



# Creativity-in-Progress Rubric on Proving v2.0

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## Background Literature

There are two different perspectives of mathematical creativity: a creative product (Runco & Jaeger, 2012), or a creative process (Guilford, 1967). For either perspective, one must ask, "For whom is the product or process creative?" This question yielded the discussion of two different perspectives on creativity: relative and absolute. Relative creativity is mathematical creativity that is relative to the person and their background in mathematics (Vygotsky, 1982, 1984), whereas absolute creativity is creativity that is recognized in the mathematical field. Our research is focused on the relative process of undergraduate students' creativity in proving. This investigation addresses a gap in the existing undergraduate proof literature.

## Creation of the Rubric

Our research group used four different sources to create the Creativity-in-Progress Rubric (CPR) on Proving: past mathematics education research on creativity (e.g., Silver, 1997; Leikin, 2009), interviews with mathematicians about their views of creativity (Karakok, Savic, Tang, & El Turkey, in press), student interviews (Tang, El Turkey, Savic, & Karakok, in press), and students' proving processes obtained via Livescribe pens. The first version of the CPR on Proving (Savic, Karakok, Tang, & El Turkey, in press) had three categories, but one of the categories (Creating Ideas) was a by-product of the other two categories, described below the rubric.

There are two categories, Making Connections and Taking Risks, and subcategories for each of the two main categories. For each subcategory, there are three levels. A student's proving process will score anywhere on the continuum arrow for each subcategory.

## Current/Future Research

We have collected Livescribe pen data from four semesters of discrete mathematics (which is considered in both universities as the introduction to proof course), along with student interviews. We are in the process of analyzing the data to examine:

- How much creativity was developed during the course of the semester in the proving process?
- One class was taught using the CPR on Proving as a main aspect of the course. What impression did this pedagogical choice have on the students?
- What aspects of the rubric were the most difficult to attain for students?
- Since the CPR on Proving focuses on the proving process, what does a creative product (or final proof) rubric entail?

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 definitions/theorems from the course and/or other resources outside the course in their proving
Between Representations <sup>1</sup>	Provides a representation with no attempts to connect it to another representation	Recognizes connections between representations	Uses connections between different representations
Between Examples	Generates one or two specific examples with no attempt to connect them	Recognizes a connection between the generated examples	Uses the key idea synthesized from generating examples

TAKING RISKS:	Beginning	Developing	Advancing
Tools and Tricks <sup>2</sup>	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 <sup>3</sup> for the course or the student	Creates a tool or trick that is unconventional for the course or the student
Flexibility	Attempts one proof technique	Acknowledges the possibility of different proving approaches, but no further examination	Acts on different proving approaches
Perseverance	Begins to engage with proving	Continues to engage with surface level features but not with the key ideas	Continues to engage with the key ideas
Posing Questions	Recognizes there should be a question asked, but does not formulate a question <sup>4</sup>	Poses questions clarifying a statement of a definition or theorem	Poses questions about reasoning within a proof
Evaluation of the Proof Attempt	Checks work locally	Recognizes a successful or unsuccessful proving attempt	Recognizes the key idea that makes the proving attempt successful or unsuccessful

## Making Connections

The ability to connect the proving task with definitions, theorems, multiple representations, and examples from the current course that a student is in, and possible prior experiences from previous courses.

## Taking Risks

The ability to actively attempt a proof, perhaps using multiple proof techniques, posing questions about reasoning within the attempts, and evaluating those attempts.

## Uses of the CPR on Proving in the IBL Classroom

We believe that mathematical creativity has more opportunity in an IBL environment, since there is commonly a variation of tasks constantly provided to the student. With carefully chosen tasks, students can dive into their creativity in proving. These tasks might include:

- Proofs that require a good amount of thought, sometimes even needing a "trick" (The proof of infinitely many primes requires both contradiction and a clever number construction)
- Conjectures, posing problems, or allowing open-ended tasks
- Tasks that force thought of the necessity of a theorem's hypothesis
- Students using the CPR on a hypothetical student's proving process

The CPR on Proving was created for instructors' or students' use. For each subcategory, instructors can evaluate their students' proving attempts and decide which part of the continuum the work could be placed. Once trained on how to use the rubric, students can also do this for their own and also for their peers' work. Our intention is that if an instructor or a student evaluates proving attempts, s/he can hopefully see what needs to be improved or worked on during future tasks (attempts).

Also, our suggestion is that the environment must be fostered to examine the proving process more than the proofs themselves. In the proving process, mistakes can occur. One aspect of the environment created is to allow students to understand the source of the mistake and attempt to self-correct. The CPR on Proving, coupled with presentations on proving in the classroom, may allow for those instances to happen.

## References

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*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)