The Relationship Between Academically Productive Talk and Instructional Quality in Mathematics Lessons

Abstract

This paper investigates the relationship between teacher and student discourse patterns, measured by accountable talk moves (Michaels & O'Connor, 2015) and the quality of mathematics instruction as measured by the Mathematical Quality of Instruction (MQI) rubric. This study uses a large public dataset of human coded MQI lesson transcripts and validated AI coding for talk moves to explore how different talk moves predict instructional quality. Results indicate that certain talk moves at certain frequencies, especially those relating to accountability to the learning community and rigorous thinking, positively correlate with higher MQI scores. Thus the nature and frequency of nuanced discourse patterns are crucial for high-quality mathematics instruction, while simple metrics like the amount of student talk have little impact.

High quality math instruction

While intuition suggests that practitioner characteristics and expertise should predict quality outcomes, this is not the case for understanding high quality mathematics instruction. Some teacher characteristics - such as strong mathematics knowledge for teaching (Hill et al., 2012) or professional certification (Silver & Mesa, 2011) - positively predict instructional quality, although associations are not always found and tend to be weak. Hiebert and Grouws (2007) caution that emphasizing teacher attributes is misguided, proposing that educational researchers focus instead on deepening our understanding of teaching and learning.

In addition to conceptual arguments for focusing on teaching and learning, substantial evidence shows that more distal proxies for teacher effectiveness such as teacher demographics or training explain very little of the variability in student learning, further bolstering the argument for a focus on proximal measures of classroom experiences (Goldhaber, 2002). Research showing that teaching is an integrated and culturally bounded system, rather than a discrete set of features or practices (Gallimore & Santagata, 2006), supports the argument for focusing on proximal measures. Schoenfeld (2023) further articulates that key questions around teaching should highlight direct connections to students' experiences related to the learning environment and interactions among students and their teachers and peers. Over the past few decades, researchers have converged on a consensus that effective classroom environments for math learning provide opportunities for students to engage with and make sense of robust mathematical concepts (Hiebert & Grouws, 2007; Stein et al., 2017).

Academically productive discourse in math

Socially-mediated and discourse-rich learning spaces are essential components of high quality instruction (Bransford et al., 2000). Some, such as Munter (2014), define high quality mathematics instruction as tightly connected to classroom discourse, along with additional

features such as the role of the teacher and the mathematical tasks assigned. Others, such as Lampert and colleagues (2010), argue that classroom discourse alone is central to high quality math instruction. The notion of academically productive discourse comes from theory and empirical research on interactive and socially constructed learning environments, particularly in mathematics (Saxe et al., 2002; Vygotsky, 1978; Webb et al., 2008). Academically productive discourse includes "accountable talk moves" that promote active engagement in rich discussions (O'Connor et al., 2015; Resnick et al., 2018). By using talk moves (TM) to guide conversations that are purposeful, coherent and productive, teachers empower students to engage intellectually in a rigorous learning environment (Michaels & O'Connor, 2015). Implementing TMs promotes student learning (Resnick et al., 2010; Walshaw & Anthony, 2008; Webb et al., 2019), increases student enjoyment, decreases anxiety (Chen et al., 2020), and encourages educational equity (Michaels et al., 2008; O'Connor & Michaels, 2019).

Measuring math instructional quality

There are many rubrics for measuring instructional quality; some content-agnostic and others domain-specific (Blazer et al., 2017). The most widely applied mathematics-specific rubrics include the Instructional Quality Assessment Mathematics Toolkit (Boston, 2012; Boston & Candela, 2018), Teaching for Robust Understanding (Schoenfeld, 2013), and Mathematical Quality of Instruction (Learning Mathematics for Teaching, 2011). In this paper we use the Mathematical Quality of Instruction (MQI) rubric which has been in use for over a decade for both research and professional development (Kraft & Hill, 2020; Mitchell et al., 2020). Studies find a positive association between the instructional dimensions captured by the MQI and students' mathematics achievement (Blazer, 2015; Lynch et al., 2017).

Research question and hypotheses

This paper addresses the question: How does discourse aligned with academically productive talk predict mathematical instructional quality? We hypothesize that math lessons with more TMs, particularly those that correspond to rigorous thinking, will predict higher ratings of instructional quality. Further, we posit that there may be an ideal number or range of certain TMs; lessons with too few or too many of those TMs may predict lower instructional quality.

Methods

Data

We use a set of publicly available mathematics lessons collected by the National Center for Teacher Effectiveness (NCTE; see Blazar, 2015 and Hill et al., 2015). NCTE collected a non-random sample of recorded observations from approximately 50 US schools across four school districts from three states. Approximately 300 fourth and fifth grade teachers were filmed three times per year, on average, from 2010-2013. All recorded lessons were scored by trained raters using the MQI. Two raters scored each lesson on instructional domains including:

mathematical richness, working with students, errors and imprecision, and student participation in meaning making and reasoning (Table 1).[1] In addition to these four instructional domains, Whole-Lesson Mathematical Quality of Instruction was also scored.

