Inquiry without Equity: A Case Study of Two Undergraduate Math Classes

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Compelling evidence supports the benefits of active learning environments in undergraduate mathematics. Research shows that such environments can benefit all students, and especially benefit students who have been traditionally underrepresented in mathematics. To move beyond the general idea "inquiry supports equity," we provide an analysis of two inquiry-oriented classrooms to highlight the ways in which equitable participation may or may not be present, particularly in terms of gender. We found some evidence of equitable participation in one of the classrooms, while the other was dominated by men in the class. These early findings suggest that more research is required to uncover the ways in which inquiry-oriented environments may or may not be equitable.

Keywords: Equity, Gender, Inquiry-oriented instruction, Instructional measure, Observational research

Inquiry-oriented pedagogy consists of a teacher exploring students' reasoning and engaging them in authentic mathematical activity (Rasmussen & Kwon, 2007). This gives students space to reconstruct mathematics through critical thinking and mathematical discussion. Laursen, Hassi, Kogan, and Weston (2014) discovered in their multi-institutional study on inquiry-based learning (IBL) that IBL can promote a more equitable learning environment in terms of gender equity when compared to non-IBL approaches. They found that women and men in inquiry-based courses reported statistically equivalent cognitive and affective gains. On the other hand, women in non-inquiry-based courses reported lower gains when compared to the men. Laursen et al. (2014) suggested that "IBL approaches leveled the playing field by offering learning experiences of equal benefit to men and women" (p. 412).

Although the courses in this study helped students achieve more equitable outcomes, what about classroom-level participation? Research shows that talk-based participation plays an important role in learning (Bransford, Brown, & Cocking, 2000). Thus, even though women may have improved outcomes, it is possible that they could be marginalized at the level of classroom participation. This has implications for identity development and belonging, and if women were truly participating less in such classrooms, it would highlight an area for improvement in the use of inquiry-oriented pedagogies for mathematics instructors. Therefore, in this study we attempt to answer the following question: Are the opportunities for talk-based participation in inquiry-oriented classrooms necessarily equitable? Given the length of this brief report we focus only on participation, recognizing there are other consequential aspects to classroom equity.

Background

Inquiry-Oriented Instructional Measure

To measure whether or not a classroom is truly inquiry-oriented, Kuster, Johnson, Rupnow, and Wilhelm (2018) developed the Inquiry-Oriented Instructional Measure (IOIM) as a tool to clearly outline seven practices that coincide with the four inquiry-oriented instruction principles as defined by Kuster, Johnson, Keene, and Andrews-Larson (2017). These principles include: (a) generating student ways of reasoning, (b) building on student contributions, (c) developing a shared understanding, and (d) connecting to standard mathematical language and notation. The classroom enactments of the seven practices of IOIM, which have been described extensively in Kuster et al. (2018), are scored along a 5-point Likert scale from low (1) to high (5).

Equity Quantified in Participation

To measure patterns in student participation, we use Reinholz and Shah's (2018) classroom observation tool EQUIP (Equity Quantified in Participation). EQUIP uses equality as a necessary but insufficient baseline towards equity, recognizing that students who are underrepresented in mathematics typically received less than a proportional share of participation opportunities. This is measured by an equity ratio of actual participation to expected participation based on the demographics of the class (Reinholz & Shah, 2018). For example, if 35% of the students in a class were women then it would be expected that those students would participate in 35% of the classroom discourse to ensure equal representation. However, if the women actually contributed to 70% of the classroom discourse, their equity ratio would be 0.7/0.35 = 2, indicating that they participated more than expected.

To be clear, our argument is not that all students should receive an equity ratio of 1, indicating proportional representation. Rather, we can use an equity ratio of 1 as a point of comparison, recognizing that if students from underrepresented groups are receiving a ratio of less than 1, it would likely indicate a problem. As outside observers, it is beyond us to say what is equitable in a classroom, especially without interviewing students for their perspectives.

