Building Lasting Relationships: Inquiry-Oriented Instructional Measure Practices

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This study examines the relationships between instructional practices in the Inquiry-Oriented Instructional Measure (IOIM). The IOIM consists of seven practices developed from four guiding principles of Inquiry-Oriented (IO) instruction: generating student ways of reasoning, building on student contributions, developing a shared understanding, and connecting to standard mathematical language and notation. A 2-tailed correlation test was applied to IOIM scores from 36 instructors and found six of the practices had strong positive correlations to each other and the seventh had a moderate positive correlation. Cronbach alpha was calculated indicating the IOIM is an internally consistent measure.

Keywords: Inquiry-Oriented, Instructional Measure, Quantitative

Inquiry based learning (IBL) encompasses a broad range of teaching approaches focused on engaging students in mathematical argumentation while performing a sequence of tasks (Yoshinobu & Jones, 2013; Laursen, Hassi, Kogan, & Weston, 2014). Studies have shown better student outcomes from self-reported IBL instructors than from non-IBL instructors (Laursen, et al., 2014; Kogan & Laursen, 2013). However, IBL is a "big tent" with different meanings to different researchers (Kuster, Johnson, Keene, & Andrews-Larson, 2017). Here we focus on the more narrow Inquiry-Oriented (IO) instruction, which generally adheres to the tenets of IBL.

Measures have been developed in other branches of math education, with purposes such as teacher noticing (Jacobs, 2017) or determining the mathematical quality of instruction (Learning Mathematics for Teaching Project, 2011). These measures can help clarify the degree to which a standard is met and can clarify how researchers are conceptualizing phenomena (Jacobs, 2017). For IO instruction, this conceptualization is particularly important because IO curricular materials have presented a number of challenges for implementation. These challenges include developing mathematical knowledge for teaching, anticipating how to build on students' ideas, and facilitating whole-class discussions (Johnson & Larsen, 2011; Rasmussen & Marrongelle, 2006; Speer & Wagner, 2009; Wagner, Speer, & Rossa, 2007). Therefore, it is essential to define what IO instruction looks like, to develop a clear measure to better understand the nature of improved outcomes observed in IBL courses, and to see to what extent they were observed in IO intending classes. This measure can also help address implementation challenges by highlighting specific aspects of high-quality IO instruction.

Researchers have created the Inquiry-Oriented Instructional Measure (IOIM), a rubric that quantifies the degree to which a class can be characterized as IO. For more background information on this measure as well as the measure itself, refer to Kuster, Rupnow, & Johnson (2018) in this volume. We used the IOIM to score 36 Abstract Algebra, Linear Algebra, and Differential Equations instructors. Based on those scores, the purpose of this paper is to explore the relationships between different practices in the IOIM to determine the value of using the IOIM to measure IO instruction.

Theoretical Perspective

The IOIM is based on four guiding principles from Kuster et al. (2017): *generating* student ways of reasoning, *building* on student contributions, developing a *shared understanding*, and *connecting* to standard mathematical language and notation. Generating student ways of reasoning includes engaging students in mathematical tasks so their thinking is shared and explored with the class. Building on student contributions involves taking students' ideas and using them to direct class discussion, potentially in unforeseen ways. Developing a shared understanding describes helping individual students understand one another's thinking, reasoning, and notation so that a common experience can be "taken-as-shared" in the classroom (Stephan & Rasmussen, 2002). Connecting to standard mathematical language and notation involves transitioning students from the idiosyncratic mathematical notation and terms used in class to standard descriptions and notation, such as "groups" or phase planes. These four principles are enacted though seven instructional practice. The four principles and the seven practices supporting them are listed in Figure 1.

