The Emergence of a Video Coding Protocol to Assess the Quality of Community College Algebra Instruction

AI@CC Research Group*
Anoka-Ramsey Community College, Delta College, Glendale Community College, Scottsdale Community College, University of Michigan, University of Minnesota

The Evaluating the Quality of Instruction in Post-secondary Mathematics (EQIPM) is a video coding instrument that provides indicators of the quality of instruction in community college algebra lessons. The instrument is based on two existing instruments that assess the quality of instruction in K-12 settings—the Mathematical Quality of Instruction (MQI) instrument (Hill, 2014) and the Quality of Instructional Practices in Algebra (QIPA) instrument (Litke, 2015). EQIPM addresses three dimensions focused on quality of instruction via 17 codes. In this paper, we describe two codes: Instructors Making Sense of Procedures from the Quality of Instructor-Content Interaction dimension, and the Mathematical Errors and Imprecisions in Content or Language, a code spanning all three dimensions. The purpose of the paper is to illustrate what we have learned from these codes and the new instrument to advance our understanding of post-secondary mathematics instruction.

Keywords: Algebra, Instruction, Video Coding, Community Colleges

Various reports have established an indirect connection between students leaving science, technology, mathematics, and engineering (STEM) majors because of their poor experiences in their STEM classrooms (Herzig, 2004; Rasmussen & Ellis, 2013). Interestingly, however, most of these reports are based on participants' descriptions of their experiences in the classroom, rather than on evidence collected from large scale observations of classroom teaching (Seymour & Hewitt, 1997). When such observations have been made, they usually focus on superficial aspects of the interaction in the classroom (e.g., how many questions instructors ask, how many students participate, or who is called to respond, Mesa, 2010) or their organization (e.g., time devoted to problems on the board, or lecturing, Hora & Ferrare, 2013; Mesa, Celis, & Lande, 2014). Undeniably, these are important aspects of instruction, yet these elements are insufficient to provide a characterization of such complex activity as instruction in classrooms.

A key concern in post-secondary mathematics education is the lack of teacher training that mathematics instructors received in their graduate education (Ellis, 2015; Grubb, 1999). We argue that the lack of a reliable and valid method to fully describe how instruction occurs hinders our understanding of the complexity of instructors' work in post-secondary settings and therefore limits the richness of professional development opportunities focused on the faculty-student-content interactions (Bryk, Gomez, Grunow, & LeMahieu, 2015). As part of a larger project that investigates the connection between the quality of instruction and student learning in community college algebra, we have developed an instrument, EQIPM, that seeks to characterize instruction.

* The AI@CC Research group includes: Megan Breit-Goodwin, Anoka-Ramsey Community College; Randy Nichols, Delta College; Patrick Kimani and Laura Watkins, Glendale Community College; April Ström, Scottsdale Community College; Anne Cawley, Angeliki Mali, and Vilma Mesa, University of Michigan; Irene Duranczyk, Dexter Lim, and Nidhi Kohli, University of Minnesota. Colleges and authors are listed alphabetically.

In this paper, we present the current form of the instrument and describe two codes that show promising findings from our pilot data.

Theoretical Perspective

We assume that teaching and learning are phenomena that occur among people enacting different roles—those of instructor or student—aided by resources of different types (e.g., classroom environment, technology, knowledge) and constrained by specific institutional requirements (e.g., covering preset mathematical content, having periods of 50 minutes, see Chazan, Herbst, & Clark, 2016; Cohen, Raudenbush, & Ball, 2003). We focus on instruction, one of many activities that can be encompassed within teaching (Chazan et al., 2016), and define instruction as the interactions that occur between instructors and students in concert with the mathematical content (Cohen et al., 2003). Such interaction is influenced by the environment in which it happens and it changes over time. Empirical evidence from K-5 classrooms indicates that ambitious instruction is positively correlated with student performance on standardized tests (Hill, Rowan, & Ball, 2005). The definition of instruction requires attention to the discipline and is fundamental in understanding mathematics teaching practice. Therefore, we assume, first, that the experiences of instructors and students while interacting with mathematical content have a significant impact on what students are ultimately able to demonstrate in terms of knowledge and understanding, and second, that it is possible to identify different levels of quality of the instruction that is enacted in mathematics classrooms.

