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EXPLORING INTERSECTIONS OF INQUIRY, EQUITY, AND CREATIVITY

CREATIVITY RESEARCH GROUP

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SETTING INFORMATION

- Introduction-to-proof course
- Small university (~5,000 undergrad and grad students) in southwest US
- Hispanic-Serving Institution (HSI)
- Instructor (Tang) is a researcher in the group

STUDENT DEMOGRAPHICS

7 females	5 Latinas	4 math majors	3 traditional-aged	3 first-generation	Junior Junior Junior
			1 unknown		Freshman
		1 biology (degree completed)	1 adult learner	1 first-generation	University Staff
	2 White	1 economics (math minor)	1 traditional-aged transfer	1 first-generation	Junior
		1 math major	1 adult learner transfer	1 first-generation	Junior
7 males	3 Latinos	2 math majors	2 traditional-aged	2 first-generation	Freshman Sophomore
		1 computer engineering	1 unknown	1 unknown	1 unknown
	1 Latino and Hispanic	1 biology (math minor)	1 traditional-aged	1 first-generation	Junior
	2 White and Asian	1 chemistry (math minor)	1 adult learner transfer		Junior
		1 physics (math minor)	1 unknown		Junior
	1 Asian	1 math major	1 unknown		Junior

MOTIVATION

- Vana: I feel like all of us, you know there was some strong students in the class that kept coming up, but then I saw the quieter ones also **get their voice** during the semester (Latina)
- Ahn Pan: Because of the nature of how the course was uh conducted**, it encourages questions**. It encourages um, questioning. It sounds very revolution type, you know **question authority and don't take anything for granted and, you know fight back**. (male, Asian/White)

MOTIVATION

- Peyton: Because of the nature of this course, but when I did finally understand something, I did feel like I had a way stronger, **I had much more confidence in it than I do generally** and I retained the information a lot more. Like I barely even reviewed anything and I still remembered it by the end of the year. (female, White)

STUDENTS' DEFINITIONS OF IBL

- Cargo: I think just having my classmates just **go up and share their work** and their thought process helped me like see things I, I didn't notice. Like even when **I was up presenting**, there was always one guy that would always just keep asking like **"How did you get that?**" And like, because he kept asking that, I kept like figuring out like "OK. I think I should probably put more details into my proofs so like they know like where I'm getting these things." (Latino)

STUDENTS' DEFINITIONS OF IBL

- Alice: She would **assign homework** and then we'd always discuss them in class…being able to have those **class discussions** as well as like our **individual group discussions** that we had in class. (Latina)
- Vana: The instructor was very, um, uh, I don't know if limited is the right word in terms of her involvement in class…[she] kind of sat at the table and more was a **listener and a mediator**, like **a facilitator of our discussions** but she never really led the discussion. So it was a lot of you know **bouncing ideas off of students** and um kind of **evaluating each other's work** in that sense. (Latina)

INQUIRY-BASED/INQUIRY-ORIENTED LEARNING

- "Deeply engage [students] in rich mathematical tasks, [give students] ample opportunities to collaborate with peers (where collaboration is defined broadly)" (Academy of Inquiry-Based Learning),
- "Enable students to learn new mathematics through engagement in genuine argumentation, … empower learners to see themselves as capable of reinventing mathematics, and to see mathematics itself as a human activity" (Rasmussen and Kwon, 2007, p. 190).

SIX MAIN THEMES
COOK, MURPHY & FUKAWA-CONNELLY (2016)

Student Ownership -- students create knowledge

Knowledge Building -- incorporating prior knowledge

Doing Math -- becoming a participant in the mathematical community

Student-Instructor Relationship -- instructors elicit student thinking

Peer Involvement -- exposure to and attempting to understand other's ideas

Student Success – better alignment to how students learn

EQUITY

- Equity teaching promotes a mindset where all students are capable of learning mathematics (e.g., Jett, 2012)
- Instructors bracket prejudices about student participation and achievement levels based on
  - race,
  - gender,
  - social class,
  - proficiency in the dominant language,
  - ethnicity (Gutiérrez, 2002),
  - and other segregating characteristics

EQUITY
GUTIÉRREZ (2009)

- Access: who gets to speak, what tools do students get, what opportunities
- Achievement: grades, future plans, decisions to continue, persistence in STEM, major/minor in Math
- Identity: how the self is positioned in society (how self is raced, classes, gendered; confidence and positive math identity
- Power: distribution of power, what counts as acceptable knowledge, whose voices can be heard, empower students to be agents of change

