2017

Introduction to the Special Issue on Teaching Inquiry (Part II): Implementing Inquiry

Brian P. Katz
Augustana College, Rock Island Illinois

Elizabeth Thoren
Seaver College, Pepperdine University

Introduction to the Special Issue on Teaching Inquiry (Part II): Implementing Inquiry

Running Head: Implementing Inquiry

Brian Katz
Department of Mathematics and Computer Science
Augustana College
639 38th St
Rock Island, IL, 61201, USA
briankatz@augustana.edu
309-794-8277

Elizabeth Thoren
Department of Mathematics
Pepperdine University
24255 Pacific Coast Highway
Malibu, CA, 90263, USA
elizabeth.thoren@pepperdine.edu
310-506-7452

September 29, 2016

Acknowledgment: The Guest Editors would like to thank the many people who supported this special issue. The authors and referees did tremendous and detailed work to bring these papers to their final forms. The Academy of Inquiry-Based Learning, the Special Interest Group of the MAA for Inquiry-Based Learning (SIGMAA IBL), and the community of mathematics educators in general have provided the energizing environment from which these papers are drawn and to which they are addressed. The Educational Advancement Foundation and Harry Lucas have provided supports that allowed us to grow as educators and leaders. The entire staff of PRIMUS has been a joy to work with, especially Matt Boelkins, who has been an invaluable mentor and guide as we undertook this project. Thank you all. We would also like to thank our families, Mike, Maxwell, Simon, and River, for their patience, understanding, and care during this project.

Biographical Sketches

Brian Katz is faculty at Augustana College; during the development of this special issue, he was an Associate Professor of Mathematics and co-director of the Center for Faculty Enrichment. He received his PhD from the University of Texas at Austin, where he met others interested in inquiry-based learning, including

Elizabeth. His research interesting include students' learning of proof in inquiry environments. In addition to his editorial work with PRIMUS, Brian is an MAA author and editor, serves as the chair-elect for the SIGMAA IBL, and is passionate about offering professional development for instructors interested in using inquiry in their classrooms.

Elizabeth Thoren is a Visiting Assistant Professor at Pepperdine University. She received her PhD from the University of Texas at Austin, where she met Brian and was also introduced to inquiry-based learning. She then spent six years with the Center for Inquiry at the University of California, Santa Barbara where she developed materials for explorations-based courses. She is currently developing inquiry courses for future elementary teachers and other non-majors when she is not distracted by a toddler.

Introduction to the Special Issue on Teaching Inquiry (Part II): Implementing Inquiry

September 30, 2016

Abstract

We provide an introduction to the special issue on Teaching Inquiry, through its motivation and themes, focusing here on Part II: Implementing Inquiry.

Keywords: teaching inquiry, structured practice, adapting materials, course projects, individual gadgets, puzzles, games, example generation, authenticity

Introduction

This editorial is an introduction to Part II of a two-volume special issue on Teaching Inquiry. The work of editing this special issue has been a joy; it inspires us to continue reflecting on our teaching, and we hope the papers included in it will similarly inspire readers.

With our previous editorial (Part I), we joined the larger discussion about teaching with inquiry. We described the impetus for this special issue from

our own experiences, both as graduate students struggling with the transition from school mathematics to research mathematics, and as teachers guiding our own students through this difficult transition. We also made a claim about the importance of equitable access and intentional coherence in course design and cited the contributions of educators, researchers, and our professional organizations to support this claim.

Our contribution to the discussion, up to this point, has emphasized advocacy for inquiry experiences because we and our sources agree that they should be more common. With this editorial, we consider some of the reasons that inquiry experiences may not be completely commonplace yet. Namely, among colleagues who would like to infuse their teaching with more inquiry, we have seen real concerns about doing so; some worry that not all students are capable of participating in mathematical inquiry, some have tried to incorporate inquiry and felt they failed, and others struggle to understand what it would even mean to teach with inquiry.

