An Exploratory Factor Analysis of EQIPM, a Video Coding Protocol to Assess the Quality of Community College Algebra Instruction

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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. It grew out of two 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). We present preliminary results of an exploratory factor analysis that suggests that the instrument captures three distinct dimensions of quality of instruction in community college algebra classes.

Keywords: Algebra, Instruction, Video Coding, Community Colleges

Various reports have established an indirect connection between students leaving science, technology, engineering, and mathematics (STEM) majors because of their poor experiences in their STEM classes (Herzig, 2004; Rasmussen & Ellis, 2013). Most of these reports, however, are based on participants' descriptions of their experiences in the classes, 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 (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 a complex activity as instruction.

A key concern in post-secondary mathematics education is the lack of preparation that mathematics instructors receive 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 preparation and 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 courses, we have developed an instrument, EQIPM (Evaluating Quality of Instruction in Postsecondary Mathematics), that seeks to characterize

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instruction. In this paper, we present the results of an exploratory factor analysis using ratings generated by coding lessons with EQIPM that suggest three aspects key to instructional quality.

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 interactions are influenced by the environment where they happen and change 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). Understanding mathematics instruction requires attention to the disciplinary content and the mathematical knowledge for teaching and learning. 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 latent constructs that might account for the observed quality of instruction.

Instruction is central to EQIPM. The instrument was designed with the goal of assessing the quality of the interactions defining instruction assessed via three distinct constructs: (1) Quality of Instructor-Student interaction, (2) Quality of Instructor-Content Interaction, and (3) Quality of Student-Content Interaction, supported by the quality of *Mathematical Explanations* and *Mathematical Errors and Imprecisions in Content or Language* that are present in a lesson. Figure 1 illustrates the theorized structure of the coding instrument by showing individual codes within the three constructs. The codes under *Segment features* help characterize the segment (i.e., Mathematics is a focus, Procedure is taught, Modes of instruction, Technology used).

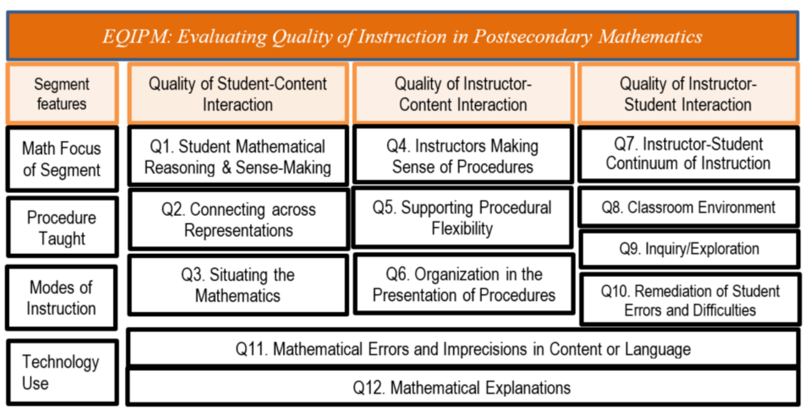

Figure 1. Dimensions and codes for the EQIPM instrument.

Methods

In the Fall 2017 semester we video-recorded 131 lessons in intermediate and college algebra classes from two different community colleges in three different states. The lessons ranged in duration between 45 and 150 minutes, and were taught by 40 different instructors (44 different unique courses video-recorded; 4 instructors taught 2 sections of a course). 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 (Breidenbach, Dubinsky, Hawks, & Nichols, 1992; Carlson, Jacobs, Coe, Larsen, & Hsu, 2002). 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 by subdividing lessons into 7.5-minute segments and rating all segments within a lesson.

