Savic et al. (2017)
Instructors Explicitly Value Creativity
Regier & Savic (2018)
Omar et al. (2018)
Student Outcomes
Confidence, Self-Efficacy, Math Appreciation
Value Creativity, Persist, Take Risks, Make Connections
Ellis & Cooper (2016)
Persistence in STEM
KEY
Shown in Proof Research
Shown in Calculus Research
This Project Will Study
This Project Will Begin Study But Needs Future Study

Project Goals

1. **Develop and utilize the Creativity-in-Progress Rubric (CPR) on Problem Solving to explicitly value creativity in Calculus I.**
    a. large and visible impact on the perseverance of STEM students from all demographic groups
    b. assessment of creativity-based tasks.
    c. examining how instructors employ the rubric, as well as pedagogical actions they use to attend to their students' affect throughout the course.
2. **Investigate effects of valuing creativity using the CPR on Problem Solving on students' mathematical identities.**
    a. Measures include affect (e.g., confidence, self-efficacy, and math appreciation) mathematical behaviors (e.g., valuing creativity, persistence in problem solving, taking risks, and making connections), and academic choices in their future.

DATA COLLECTION: INSTRUCTOR





DATA COLLECTION: STUDENT

Tasks that Promote Creativity

- We provide 2 out of 6 tasks to instructor participants
  - Based on creative task design principles (Beghetto, 2017; Levenson, 2013; Sriraman, 2005)
- Instructors create 4 tasks
- Task design supported by online professional development

Task: Consider the limit $\lim_{x \to 1} \frac{\sqrt{x}-1}{x-1}$:

(a) (Intro to limits) Conjecture the value of this limit using a numerical approach

(b) (Limits) Evaluate the limit in two ways, e.g.

  i. by factoring

  ii. using the conjugate

(c) (Derivatives) This limit is the slope of a tangent line to a function $f(x)$ at $x = a$.

  i. What is $f(x) =$ and $a =$?

  ii. Compute $f'(a)$ in two ways

  iii. Find the equation of this tangent line

  iv. Graph $f(x)$ and draw this tangent line

(d) (L'Hospital's Rule) Apply L'Hospital's rule to find this limit.

Research Sites

- Spring 2019
  - University of Oklahoma
  - University of Central Oklahoma
    - 4 instructors teaching over 200 students
- Fall 2019
  - University of La Verne
  - Cal Poly Pomona
- Spring 2020
  - 6 instructors recruited nationwide

Thank You!

Questions?

If you are teaching calculus in Fall 2019 or Spring 2020 and want to be an instructor participant, contact me at:

- ecilli-turner@laverne.edu
- www.creativityresearchgroup.com

Implementations of the Rubric

How can the rubric be used in a classroom environment?

- Data collected in three different courses
  - Teachers' impressions (diaries, goals, interviews)
  - Teachers' instruction (Livescribe™ data, notes, video)
  - Students' impressions (online survey, interviews, homework)
- Coded teacher actions then student data used to corroborate effectiveness of teacher action

Described further in El Turkey et al. (2017)

Implementation I

- 6 students, Number Theory course, Fall 2015
- Dr. X explained the rubric in one class period (third week)
- Led discussion by asking about subcategories in CPR
- Had co-constructions of proofs in class, and would refer to the rubric to push proving further

- Students were formally asked to use CPR five times in the course
  - Homework as an evaluation tool
  - During the final for extra credit

Implementation II

- 18 students, Combinatorics course, Spring 2016
- Primarily lecture in class
- Used rubric for “portfolio problems”
  - “much more involved, and the intention is to allow freedom to roam with it in any direction you wish.”
- One portfolio problem worth three exercises
  - Minimum 3-page essay summarizing the proving process the students used
- Included open problems in Combinatorics
- Students said “I felt like a mathematician”

- Discussed further in Omar et al. (2018)

Implementation III

- 15 students, Transition to proof course, Spring 2016
- Taught using Inquiry-Based Learning
- Utilized rubric language before introducing CPR
- Reflections throughout the course asking about mathematical creativity

- Showed an attempt from a previous course and had students in group discussion evaluate the students' work using CPR
- Also had a question on exams about using the rubric to evaluate a proof attempt