Methods

In the pilot phase of the larger research study, we video-recorded 15 lessons in introductory, intermediate, and college algebra classrooms from three different community colleges in three different states during the Fall 2016 semester. The lessons ranged in duration between 45 and 120 minutes, and were taught by six different instructors (two part-time and four full-time). The lessons covered one of three topics: linear equations/functions, rational equations/functions, or exponential equations/functions. These topics were chosen because they offer us opportunities to observe instruction on key mathematical concepts (e.g., transformations of functions; algebra of functions) and to attend to key ways of thinking about equations and functions (e.g., preservation of solutions after transformations; covariational reasoning), which are foundational algebraic ideas that support more advanced mathematical understanding. The development of EQIPM was similar to the process used by Hill and colleagues (2008) and by Litke (2015). Their instruments describe and qualify instructional practices from video-recorded lessons deemed representative by rating all individual 7.5-minute segments.

EQIPM evolved through various iterations of segment and lesson coding and discussion with a subset of segments. In the final phase of development, all 151 segments in the data corpus were double-coded using an earlier version of EQIPM. Each code received a score ranging from 1 to 5. The team of 10 researchers, all co-authors on this paper, worked in pairs to independently code three lessons; for each of their lessons, each pair held calibration meetings to discuss codes with a discrepancy in ratings greater than one point.

The instrument consists of three dimensions: (1) Quality of Instructor-Student interaction, (2) Quality of Instructor-Content Interaction, and (3) Quality of Student-Content Interaction; two cross-cutting codes (*Mathematical Explanations and Mathematical Errors and Imprecisions in Content or Language*); and three additional codes that help characterize the type of work done on each segment in a lesson (i.e., Mathematics is a focus of the segment, Procedure taught in the segment, and Modes of instruction, see Figure 1). In this paper, we describe one code from the

Quality of Instructor-Content Interaction dimension (*Instructors Making Sense of Procedures*) and one cross-cutting code (*Mathematical Errors and Imprecisions in Content or Language*) to provide the reader with a sense of how these two codes are useful in characterizing key practices in the community college algebra classrooms that we have observed.

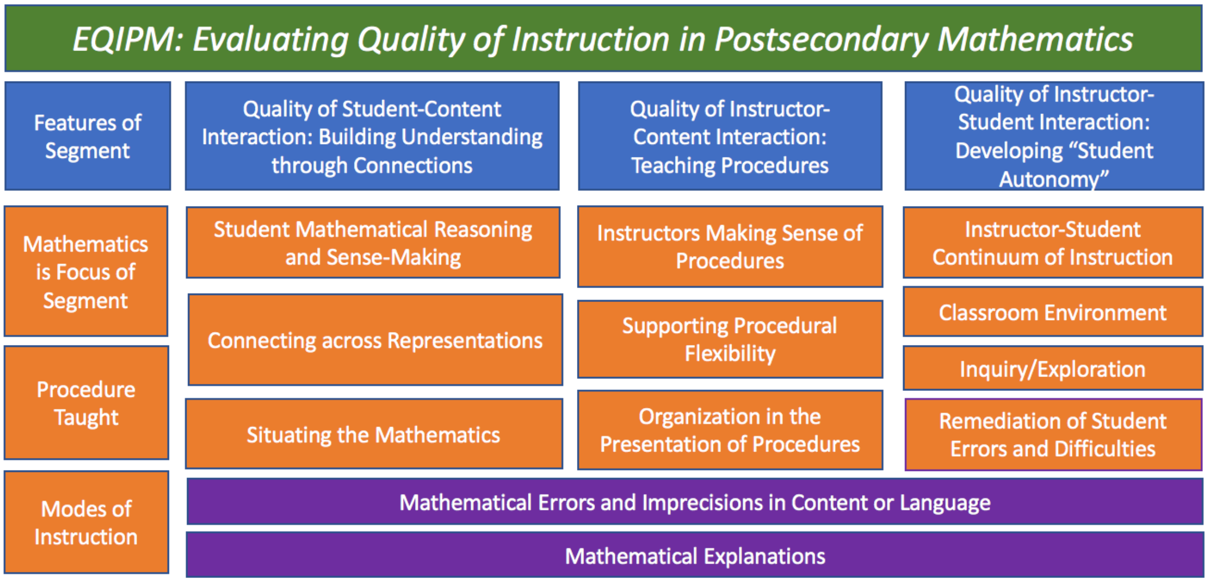

Figure 1: Dimensions and codes for the EQIPM instrument.

Preliminary Findings

Instructors Making Sense of Procedures was a code originally from the QIPA instrument, which defined a procedure as "instructions for completing a mathematical algorithm or task" (Litke, 2015, p. 160). With this code, we sought to identify ways in which instructors used mathematical relationships or properties to motivate a particular procedure. Such work includes activities that attend to, for example, the type of solution generated by a procedure and its interpretation or to the conditions of the problem that may suggest what procedure to apply and where in the process to use it. This work also includes activities that attend to the symbols used in mathematical expressions and equations, as well as to the structure of an algebraic expression and how it is transformed by each step in a mathematical procedure. Thus, in general, this code seeks to capture all mathematical work that instructors do to make salient mathematical properties, relationships, and connections embedded in a particular mathematical procedure. Making sense of procedures helps students to understand the underlying logic of the procedure of how to get from one step to the other, not merely reproducing the work from a textbook example. We believe that when the instructors make explicit the sense-making behind procedures, then their students will have an opportunity to make sense of the mathematics as well so that they can engage more substantively with the mathematics.