Using version 3a of EQIPM, each 7.5-minute segment within a lesson was coded by one member of a team of 14 researchers using a rubric that described the coding (AI@CC Research Group, 2017). Each code was rated on a 1 to 5 scale and each coder provided a justification for that rating that included evidence linked to a timestamp in the video. The researchers independently coded a maximum of 3 to 4 segments of a lesson to minimize bias due to familiarity with the instructor or the lesson. Ten percent of segments were randomly chosen for double-coding by a pair of researchers. Each pair held calibration meetings to discuss codes with a discrepancy greater than one point between ratings and subsequently reconciled when the researchers scores were more than 1 point apart or when a researcher identified a justification for their code and that justification was "missed" by the second researcher. The reconciled scores of the double-coded lessons were used for the exploratory factor analysis along with single coded segments in the corpus.

We conducted an initial exploratory factor analysis [EFA] using the 12 EQIPM items using Mplus 7.2. We extracted factors using the Mean and Variance Weighted Least Square (WLSMV) estimator with an oblique rotation (geomin). This extraction method is appropriate when using items that do not follow a normal distribution or items measured on a 5-point scale. We preferred an oblique rotation over an orthogonal one because this allows us to freely estimate the correlation between the extracted factors rather than assuming it to be zero. We used a Full Information Maximum Likelihood (FIML) approach to account for missing data. The scree plot for the 12-item EFA suggested that a solution between 1 and 3 factors would be appropriate (see Figure 2). We fit four separate EFAs by progressively adding these possible factors. At the time of this submission, we had coded 17 out of the 88 target lessons (19%) with a dataset large enough to run either a CFA or an EFA (169 segments). We chose to do an EFA because this allows us to make the least number of assumptions about the factor structure of our data. The data set included lessons from all but one of the colleges (8 from College 1, 1 from College 3, 2 from College 4, 2 from College 5, and 4 from College 6), six of which were calibrated. The lessons are from 15 distinct instructors (34% of instructors in sample)

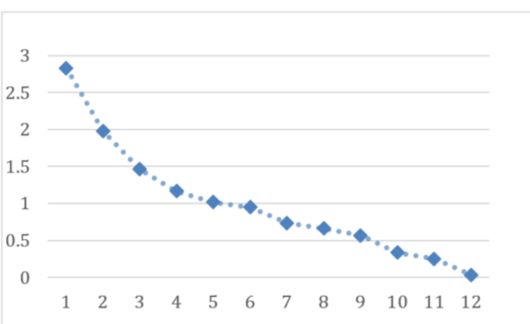

Figure 2. Scree plot

Preliminary Findings

We found that the 3-factor solution was an adequate to good fit to the data: $\chi^2 = 47.466$, $p = 0.049$, RMSEA = 0.051, 90% CI = [0.003, 0.082], CFI = 0.972, TLI = 0.944, SRMR = 0.065 (Hu & Bentler, 1999). This suggested that we did not have to do any model modifications, such as dropping items, in order to reach an acceptable solution.

Our preferred EFA model extracted three meaningful factors using all 12 codes (see Table 1). We also found that these three factors are weakly and positively correlated: corr Factor 1-Factor 2 = 0.184, corr Factor 1-Factor 3 = 0.245, and corr Factor 2-Factor 3 = 0.391. We noted that Q5 and Q12 have loading patterns that would suggest not to include them in the EFA solution (Worthington & Whittaker, 2006). We decided to retain these items in our model because we plan to confirm the extracted factor structure using a confirmatory factor analysis once the full lesson dataset becomes available. Moreover, the loadings on factor 3 are not high, which may suggest more commonality with the other two factors than what we would like to have. Descriptive information (e.g., item distribution will be made available in the presentation).

Table 1. Factor Loadings for the 3-Factor Solution

	Factor 1	**Factor 2**	**Factor 3**
Q1 – St. Mathematical Reas.	**0.790***	-0.001	-0.028
Q7 – Instructor-Student Cont.	**1.055***	-0.182	0.012
Q9 – Inquiry/Exploration	**0.594***	0.039	-0.016
Q10 – Remediation Std Errors	**0.281***	0.187	-0.057
Q4 – Instr. Making Sense Proc.	-0.179	**0.661***	0.022
Q5 – Supp. Proc. Flexibility	0.051	**0.307***	-0.283*
Q6 – Organization Pres. of Proc.	0.072	**0.454***	0.297
Q11 – Math. Err & Impr. Cont.[a]	0.023	**-0.224***	-0.156
Q12 – Math. Explanations	-0.001	**0.954***	**-0.792***
Q2 – Conn. across Reprs.	0.036	-0.053	**0.300***
Q3 – Situating Math.	-0.05	0.222	**0.325***
Q8 – Class Environment	0.374	0.011	**0.530***

Notes. * Significant loadings at the 95% level.
[a] A high rating in this code implies low quality of instruction.