ALIGNMENT: EQUITY AND INQUIRY

- Access
  - "Equity to me is related to access by all students to opportunities to engage in rich mathematics" (Civil, 2007; p. 56)
  - Inquiry invites and encourages all students' participation in doing, discussing, and presenting mathematics (*Peer Involvement*).
  - When all students are given opportunities to be active participants in the classroom (*Doing Math*), students are given an additional access point to learn

ALIGNMENT: EQUITY AND INQUIRY

- Achievement
  - Related to *Student Success*
    - not only in the classroom, but in future math courses and career decisions
  - Participation in IBL courses does increase student performance as well as other measures related to this definition of achievement (Laursen, Hassi, Kogan & Weston, 2014)

ALIGNMENT: EQUITY AND INQUIRY

- Identity
  - When students are actively engaged with each other and each other's thinking (*Peer-Involvement*), it can lead to a shift in mathematical identity. (Hassi & Laursen, 2015)

ALIGNMENT: EQUITY AND INQUIRY

- Power
  - Opportunities to provide explanations and justifications of their thinking while others attempt to understand the ideas being discussed or presented (*Peer Involvement*), power shifts to the students because they decide on "what counts as acceptable knowledge" (Adiredja et al., 2015, p. 66)
  - The instructor is the primary architect of the problems worked on (Laursen et al., 2011), and when the tasks assigned include problem-posing, students create and solve their own problems (*Doing Math*).

ACHIEVEMENT & STUDENT SUCCESS

- Vana: I would say that [the class] impacted me or **influenced me to continue on to get a complete minor in math**…which was pretty important and kinda neat cause I don't know if I would've considered it before… And it made me wanna develop more of an understanding instead of just taking a class to get it over with for prereq to satisfy a prerequisite…I was able to develop a relationship with math if that makes any sense, … and actually start enjoying it…[The class] built up **my confidence and that I felt like, "yeah I can get a minor in math, why not?" and "Let's do it"**

STUDENT OWNERSHIP & ACCESS

- Luna: [W]ell I'm a really shy person so **I don't really like talking in class and this class I was actually forced to** like, get up. ... Like my group would know like, "do you understand something" ... and then I kinda wanna say no and like, "I'm actually kinda confused on this." And they would, like, taught me like "oh, you would do this" and ... we'd go up on, on the white boards and they'd let me, like, okay like try this. And like, **I was able to understand it cause I was actually doing it at the same time**. (Latina)

POWER & PEER INVOLVEMENT

- Luna: We were kinda like the professors themselves at the same time, like **we were all professors** in there cause we would help each other figure out whatever it was. (Latina)

THE CONJECTURED INTERSECTION

TANG ET AL. 2017

	Access	Achievement	Identity	Power
Student-Teacher Relationship When instructors are enabled to have a deeper understanding of student thinking...	…students are given an access point to learn because this helps instructors identify and address student concerns.	…students' learning, confidence, enjoyment of mathematics, and participation in class may be positively affected.	…they may see students as mathematical learners, which may impact how students see themselves as mathematical learners.	…the power dynamic in the classroom changes since the instructor is concerned with student thinking and not just covering material.
Doing Math When all students are invited to participate in the mathematical classroom community…	…there is an access point to learn since they are given the chance to do, discuss, and present mathematics.	…students may retain more content by participating and building on others' contributions.	…students can reflect on their own mathematical identities as a member of the community.	…power shifts from instructor as the only source of knowledge to students as producers and users of knowledge.
Student Ownership When all students are encouraged to create, generate, and develop their own knowledge...	…there is an access point to learn because they can work in a way that is different from a prescribed manner.	…there may be gains in learning, confidence, mathematics enjoyment, and class participation.	…students can reflect on their experiences to deepen how they see themselves as mathematical learners.	…power shifts because students shape traditionally instructor-led components (pacing and content delivery).
Knowledge-Building When all students are encouraged to use prior knowledge to build new knowledge...	…instructors honor what students already know, encouraging an asset perspective instead of a deficit perspective.	…they add to their own understanding, which may lead to gains in learning, confidence, mathematics enjoyment, and class participation.	…students can reflect on their mathematical experiences because they can see the progression in their construction of knowledge.	…power shifts since the classroom is guided by what they already know as opposed to what instructors assume they know.
Peer Involvement When all students provide justifications while others listen and attempt to understand…	…students are given an access point to learn because they are exposed to other ways of thinking.	…students may achieve together and carry that style of group learning to subsequent courses.	…students' perceptions of their abilities are heightened as they observe how others react to their ideas.	…the power dynamic changes as students lead the class and ask each other questions, as well as asking the instructor.
Student Success Since IBL/IOI can lead to increased student success...	… and broader access to learning for women, men, low-achieving and first-year students.	… students' career choice and course-taking patterns may be affected.	… students may identify themselves as more of a mathematician or enjoy mathematics more.	… distribution of power in the global society may change with a more diversified STEM force.