While we understand some of the sources of the first concern, we believe that all students are capable of mathematical inquiry. From a research perspective in the elementary school context, there is a long-standing conversation about leveraging children's curiosity to teach with inquiry in the classroom [1,5,6], and research is impacting practice at this level. For example, the Mathematics in the City project [9] uses a huge video library to demonstrate that this kind of inquiry is possible in diverse classrooms, such as those in the New York City public school system. This work has been connected to research on undergraduate mathematics education, for example [8], but it does not appear to have penetrated as far into mathematicians' discussions of their practice as teachers. Beliefs about students' capacity for inquiry can support or undermine equitable access; rather than asking if students can participate

in inquiry as we might design it, we must develop strategies that make space in our classrooms for the competencies students bring to us and help them grow. Readers will find strategies (and research resources) for designing courses to start where students enter in the papers of this issue.

Similarly, we see the intentional coherence in well-designed inquiry environments as a powerful tool for responding to the second concern, that of failing when teaching with inquiry. When we, as teachers, subtly frame inquiry as unusual or separate from the rest of our course work, we invite students to resist or disengage; when inquiry is integrated as a consonant part of a course, we teach students that it is a normal part of doing mathematics. Intentional coherence is a challenging goal to meet, but the papers in this issue can help the reader on their journey towards this goal.

In some ways, the third concern subsumes the first two: those who wish to teach with inquiry may not have access to detailed examples of implementations of mathematical inquiry since many mathematicians have only seen it at the level of their own research and have never experienced it as students. As a result, they may not see how the essential elements can be adapted for teaching. The papers in this special issue provide exactly the diverse set of existence-proofs of inquiry classrooms needed to help instructors address these concerns.

Reflecting on the discussion up to this point leaves us with two related questions: what is inquiry, and how do we support its development in students? We have organized the papers in this two-volume special issue around the ways that they contribute to the discussion of these two questions. Part I, entitled "Illuminating Inquiry", focuses on the nature of inquiry, from discussions of its theoretical foundations and generalizations across disciplines to descriptions and analyses of the experience of inquiry from the inside. Part II, entitled

"Implementing Inquiry", focuses on approaches to offering inquiry experiences, from discussions of strategies to change student and instructor behaviors to descriptions and analyses of course design and project structures. Of course, a reader will find insight into both the nature of inquiry and approaches to achieving it in any paper in either part, and each part contains ideas for both instructors who have experience teaching with inquiry and those who are hoping to start.

Implementing Inquiry

Each of the papers in this part of the special issue offers implementation strategies for intentionally building a culture of asking and exploring questions. We have organized the papers around the scale of each implementation.

The first four papers discuss subtle changes to small scale, recurring activities intended to teach students to ask questions in the classroom. We especially encourage readers new to inquiry teaching to read these papers because we believe that these suggestions are particularly approachable as these are the kinds of changes that an instructor could layer onto existing courses. However, we think that an intentionally coherent implementation of these changes would eventually lead to a pervasive shift in habits. The first paper in this part of the special issue, "Ask Questions to Encourage Questions Asked" by belcastro, outlines four kinds of instructor moves that provide students with structured practice intended to make asking questions an automatic habit for students. The second paper, "Turning Routine Exercises into Activities that Teach Inquiry: A Practical Guide" by Dorée, gives an accessible approach to modifying standard textbook questions into springboards for substantial inquiry. The third paper "Teaching Students to Formulate Questions" by

Jensen-Vallin, describes daily pre-class assignments in which students generate questions about readings that are leveraged both to improve understanding and to teach inquiry. The fourth paper, "Puzzle Pedagogy: A Use of Riddles in Mathematics Education" by Farnell, describes how the author uses puzzles to foster a culture of inquiry and curiosity in her own classes.

The next few papers describe interventions at the scale of a course project. While these projects could be incorporated as stand-alone modules, we believe they are probably best implemented when the project and other course goals explicitly support and extend each other. The fifth paper, "Encouraging Example Generation: A Teaching Experiment in First-Semester Calculus" by Wagner, Orme, Turner, and Yopp, shares three accounts of students' experiences with a research intervention designed to teach students to generate their own productive examples. While the intervention described in this paper represents a multi-phase course module, we can also imagine instructors implementing these authors' ideas in a recurring activity like those in the group of papers described above. The sixth paper, "To Each Their Own: Students Asking Questions Through Individualized Projects" by Cook, Hartman, Pierce, and Seaders, offers an adaptable project structure: each student has a personal mathematical object (a "gadget") through which they test out and integrate all ideas in the course. The seventh paper, "Acting Like a Mathematician: A Project to Encourage Inquiry Early in the Math Major" by Camenga, shares an exploratory research project and the integration of the project with a department document entitled "How to be a Great Math Major".