Discussion

We interpret factor 1 as the **quality of instructor-student interaction**, as it embeds three of the codes under the fourth column of Figure 1 that were meant to address how students and the instructor were working together. This factor also included the *Student mathematical reasoning and sense making* code, which was theorized to be part of the student-content interaction. Being part of the instructor-student interaction factor may suggest that such reasoning occurs through invitations by the instructor. Some corroboration of this conjecture is grounded in the high number of segments in which lecture was the main mode of instruction (94%, 159 of 169 segments coded involved lecture and 90 of those used only lecture). In theory, mathematical reasoning and sense making should be evident without the mediation of the lecture; we anticipate that professional development targeting the importance of this feature of instruction, might yield differences that might align this code under the student-content interaction as theoretically envisioned. As more segments with other modes of instruction appear, we might be able to see if this code continues to be under this factor. We interpret factor 2 as addressing the **quality of instructor-content interaction**; its five codes, three hypothesized under the third column of Figure 1, and the two codes we hypothesized as cross-cutting the three constructs, speak directly about how instructors manage the discussion of the mathematical content. While the cross-cutting code, Mathematical Explanations, allows for students providing explanations that this code loads on the instructor-content interaction suggests that there are few opportunities for students to provide explanations, and could be a consequence of the emphasis on lecturing in these segments. Finally, factor 3, seems to capture the **quality of student-content interaction** by embedding two of the three codes found in the second column of Figure 1 with the *Classroom environment* code which suggests that student engagement in mathematics may be occurring in situations where the classroom environment is supportive of students' interaction with the content. The negative high loading of the code *Mathematical Explanations* in this factor suggests that explanations might not occur when connections across representations, situating the mathematics, and classroom environment are rated highly. This is a puzzling result and merits further investigation.

While these EFA results are encouraging, we recognize that the extracted structure depends on the lessons that were available to perform the exploration, which are not representative of our corpus. We will need to confirm our results using our whole corpus of data. We plan to run a split sample EFA/CFA to explore and validate the instrument's factor structure once we have the full dataset coded. This will allow us to account for the multi-level structure of our data, specifically, segments within lessons.

Being able to identify three distinct factors that can be used to describe the quality of community college algebra instruction is promising for the field: each of the constructs suggest specific areas for supporting the work of instructors in teaching community college algebra. These results also support previous research in K-12 that models learning via assessing the quality of instruction defined as the interactions between teacher, student, and content. The connections between the classroom environment and the quality of student-content interaction rather than quality of instructor-student interaction may highlight the importance of classroom environment on building student engagement with the content. The factors used will be included in the full model of our data to determine links between instructional qualities and student performance. We plan to use the instrument in the design of professional development.

Questions for the Audience

The preliminary factor analysis of EQIPM, version 3a, supports the theoretical dimensions underlying the quality of algebra instruction at community colleges and three possible variables that can be used to assess quality and model student performance in these courses. Given these findings, we have the following questions:

1. Is our interpretation of the EFA results plausible? Are there other links between the codes and the underlying factor structure revealed by the EFA that you believe can be made and be supported by current literature on teaching and learning?
2. EQIPM is based on our conceptualization of instruction, and looks at the quality of interactions between instructors, students, and content. Other than modes of instructions playing a role in the results of the analysis, are there other segment features (e.g., technology) that come to mind that could also impact the loadings? Are there other ideas that come to mind about the EQIPM coding rubric or EFA that could enhance this research approach to describe the quality of instruction in community college settings?

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