Table 1: Alignment of Equity and Inquiry

CONCLUSION

- Our table is a first step towards seeing why inquiry (in the sense of Cook, Murphy & Fukawa-Connelly, 2016) intersects with equity (in the sense of Gutierrez, 2009)
- We do not claim that IF you teach inquiry, THEN you will have an equitable classroom

WHAT IS 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 (Savic, et al., 2017)

TEACHING FOR CREATIVITY

Sririman (2005) conjectured 5 Principles to maximize 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

FIVE PRINCIPLES (CONT.)

- Free Market
  - Creating a classroom environment that allows students to freely take risks, input ideas, thoughts, and solutions
- 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 [are] exposed to the uncertainty and the difficulty of creating mathematics" (p. 28)

INQUIRY INSTRUCTION

- Academy of Inquiry-Based Learning: students
  - (a) are deeply engaged in rich mathematical tasks;
  - (b) have ample opportunities to collaborate with peers
- Kuster et al. (2017) describe four components of IOI:
  - (1) Generating student ways of reasoning;
  - (2) building on student contributions;
  - (3) developing a shared understanding; and
  - (4) connecting to standard mathematical language and notation.

RESEARCH QUESTIONS

- What teacher actions or practices in the proof-based undergraduate classroom might foster students' perceptions of mathematical creativity?

- What are some commonalities and differences between Teaching for Creativity and Inquiry Instruction?

DATA COLLECTION

- Teacher's impressions (diaries, goals, interviews)
- Teacher's instruction (Livescribe™ data, notes)
- Students' impressions (online survey, interviews, homework, reflections)

CLASSROOM DISCUSSION

- Xiomara finished demonstrating her proof of the following theorem: "The sum of the squares of two odd integers cannot be the square of an integer."
- **(A)** Gail: Okay everyone look at what you did and compare to what Xiomara did... Questions? Comments?
- Peyton: Is the "two times an odd number, therefore it cannot be a perfect square", is that... is that like a rule that we can use?
- **(B)** Gail: Is it? [followed by an explanation by Xiomara]
- Peyton: Oh no, I just... I got to that point too but I just didn't know to do with it so... [chuckles]
- **(C)** Gail: So do you believe her argument?
- Peyton: Yeah? Yeah, I think so.

CODING GAIL'S ACTIONS

- **(A)** Gail: Okay everyone look at what you did and compare to what Xiomara did... Questions? Comments?
- Creativity: Scholarly and Free Market
- Inquiry: Building on student contribution (2); Developing a shared understanding (3)

CODING GAIL'S ACTIONS

- Peyton: Is the "two times an odd number, therefore it cannot be a perfect square", is that... is that like a rule that we can use?
- **(B)** Gail: Is it? [followed by an explanation by Xiomara]

➢ Creativity: Uncertainty and Free Market

➢ Inquiry: Generating student ways of reasoning (1); Building on student contributions (2)

CODING GAIL'S ACTIONS

- Peyton: Oh no, I just... I got to that point too but I just didn't know to do with it so... [chuckles]
- **(C)** Gail: So do you believe her argument?
- Peyton: Yeah? Yeah, I think so.
- Creativity: Scholarly
- Inquiry: Developing a shared understanding (3)

STUDENT RESPONSES

- Carrie: "**There were times like 'Well I did this proof, but I'm not sure it's right because of this' and she would respond with 'Well, what do you think class?'** And the class would participate in it…And it's just, using each other and building off of each other in the class to build what we need, create, made us creative. It built that creative environment for us."
- Creativity: Uncertainty
- Inquiry: Generating student ways of reasoning (1) ; Developing a shared understanding (3)

STUDENT RESPONSES

- Carrie: "There were times like 'Well I did this proof, but I'm not sure it's right because of this' and she would respond with 'Well, what do you think class?' **And the class would participate in it…And it's just, using each other and building off of each other in the class to build what we need, create, made us creative. It built that creative environment for us.**"
- Creativity: Scholarly
- Inquiry: Building on student contributions (2); Developing a shared understanding (3)

DIFFERENCES?