In order to make an assessment of the evidence found in the videos, each segment was rated on a scale of 1 to 5 depending on whether the instructor did not engage in sense-making while teaching a procedure (a rating of 1) or when the instructor consistently engaged in sense-making throughout the segment (a rating of 5). A rating of 3 is reserved for cases in which sense-making is observed on several occasions in the segment, but they are brief, or for cases in which procedures are not the focus of instruction. Ratings of 2 and 4 were used when the evidence was not sufficient for a 3 or a 5. Out of segments in which a procedure was taught, we only identified one in which no sense-making was present; 59 segments (43%) had a rating of 3, and 55 segments (39%) had a rating of 4 or 5 (30% and 9%, respectively). Thus, in these lessons, we were able to provide evidence for all of the ratings, which suggests that the instrument allows for differentiation of the role of sense-making in the classroom. In most cases, we can say that instructors were making a genuine effort of assisting students in making sense of the procedures taught during the video recorded sessions.

For example, in a lesson on linear functions, instructor 0613 presented a word problem in which students are asked to model the value of a copy machine, v, as a function of time, x. The instructor asked students to consider how to write a linear function v as a function of x. Students contributed three answers: $f(x)$, $f(v)$, and $v(x)$. The instructor reasoned through all three responses using the information in the problem to make sense of the appropriate way to write the function as $v(x)$ (0613_L1, 2016, 26:22). Later in the segment, the instructor asked, "What does the value of $120,000 mean in this problem? What does a slope of negative 12,000 mean in this problem?" (0613_L1, 2016, 29:00). The subsequent conversation detailed the meaning of the values of the y-intercept and slope for this specific context. This segment received a rating of 3 because within the segment, the instructor made sense of the procedure more than briefly, but sense-making was not the focus of the instruction on the procedure (how to write an equation to model a situation given in a problem). Instructor 0112 demonstrated sense-making that was rated as a 5, when working with a growth problem modeled by $y = 3(2)^x$. He asked students to think about the meaning of the general equation $y = ab^x$ with a concrete example that used paper folding to demonstrate the meaning of 2^x, where x was the number of times a piece of paper was folded by half and y the size of the stack of papers generated by the fold: One fold created a stack of 2, two folds created a stack of 4, three folds created a stack of 8, and so on (0112_L1, 2016, 30:00). This segment was rated 5 because, sense-making was the focus of the segment and it saturated the segment.

Mathematical Errors and Imprecisions in Content or Language was a code originally from the MQI. The code is intended to capture events in the segment that are mathematically incorrect or that have problematic uses of mathematical ideas, language, or notation. This code applies to the work and utterances of the instructor. Errors made by students are ignored except when the instructor does not correct them. This code also captures cases in which problems are solved incorrectly, when definitions are incorrect, or when the instructors do not use or forget to mention a key condition in a definition. Finally, we apply this code when instructors use imprecise or colloquial mathematical language. Our interest in this code stems from the realization that in some of the lessons we observed, instructors used language that was not mathematically correct to convey ideas, and whereas such uses were appropriate for the lesson—their meaning had been negotiated within the classroom—the continued use of that language could put students at a disadvantage because they would not be gaining proficiency in using correct mathematical language. A rating of 1 indicates that no errors or imprecisions were observed, a desirable situation, whereas a rating of 5 indicates major content, notation, or language errors were made throughout the segment, an undesirable situation. A rating of 3 is reserved for some errors that obscure the mathematical meaning for part of the segment. Out of 138 segments in which a procedure was taught, we only identified one segment with a rating of 5 signaling that major errors were seen, and 45 segments (33%) in which no errors were observed. Fifty-eight segments (42%) had minor imprecisions (rating of 2, e.g., using "bottom" for denominator) and 34 segments (24%) had a rating of 3 or 4 (23% and 1%, respectively). Given that about one fourth of the segments were rated with a 3 or more in this sample, we note that the instrument may suggest areas for professional development that relate to strengthening the rigor in using accurate mathematical language, relationships, and notations. For example, in a lesson on rational equations, instructor 0112 used a graphing calculator to graph $y = \frac{x+1}{x^2-5x+6}$. While identifying the asymptotes using graphical and symbolic representations of the function, the instructor stated that the zeros of the denominator "equal" the vertical asymptotes. We considered this statement as an error in language because that precise statement would require writing a linear equation, as well as an error in content because it does not recognize that there is a removable discontinuity. Later in the segment, the instructor asked the students: "If I let x be equal to 2, with what do I end up at the bottom?" (0112_R1, 2016, 57:12). We considered the replacement of precise mathematical terms (e.g., denominator) with an everyday, colloquial term (e.g., bottom) an imprecision in language. However, the segment was rated as 2 in this code because the imprecise language did not hinder the procedure of identifying the asymptotes.

