The 14th International Congress on Mathematical Education
Shanghai, 12th –19th July, 2020

TEACHING MATH VERSUS TEACHING STUDENTS

Gail Tang
University of La Verne

Miloš Savić
University of Oklahoma

Emily Cilli-Turner
University of La Verne

Through participation in a research project on fostering creativity in calculus, two instructors showed shifts in their beliefs on teaching. Participation in the project entailed creating mathematical tasks designed to elicit creative responses from students. Support for task development included participation in weekly online professional development (PD) sessions. Preliminary analysis of one instructor's entrance tickets to the PD sessions and her exit interview indicates that she shifted her previous beliefs about a perceived time pressure. This has major implications for her students since the perceived time pressure is a reason often cited by professors for why they do not engage in more student-centered pedagogies.

Due to the ever-changing landscape of economies and jobs, creativity is a skill that is sought after by employers in STEM fields (Wilson, Lennox, Hughes, & Brown, 2017). As mathematical researchers and instructors, our roles in preparing students depend on our interactions with them, as they comprise the future STEM task-force. Since "the process [of promoting creativity] is influenced by teacher beliefs and biases" (Hershkovitz, Peled, & Littler, 2009, p. 265), positive instructor beliefs regarding the role of mathematical creativity in a course are vital to students' experiences. As part of a larger study, we found that providing Calculus professors professional development (PD) that included opportunities to create, share, and reflect on creativity-based tasks (El Turkey et al., submitted) helped one instructor shift her thinking about a perceived time pressure to cover all content.

Calculus courses at the post-secondary level are packed with content, often leaving instructors with a helpless feeling of racing through the material in order to cover it all. While teaching content is important, so is teaching students to construct examples, generalize, make connections across classes, reflect, pose problems/questions, incubate on problems. Privileging content over reflection has been reported as a "dehumanizing" experience for students and instructors (Gutiérrez, 2018). Indeed, two reasons students cited for dropping their STEM majors is an oversaturation of course content and pacing that inhibits adequate reflection (as cited by Johnson, Ellis, & Rasmussen, 2016). The time pressure that is imposed on both students and faculty have major implications on student success; the perceived time pressure is a reason often cited by professors for why they do not engage in more student-centered pedagogies (Yoshinobu & Jones, 2012). These pedagogies have positive impacts on examination performance (Freeman et al., 2014), conceptual understanding of central ideas, affective traits such as students' mathematical confidence, interest, attitudes, and persistence (Laursen, Hassi, Kogan & Weston, 2014), and social and academic integration into university life (Rasmussen & Ellis, 2013). Thus, helping instructors shift their beliefs about a time pressure can help them engage in more student-centered pedagogies that have been shown to positively impact students.

Belief are "[p]sychologically held understandings, premises, or propositions about the world that are felt to be true" (Richardson, 1996, p. 103). A belief is individualistic; a person with a belief can respect

another person's contradicting belief if they find the opposing belief explained in a reasonable manner (Philipp, 2007). Accepting another's belief is different from changing one's belief, which is a difficult process (Schoenfeld, 2011) because "for an individual to change their beliefs, they need to desert premises that they hold to be true" (Grootenboer & Marshman, 2016, pp. 16-17). Due to the opportunities in PDs to engage instructors in reflecting on assessment, implementation, collaboration, and problem-solving, those experiences are critical in influencing thinking about change (Capps et al., 2012; Enderle et al., 2014; Woodbury & Gess-Newsome, 2002).

DATA COLLECTION AND DATA ANALYSIS METHODS

Two instructors from a South-Midwest regional university participated in a Spring 2019 study on fostering creativity in calculus. We focus on Jo Parker, a white female with 11 years of teaching experience. Instructors attended two 2-day, 2-hour PD sessions in December 2018, uploaded previous semesters' calculus materials, attended weekly online PD meetings, filled out entrance tickets to the PD, and were interviewed after grades were submitted. Most importantly, instructors implemented two creativity-based tasks created by the researchers and created at least four more to use in their classroom. *Creativity-based tasks* could allow for multiple solutions (Leikin, 2014), provide opportunities for students to pose questions/problems then solve their own problems (Haylock, 1997), or are open-ended such that posing questions is necessitated (Kwon, J.H. Park, & J.S. Park, 2006). Instructors video-recorded the classes in which the tasks were implemented. They were encouraged to incorporate the Creativity-in-Progress Rubric (CPR) on Problem Solving (modeled after the CPR on Proving; Savić, Karakök, Tang, El Turkey, & Naccarato, 2017) with each task.