Principles	Practices Supporting Each Principle
Generating student ways of reasoning	1. Teachers **facilitate** student engagement in meaningful tasks and mathematical activity related to an important mathematical point.
Generating student ways of reasoning **Building** on student contributions	2. Teachers **elicit** student reasoning and contributions.
Generating student ways of reasoning **Building** on student contributions	3. Teachers **actively inquire** into student thinking.
Building on student contributions Developing a **shared understanding**	4. Teachers are **responsive** to student contributions, using student contributions to inform the lesson.
Developing a **shared understanding**	5. The teacher engages students in **one another's reasoning**.
Building on student contributions	6. The teacher guides and manages the development of the **mathematical agenda**.
Developing a **shared understanding** **Connecting** to standard mathematical language and notation	7. Teachers support **formalizing** of student ideas/contributions and introduce language and notation when appropriate.

Figure 1: Principles and their supporting practices

Practice one reflects the extent to which the teacher engages students in "doing mathematics," or the extent to which students engaged in cognitively demanding tasks and used mathematical argumentation to support or refute any claims (Stein, Engle, Smith, & Hughes, 2008). Practice two reveals the degree to which the teacher elicits rich mathematical reasoning from students, as opposed to simple recitation of procedures. Practice three signals the level to which the teacher further probes students' statements and reasoning in order to improve their own understanding of what students meant and in order to help students reflect on their own thinking. Practice four indicates how much the teacher uses students' questions and ideas as a springboard for further discussion in class that enriches the mathematical development for the class as a whole. Practice five examines the extent to which the teacher prompts students to directly compare and contrast each other's reasoning without the teacher needing to act as a filter that interprets statements for the students. Practice six exhibits the level to which the teacher guides and manages the development of a lesson in a coherent way that reaches a mathematical goal while using student reasoning and contributions to reach that mathematical goal. Practice seven displays the degree to which the teacher transitions from students' own language and notation, which have been developed to address tasks, to standard mathematical language and notation and the extent to which the teacher allows students to take ownership of this transition (i.e., at a high level, the teacher provides the standard name but the students translate their notation into standard notation once given a template for the standard form). Based on this perspective, we explore the following question: To what extent are the practices related?

Methods

This quantitative study uses a relational research design to look at the relationships among the seven IOIM practices by investigating data collected from a project designed to support instructors interested in implementing IO instructional materials. Five volunteers trained for five days to understand how to score videos with the IOIM. Coders then scored videos of professors teaching Abstract Algebra, Linear Algebra, and Differential Equations that had been collected during the IO project. Mean scores for each video were calculated and examined using correlation and linear regression analysis to determine the relationships among the practices.

Coders

Classroom videos were coded by one expert coder and five graduate students recruited by researchers involved in a large project designed to support instructors as they implemented IO curricular materials. The expert coder was a graduate student involved in the development of the IOIM, who had been trained by an IO project researcher on coding each practice. The other five coders were recruited from three different universities associated with the IO project. These five coders completed a week of training conducted by the expert coder to learn about scoring the IOIM practices from 1 to 5, with 1 being low and 5 being high (Kuster, et al., 2018). The first three days were spent in online meetings watching and discussing different teaching scenarios representing the five levels of IO teaching described in the IOIM. Special emphasis was placed on characterizing low, medium, and high levels of IO teaching to aid interpretation of the IOIM. During this time, the expert coder explained each IOIM practice and the associated score for each of the videos. The expert coder also answered the coders' questions and facilitated debates about scores to ensure all coders gained an understanding of the IOIM practices and scores. The last two days involved coding practice videos. Each coder individually scored a video, discussed their scores with another coder, and then met as a group online with the expert coder. Once the coders and expert coder reached agreement on a score for each IOIM practice, they scored the next video. This repetitive process continued throughout the last two days. Coders had to be within one score from the expert coder for each IOIM practice before coding another video. This benchmark helped ensure coders understood the IOIM practices and scoring.