Questions for the Audience

The current version of the EQIPM instrument seeks to gather evidence on the quality of the instructor-content, instructor-student, and student-content interactions, thus mirroring the framing on instruction of our work. To advance our work, we have the following questions:

- Are there features of quality instruction that are not being captured in this version of the EQIPM instrument? A preliminary factor analysis with the pilot data points to a three-factor structure (with mathematical errors and imprecision being by itself). During the presentation, we will share the instrument and the current definitions, and we will illustrate how some of the codes fit in this factor analysis.
- The labels for the main categories of codes, mirror our definition of instruction. Are there other possible structures or organizations of the codes? What theoretical framing about quality of instruction could be used for such reorganization?
- Which additional video coding protocols could be leveraged to make the EQIPM instrument more robust?

Acknowledgement

Funding for this work was provided by the National Science Foundation award EHR #1561436. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

References

Bryk, A. S., Gomez, L. M., Grunow, A., & LeMahieu, P. G. (2015). *Learning to improve: How America's schools can get better at getting better*. Cambridge, MA: Harvard Education Press.

Chazan, D., Herbst, P., & Clark, L. (2016). Research on the teaching of mathematics: A call to theorize the role of society and schooling in mathematics instruction. In D. H. Gitomer & C. A. Bell (Eds.), *Handbook of research on teaching* (5th ed., pp. 1039-1097). Washington DC: American Educational Research Association.

Cohen, D. K., Raudenbush, S. W., & Ball, D. L. (2003). Resources, instruction, and research. *Educational Evaluation and Policy Analysis, 25*, 119-142.

Ellis, J. (2015). Three models of graduate student teaching preparation and development. In D. M. Bressoud, V. Mesa, & C. L. Rasmussen (Eds.), *Insights and recommendations from the MAA National Study of College Calculus* (pp. 117-122). Washington, DC.

Grubb, N. W. (1999). *Honored but invisible: An inside look at teaching in community colleges*. New York: Routledge.

Herzig, A. (2004). Becoming mathematicians: Women and students of color choosing and leaving doctoral mathematics. *Review of Educational Research, 74*, 171-214.

Hill, H. C. (2014). *Mathematical Quality of Instruction (MQI)*. Retrieved from Harvard, MA: https://hu.sharepoint.com/sites/GSE-CEPR/MQI-Training/Shared Documents/MQI 4-Point.pdf

Hill, H. C., Blunk, M., Charalambous, C., Lewis, J., Phelps, G., Sleep, L., & Ball, D. L. (2008). Mathematical Knolwedge for Teaching and the Mathematical Quality of Instruction: An exploratory study. *Cognition and Instruction, 26*(4), 430-511.

Hill, H. C., Rowan, B., & Ball, D. L. (2005). Effects of teachers' mathematical knowledge for teaching on student achievement. *American Educational Research Journal, 42*, 371-406.

Hora, M. T., & Ferrare, J. J. (2013). Instructional systems of practice: A multidimensional analysis of math and science undergraduate course planning and classroom teaching. *Journal of the Learning Sciences, 22*(2), 212-257. doi:10.1080/10508406.2012.729767

Litke, E. G. (2015). *The state of the gate: A description of instructional practice in algebra in five urban districts,* (PhD). Harvard University, Cambridge, MA.

Mesa, V. (2010). Student participation in mathematics lessons taught by seven successful community college instructors. *Adults Learning Mathematics, 5*, 64-88.

Mesa, V., Celis, S., & Lande, E. (2014). Teaching approaches of community college mathematics faculty: Do they relate to classroom practices? *American Educational Research Journal, 51*, 117-151. doi:10.3102/0002831213505759

Rasmussen, C. L., & Ellis, J. (2013). *Who is switching out of calculus and why*. Paper presented at the 37th Conference of the International Group for the Psychology of Mathematics Education, Kiel, Germany.

Seymour, E., & Hewitt, N. (1997). *Talking about leaving: Why undergraduates leave the sciences*. Boulder, CO: Westview.