Methods

For this study, three coders analyzed lessons from 42 teachers in a broader project focused on inquiry-oriented instruction; 20% of the videos were double coded and Krippendorf's alpha > 0.8 was achieved, indicating sufficient interrater reliability. Prior to this study, each of these classes were analyzed and scored using the IOIM rubric (Rupnow, LaCroix, & Mullins, 2018). We then aggregated the scores across the seven dimensions of the rubric, which ranged from 15.5 (low-level implementation of inquiry-oriented instruction) to 35 (high-level implementation of inquiry-oriented instruction). Of the 42 classes, we chose two classes that received high IOIM scores (Class A scored 33 and Class B scored 34) and had roughly the same number of students. Class A consisted of 5 men and 2 women while Class B consisted of 5 men and 3 women. The gender composition of the classrooms was determined by the coders, where visual and audio cues were used as determinants; we acknowledge that this is a limitation of our study.

We coded participation sequences in the whole class discussions along several EQUIP dimensions including Student Talk. A participation sequence refers to a chain of utterances from a student where a new sequence begins once a new student enters the discussion (Reinholz & Shah, 2018). We provide a brief description of the relevant codes in Table 1. Each participation sequence is coded at the highest level of contribution (e.g., if a student gives both an "other" response and a “how” response within a sequence, the sequence is coded as “how” for Type of Talk). The codes for the sub-dimensions of Student Talk in Table 1 are listed from low to high.

Table 1. Descriptions of Student Talk from EQUIP.

Dimension	Codes & Description
Type of Talk	Other - Student asks a question or does not say a mathematical idea. What - Student reads our part of a problem, recalls a fact, or gives a numerical/verbal answer without justification. How - Student reports on steps taken to solve a problem. Why - Student explains the mathematics behind an answer.
Length of Talk	1-4 words – short single-worded responses. 5-20 words – a short response consisting of a sentence. 21+ words – a long response consisting of several sentences.

Findings

We found that even though these classes successfully adopted inquiry-oriented practices in their classrooms as evidenced by their IOIM scores, opportunities to participate were not evenly distributed. With equity ratios below one, we see from Figure 1 that women were underrepresented in the classroom discourse in both classes.

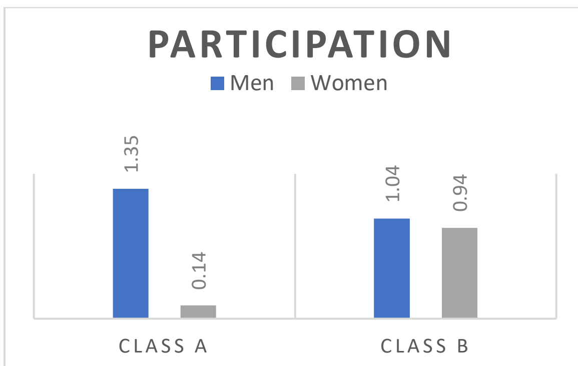

Figure 1. Gender equity ratios by class.

Out of the 51 participation sequences, the women in Class A only contributed to 2 of them. The first sequence played out as follows:

> *Teacher:* *So, what can we do with that? What conclusion did you draw?*
> *Michelle:* *When you multiply the (inaudible) a subset with itself you won't get it back.*
> *Teacher:* *So okay, so you won't get it back …*

The second participation sequence played out in a similar fashion.