- Does teaching for creativity and inquiry instruction have any differences?
  - Does IBL/IOI lead to what the teacher desires?
  - How much "freedom of time and movement" does a person have (Gestalt) or uncertainty in an IBL/IOI classroom?

DIFFERENCES?

- "And **I worked on this proof like I said all semester.** It appeared on our first exam and then it appeared later on in the course … And so I went through and did it probably a hundred times. **Finally I ended up proving it and when [Gail] 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.**" - Carrie

DISCUSSION

- There are signs that using the five principles may shed light on the commonalities between Teaching for Creativity and Inquiry Instruction
  - Scholarly and components 2 and 3
  - Free market and components 1 and 3
  - Uncertainty and component 1
  - Gestalt and aesthetic? Component 4?
- We intend to compare/contrast Teaching for Creativity and Inquiry Instruction in terms of teachers' and students' actions.

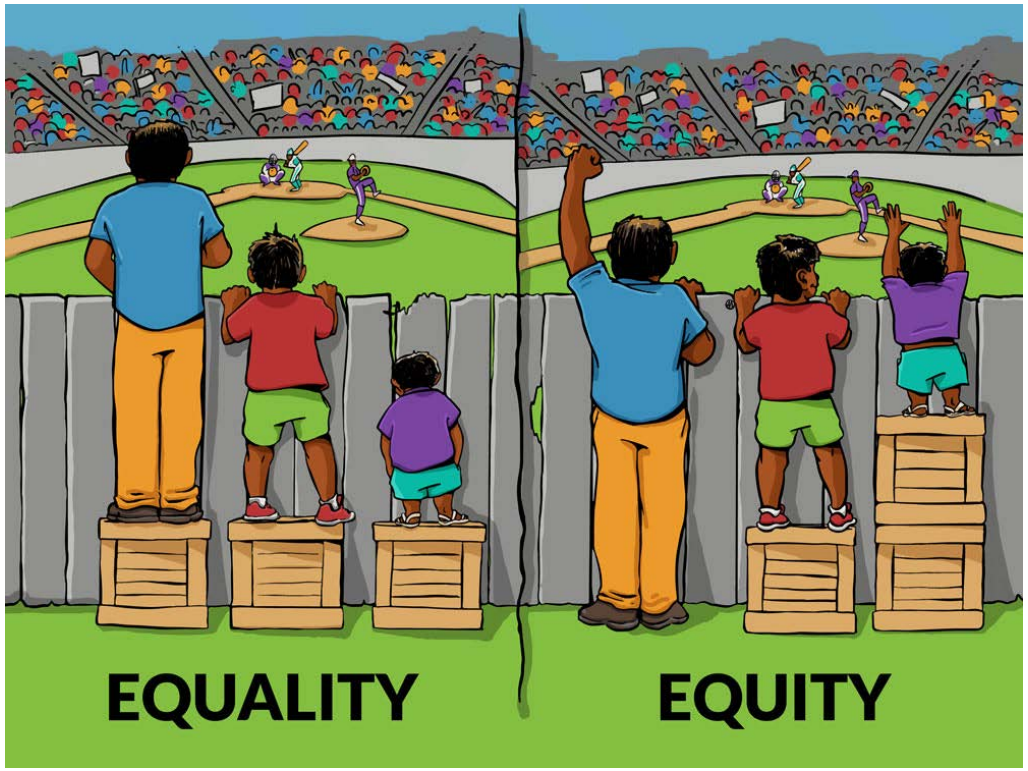
CREATIVITY AND EQUITY

- Seems slightly natural
  - When one creates and is valued for one's own process, then there can be chances to capitalize on power and identity (Gutierrez, 2009)
- Literature is quite sparse on the intersection (Luria, Sriraman, & Kaufman, 2017)
  - "People who endorse racial stereotypes have been found to be less creative… (Tadmor, Chao, Hong & Polzer, 2013). One of the many possible explanations is that endorsing stereotypes (especially potentially negative ones) may indicate a more rigid way of thinking" (pp. 1033-1034).

CONCLUSIONS?

- Our research group sees the potential for the intersection of creativity and equity, but wants to be careful with respect to how equity is researched (Bullock, 2012)
- Inquiry could be a springboard for equity (Tang et al., 2017) and creativity (El Turkey et al., 2017), but is not necessary (Omar et al., accepted)
- Any other thoughts?

EQUITY VS. EQUALITY



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