Holistic coding was used on the exit interviews to look for perceived belief shifts or evidence of enacting pre-existing beliefs and coders met together to discuss the shifts. After agreement, we used narrative coding to analyze the entrance tickets and end-of-semester interviews.

BELIEF SHIFT: TIME PRESSURE

The three most prominent themes extracted from Jo's entrance tickets, PD sessions, and exit interviews were beliefs related to *Time Pressure*, *Multiple Approaches*, and *Posing Questions*. In this paper, we show Jo's belief shift in *Time Pressure*. Her alignment of a pre-existing *Multiple Approaches* belief to her classroom practices is discussed in Tang et al. (submitted), so only a cursory treatment is presented along with Posing Questions in the Conclusion.

Jo perceived a lack of time in previous semesters that impacted her capacity to incorporate creativity into her Calculus 1 course: **"[d]uring a 'normal' semester, I typically feel time pressure**, so I didn't make as much of an effort to incorporate creativity activities within the classroom" (exit interview, May 2019). During the semester of her participation, she initially assigned the first few creativity-based tasks outside of class, but then changed the last couple of tasks to be done in class because:

> **I realized that I have time to do them in class**. And I wanted them to do them in class…they worked well together so why not let them utilize their time doing these together? **I have time**. It's really the time dictated and how I did things and our Calc 1 is very packed and since we only meet for three hours a week. **I was very nervous in the beginning** (exit interview, May 2019).

By the end of participating in the grant, she had shifted her thinking about the time pressure. She explained her shift in the exit interview:

> **[a]t the beginning of the semester, I was very nervous about time. Very packed but, who cares - in some sense - I can spend 15 minutes once a week** just saying, "hey do this problem in class" or I can give it to them outside of class and then say, "hey let's come to the board and you all put up your solutions and we can talk about them." I'm much more aware of that.

CONCLUSION

Consistent with Enderle et al. (2014), we showed that teaching beliefs and practices have a reciprocal nature; not only can beliefs influence the promotion of creativity in the classroom, but promoting creativity can shift teaching beliefs. When implementing change, instructors assess students' reactions to the changes and use these reactions to inform them of what is "working" (Woodbury & Gess-Newsome, 2002). In week 10's PD, Jo talked about students' reactions to fostering creativity:

> [O]n Monday, my students-**I'm now behind**, **but they were asking phenomenal questions**-we were talking about increasing and decreasing and then all of a sudden one of the students goes 'well doesn't that show you that you have an absolute min at this point?' 'Heck yes, it does.'…**, they're saying and thinking great things that I don't normally get out of my students**…**they're thinking about things a different way.**"

Referring to semesters prior to project participation as "normal", Jo also commented in her exit interview that she had fewer students come to her office and complain about non-routine tasks compared to a "normal" semester. The reactions and successes of the classroom were reflected on, discussed, and reinforced through the PD for fostering mathematical creativity, which we believe impacted her shift her belief in not having enough time to cover everything in Calculus 1.

As we observed these shifts in beliefs and enacting beliefs, we examined our PD using nine critical features of effective PDs (Capps et al. 2012), which are italicized in the next few sentences. The initial PD (*Total Time*) followed by a semester-long PD (*Extended Support*) provided opportunities for instructors to reflect (*Reflection*) on teaching practices through developing creativity-based tasks (*Developed Lessons*). The research group provided two tasks as models *(Modelling*). Once the tasks were developed with the content in mind (*Content Knowledge*), instructors presented them in the PD and received feedback on the task and implementation (*Transference*). Going through this process of taking risks and creating new ideas is parallel to the creative process mathematicians engage in during problem-solving (*Authentic Experiences*). The participants were presented with the importance of mathematical creativity as posited by mathematicians (*Coherency*). Although the PD sessions touched on all nine of these features, the degrees of engagement in these features varied.

Not having enough time to cover Calculus 1 material is cited as a reason to not engage in student-centered pedagogies; shifting to the belief that there *is* enough time shifting to the belief that there is enough time allowed Jo to use this time to implement tasks and pedagogies to help students think mathematically. This is a monumental step towards helping our students gain the mathematical thinking skills that will prepare them for the future. Our research shows that PD to foster creativity in the classroom can help with such belief shifts.

References

Capps, D. K., Crawford, B. A., & Constas, M. A. (2012). A review of empirical literature on inquiry professional development: Alignment with best practices and a critique of the findings. *Journal of science teacher education*, *23*(3), 291-318.