The final papers of this issue offer examples of courses built from the ground up to support and develop mathematical inquiry in students. As a result, these papers focus on intentional and integrated design choices at the scale of an entire course. Significantly, each of these courses provides a context that allows

for play and easy experimentation so that students become authorities in this limited context. The eighth paper, "Using Games to Engage Students in Inquiry" by Byrne, reflects on the author's experience teaching a project-based course where some popular mathematical games serve as contexts for inquiry. The ninth paper, "Teaching Inquiry through Experimental Mathematics" by Pudwell, describes a course in experimental number theory, including details about the scaffolding of expectations to account for students' increasing independence over time. The tenth paper, "A Combinatorics Course with One Goal: Authentic Mathematical Inquiry" by Storm, describes the design and implementation of a course that has student ownership of and responsibility for results as its highest goals.

The papers in this part of the special issue constitute a collection of examples that can help address concerns about teaching with inquiry. However, this work is also likely to generate additional questions, so here we point out connections to those from Part I: Illuminating Inquiry that could address such new questions. First, all of the papers in Part I contain further ideas for implementing inquiry. They give particularly detailed insight into the daily workings of their classrooms [2,11,13,14] and ideas about implementing courses for future teachers [2, 4, 10, 12], a population that is not represented here in Part II. Moreover, they explicitly discuss courses for students not majoring in mathematics [3, 11, 13], revealing connections between mathematical inquiry and inquiry in other disciplines, further clarifying the nature of inquiry. Finally, these papers ground these implementations in research about inquiry in mathematics classrooms, including discussion of the skills and perspectives of teachers [7, 12], student motivation and curiosity [13], and roles of students and instructors in their interactions [14].

We hope this collection of papers inspires and empowers you to overcome

the challenges of bringing inquiry to your students, with equitable access and intentional coherence in mind.

References

[1] Boaler, J. (2015). *Mathematical Mindsets: Unleashing students' potential through creative math, inspiring messages and innovative teaching*. John Wiley & Sons.

[2] Cook, S.A. and Borkovitz, D. (2016). *Student Perceptions of a Mathematics Major for Prospective Elementary Teachers with an Inquiry Based Philosophy*. PRIMUS.

[3] Firkins Nordstrom, J. and Sumner, D. (2016). *It's All about Inquiry: A Cross-Disciplinary Conversation about Shared Foundations*. PRIMUS.

[4] Flores, A., Phelps, C. & Jansen, A. (2016). *Reflections on Transformative Experiences with Mathematical Inquiry*. PRIMUS.

[5] Fosnot, C.T. & Dolk, M. (2001). *Young mathematicians at work: constructing number sense, addition, and subtraction*. Portsmouth, NH: Heinemann.

[6] Green, E. 2014. *Building a better teacher: How teaching works (and how to teach it to everyone)*. WW Norton & Company.

[7] Greenstein, S., Buell, C. & Wilstein, Z. (2016). *Constructing an Inquiry Orientation from a Learning Theory Perspective: Democratizing Access through Task Design*. PRIMUS.

[8] Marrongelle, K., & Rasmussen, C. (2008). *Meeting new teaching challenges: Teaching strategies that mediate between all lecture and all student dis-*

covery. Making the connection: Research and teaching in undergraduate mathematics education, 73, 167-177

[9] Mathematics in the City Resources. http://education.ccny.cuny.edu/mitcccny/?page_id=134 (accessed August 16, 2016).

[10] Miller, N. (2016). *Teaching Inquiry to High School Teachers through the Use of Mathematics Action Research Projects*. PRIMUS.

[11] Piercey, V. and Cullen, R. (2016). *Teaching Inquiry with Linked Classes and Learning Communities*. PRIMUS.

[12] Slavit, D. and Lesseig, K. (2016). *The Development of Teacher Knowledge in Support of Students Mathematical Inquiry*. PRIMUS.

[13] von Renesse, C. and Ecke, V. (2016). *Teaching Inquiry with a Lens toward Curiosity*. PRIMUS.

[14] Zandieh, M., Wawro, M. & Rasmussen, C. (2016). *An Example of Inquiry in Linear Algebra: The Roles of Symbolizing and Brokering*. PRIMUS.