Data Collection

The five coders individually watched eight to twenty-one classroom videos from the Abstract Algebra, Linear Algebra, and Differential Equations IO project professors. The videos were from TIMES fellows, who had engaged in professional development while using IO materials. After watching each video, coders used the IOIM to score each practice and wrote a justification of the score. Individual coders met online with the expert coder after every fifth video to discuss scores. If all of the coder's IOIM scores were at most one away from the expert's scores, the coder proceeded to the next set of videos. However, if the coder's IOIM scores were off by more than one score, the coder was asked to re-watch and recode the video. This benchmark ensured consistency in coding. Final IOIM scores were compiled in a spreadsheet for each video. The goal was to have at least two coders score each video.

Data Analysis

To determine the relationships among the IOIM practices, correlations and linear regression analysis were conducted using the mean scores of each IOIM practice for each video. The goal was to determine the strength of the relationships between practices and if the score of one practice predicted the score of other practices from the IOIM rubric. A total of 36 scored videos were used, each containing one mean score for each of the seven IOIM practices. Simple linear regressions were conducted by defining one practice as the independent variable with all other practices defined as the dependent variables for all 36 videos. To assess this measure's internal consistency, Cronbach's alpha analysis was conducted using all seven practices.

Results

The preliminary results indicate each practice is positively correlated with every other practice, which provides justification for the cohesion of the measure (Table 1). Cronbach's alpha was calculated to assess internal consistency for the seven practices ($\alpha = .969$). This indicates the IOIM has high internal consistency and is a reliable measure for assessing IO instruction. As a video receives high scores for one practice, it receives high scores for the other practices, and likewise if the scores are low. We found practices one through six had very strong correlations to each other, and practice seven had a moderate correlation with the other practices (Table 1). This means video scores for practices one though six strongly depended on each other, whereas video scores for practice seven were only moderately dependent on the scores from practices one though six.

Table 1. Correlations between IOIM Practices

Correlations							
Practices	Practice 1	Practice 2	Practice 3	Practice 4	Practice 5	Practice 6	Practice 7
Practice 1	1	.892**	.932**	.883**	.817**	.932**	.716**
Practice 2	.892**	1	.910**	.893**	.889**	.917**	.726**
Practice 3	.932**	.910**	1	.834**	.798**	.911**	.659**
Practice 4	.883**	.893**	.834**	1	.883**	.871**	.695**
Practice 5	.817**	.889**	.798**	.883**	1	.846**	.642**
Practice 6	.932**	.917**	.911**	.871**	.846**	1	.660**
Practice 7	.716**	.726**	.659**	.695**	.642**	.660**	1

Discussion

The preliminary results indicate practices one through six have strong, positive correlations between each other, but practice seven is only moderately correlated with the other practices. According to our theoretical perspective, the first six practices map to the generating student ways of reasoning, building on student contributions, and developing a shared understanding IO principles. This explains the strong correlation between them since they rely primarily on student thinking and how the instructor responds to such thinking. However, practice seven is the only practice mapped to the connecting to standard mathematical language and notation principle. Practice seven focuses on formalizing student contributions to standard mathematical language and notation, which does not appear to strongly depend on student thinking stemming from an IO task. Due to the difference in mapping, this could explain the difference in correlations between practices one through six with practice seven. For practices 1-6, the high correlations suggest, for example, that a teacher who can probe student thinking also has students engaged in mathematics and vice versa.

Because only TIMES fellows who were trained in doing IO instruction were scored with this rubric, a future area of research would be to use the measure with professors who lecture, who use other forms of IBL, or who use a mixture of IO and lecture to see if the measure can distinguish among teaching styles. Professors who are excellent lecturers could also be a potential subject pool to investigate whether the correlations would be similar with professors who excel with a different instructional method. It is also worth studying whether there are differences between practice scores when the data is broken down by course or coder. Additional research could investigate the interaction between practice, course, and coder.

Questions for Audience

1. We analyzed the data with correlations. What other data analysis methods would be appropriate and for what purposes?
2. What might we learn by using this rubric on other data sets (e.g., IBL or lecture based)?
3. Do you think the rubric would be applicable for K-12 instruction? If so, how?
4. Do you think the rubric would be applicable for mathematics preservice teacher evaluation? If so, how?

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