El Turkey, H., Karakök, G., Tang, G., Regier, P., Savić, M., & Cilli-Turner, E. (submitted). Tasks to foster mathematical creativity in Calculus I. *Research in Undergraduate Mathematics Education*. Boston, MA.

Enderle, P., Dentzau, M., Roseler, K., Southerland, S., Granger, E., Hughes, R., … Saka, Y. (2014). Examining the influence of RETs on science teacher beliefs and practice. *Science Education*, *98*(6), 1077-1108.

Freeman, S., Eddy, S., McDonough, M., Smith, M, Okoroafor, N., Jordt, H., Wenderoth, M. (2014). Active learning increases student performance in science, engineering, and mathematics. In B. Alberts (Ed), *Proceedings of the National Academy of Science, 111*(23). 8410-8415.

Grootenboer, P., & Marshman, M. (2016). The affective domain, mathematics, and mathematics education. In *Mathematics, affect and learning* (pp. 13-33). Springer, Singapore.

Gutierrez, R. (2018). Why we need to rehumanize mathematics. In I. Goffney, R. Gutiérrez, & M. Boston (Eds*.), Rehumanizing mathematics for Black, Indigenous, and Latinx students* (pp. 1-10) Reston, VA: NCTM.

Haylock, D. (1997). Recognising mathematical creativity in schoolchildren. *ZDM, 29,* 68-74.

Hershkovitz, S., Peled, I. R. I. T., & Littler, G. (2009). Mathematical creativity and giftedness in elementary school: Task and teacher promoting creativity for all. *Creativity in mathematics and the education of gifted students*, 255-269.

Johnson, E., Ellis, J. & Rasmussen, C. (2016). It's about time: the relationships between coverage and instructional practices in college calculus, *International Journal of Mathematical Education in Science and Technology*, *47*(4), 491-504.

Kwon, O. N., Park, J. H., & Park, J. S. (2006). Cultivating divergent thinking in mathematics through an open-ended approach. *Asia Pacific Education Review, 7(1)*, 51-61.

Laursen, S., Hassi, M., Kogan, M., & Weston, T. (2014). Benefits for women and men of inquiry-based learning in college mathematics: A multi-institution study. *Journal for Research in Mathematics Education, 45*(4), 406-418.

Leikin, R. (2014). Challenging mathematics with multiple solution tasks and mathematical investigations in geometry. In Y. Li, E. Silver, S. Li (Eds.). *Transforming Mathematics Instruction*. Springer, Cham.

Philipp, R. A. (2007). Mathematics teachers' beliefs and affect. *Second handbook of research on mathematics teaching and learning*, *1*, 257-315.

Rasmussen, C. & Ellis, J. (2013). *Who is switching out of calculus and why.* Paper presented at Annual Meeting of the International Group for the Psychology of Mathematics Education. Chicago, IL: UIC.

Richardson, V. (1996). The role of attitudes and beliefs in learning to teach. *Handbook of research on teacher education*, *2,* 102-119.

Savić, M., Karakök, G., Tang G., El Turkey, H., & Naccarato, E. (2017) Formative Assessment of Creativity in Undergraduate Mathematics: Using a Creativity-in-Progress Rubric (CPR) on Proving. In R. Leikin., B. Sriraman (Eds.), *Creativity and giftedness*: *Advances in mathematics education*. Springer, Cham.

Schoenfeld, A. H. (2011). Toward professional development for teachers grounded in a theory of decision making. *ZDM*, *43*(4), 457-469.

Tang., G, Savić M., Cilli-Turner, E., Regier, P., Karakök, G., & El Turkey, H. (submitted). Shifting pedagogical beliefs into action through teaching for mathematical creativity. In *Research in Undergraduate Mathematics Education*. Boston, MA.

Wilson, C., Lennox, P.P., Hughes, G.& Brown, M. (2017) How to develop creative capacity for the fourth industrial revolution: creativity and employability in higher education. In F. Reisman, (Ed.), *Creativity, Innovation and Wellbeing*. London: KIE Conference Publications.

Woodbury, S., & Gess-Newsome, J. (2002). Overcoming the paradox of change without difference: A model of change in the arena of fundamental school reform. *Educational Policy*, *16*(5), 763-782.

Yoshinobu, S & Jones, M. (2012). The Coverage Issue, PRIMUS, *22*(4), 303-316.