> *Teacher:* *Is there another one that does work?*
> *Suzy:* *The only one we haven't checked is IFR^3.*
> *Teacher:* *IFR^3?*
> *Suzy:* *Assuming that the identity has to be in the identity.*
> *Teacher:* *Okay. So, let's see we don't have that much time left but maybe we could try to verify if I and FR^3 works.*

The student responses in each of the sequences were short (5-20 words) "what"-type contributions. Both students contributed to the mathematical development in the class by simply stating facts. According to the hierarchy in the EQUIP framework, these are low-level contributions. An example of a high-level "why" contribution from another participation sequence from Class A between the instructor and one of the men progressed as follows:

Anthony: *Um if it's the identity then it has to be abelian. Because that's on identity element, right?*

Teacher: *Um so let's see. So where did abelian come? So you're saying it has to be commutative, where's the rationale behind that?*

Anthony: *Because if you did the identity, if purple's the identity… If you did purple then yellow, you'd get yellow. And yellow on purple should also be yellow. The vertical column would be the same as the horizontal column…*

This student speaks at length (21+ words) about his reasoning ("why") behind his initial conclusion.

In Class B, the women only contributed to 12 out of the 34 participation sequences. These contributions were either "what" or "why" responses. Although they were overrepresented in overall participation, Figure 2 shows that the men in Class B were underrepresented (equity ratio less than 1) for both "what" and "why" talk. This indicates that in this inquiry-oriented classroom, women were providing the majority of the mathematical explanations.

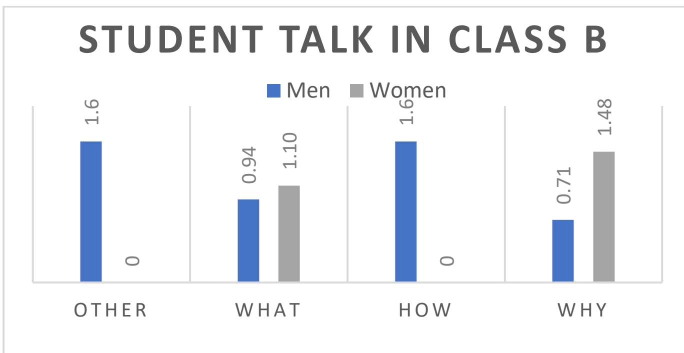

Figure 2. Gender equity ratios for Student Talk in Class B.

According to Table 2, we see that even though most of the participation sequences were more than 1-4 words, the men spoke longer more frequently than the women. In terms of equity ratios, men were overrepresented for the "5-20 words"-length of talk (1.1 to .83) and "21+ words"-length of talk (1.07 to .89).

Table 2. Frequencies for Length of Talk by Gender in Class B.

Length of Talk	Men	Women
1-4 words	1	2
5-20 words	11	5
21+ words	10	5

Discussion and Conclusion

Our findings show that high-inquiry does not imply equitable access to classroom discourse. Both high-inquiry courses provided more opportunities overall for men to participate in the mathematical discourse. The women in Class A contributed to the mathematical development in only 2 out of the 51 participation sequences, all of which were low-level contributions. Likewise, the men in Class B also participated more than we would expect based on demographic representation, but there was a much better gender balance. In addition, the women in Class B were overrepresented in high-level talk ("why" responses), which indicates that when they did participate, they did so in mathematically meaningful ways.

Though the IOIM does measure the degree to which the four principles of inquiry-oriented instruction are implemented (Kuster et al., 2018), it does not highlight which students are driving the discourse. The results from this study demonstrate to us that two courses with a high degree of inquiry can potentially provide a very different learning environment for the students. While inquiry-oriented instruction allows students to interact with mathematics in a meaningful way, it may also amplify inequitable environments by allowing more dominant personalities to overwhelm the classroom discourse and restricting access to other groups of students.

Based on their IOIM score, the teachers of both classes demonstrated that they elicit student reasoning and contributions at a high level. From our findings, we now understand that their implementation was inequitably distributed. This shows us that we must not only be vigilant about increasing student engagement but also conscientious about the ways in which we engage different students. A future direction would be to consider how race factors into student engagement in inquiry-oriented classes. In addition, we would like to further study how equity in opportunities to participate may or may not relate to equity in student outcomes. Here are questions for audience consideration:

1. What is required for inquiry-oriented classes to be equitable?
2. Beyond participation, what other ways should we conceptualize equity in these classrooms?

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