Analyses

A subset of the NCTE transcripts (n=119) were coded for ten teacher and student TMs (Table 2) by two individuals with established high inter-rater reliability (Authors 2022a). We ran these 119 human-coded NCTE transcripts through computational models trained to detect the same TMs (Authors, 2022b; Authors, in press) to check whether human coding and computational models produced similar TM frequencies. Results were indeed very similar, justifying our use of the AI models to detect talk moves in the set of 1313 MQI-coded transcripts which generated a larger dataset for the analyses that follow.

We conducted correlational and regression analysis to explore associations between the 10 TMs and MQI ratings (with the low, mid and high ratings assumed to be scalar scores of 1, 2 and 3, for simplicity). We explored correlations first using the "gold standard" human-coded sample (n=119), then using the same sample with AI-generated TMs (n=119), and finally using the full dataset of 1313 AI-generated TMs. These analyses allowed us to compare correlations across the three data sets.

Next we used the full dataset (n=1313) to predict overall MQI scores from TMs using OLS regression. For these analyses, each of the ten TMs were divided into terciles based on the frequency distribution for each move. We anticipated that predicting MQI scores using ranges of TMs (low, middle, high) would be more informative than predictions using simple counts. In particular, using terciles allows us to explore the extent to which there may be an optimal range for each TM. For the regression analysis, the omitted category is the low (bottom third of the range) for each TM. In addition to including the 10 TMs by tercile, we also control for total number of sentences spoken during the lesson and percentage of student talk (versus teacher talk) in the models.

Results

Correlations between TMs and MQI

As Table 3 shows, the correlations between TMs and MQI submeasures were similar in terms of direction and size of correlation coefficients for the human-coded and AI-generated TMs in the smaller dataset. As such we then ran correlations using the larger dataset where, as expected, we find more statistically significant correlations due to the substantial increase in statistical power.

[1] Some of the NCTE data ware coded using a different version of the MQI, which applied a different rating scale. These lessons were excluded from our study. See Table 1 for further details.

Six of the ten TMs are significantly ($p<0.05$) and positively correlated with overall MQI scores. Looking at the MQI instructional domains (e.g., Overall Richness) we find that all 10 TMs are correlated with one or more MQI domains. We also note that the percent of student talk is not correlated with overall MQI.

Talk Move Frequencies

Figure 1 shows frequency distributions of each of the ten TMs using box plots. The center line of each TM represents the median, with the box indicating the interquartile range. As shown in the figure, some TMs are more common, such as Keeping Everyone Together whereas others are relatively infrequent such as Getting Students to Relate. This variability across different TMs, while expected, is important to keep in mind. Futhermore TMs comprise a specific type of classroom discourse, with most talk not containing any of the TMs.

Predicting MQI with TMs

Table 4 shows the results of each TM (again, by tercile with the lowest category always omitted for comparison) in a single model predicting MQI domains (columns 1-4) and overall MQI (column 5). We will provide results for the simpler models in the full paper; here we include only the results for our fully saturated model. Note that no correlation coefficients are large enough to indicate possible multicollinearity concerns.

Several TMs are significant and positive predictors of both overall MQI ratings as well as MQI domains. For example, both the second and third terciles of Keeping Everyone Together are significant, positive predictors of most MQI domains (with the exception of Overall Errors and Imprecision) as well as overall MQI. However, the larger coefficient on the third tercile (0.22) compared to the second (0.13) indicates that more Keeping Everyone Together TMs predict higher overall MQI scores. On the other hand, only the top tercile of Getting Students to Relate significantly predicts MQI domains and overall MQI (recall from Figure 1 that this is a low frequency TM). We also find that the teacher TMs Pressing for Reasoning and Revoicing positively predict both MQI domains and overall MQI scores. The only student TM that positively predicts both MQI domains and overall MQI scores, controlling for all other TMs, is Providing Evidence, and only the top tercile is statistically significant. Interestingly, the top tercile for the student TM Making a Claim predicts lower scores on several MQI subdomains as well as on overall MQI ($p<0.10$).

Finally, we find that several TMs do not predict subdomains or overall MQI scores, including the student TMs Relating to Another Student and Asking for More Information and the teacher TM Pressing for Accuracy.

Discussion

Results from this study provide evidence about which types and frequency of discourse aligned with academically productive talk predict mathematical instructional quality. The findings offer validation for the frequent use of specific TMs, underscoring the importance of productive talk in mathematics lessons. Overall the results support our hypothesis that lessons with more talk moves are associated with higher ratings of instructional quality, particularly with regard to accountability to the learning community and rigorous thinking.

Our findings contribute to the extant literature on talk move frequency as an important indicator of instructional quality. However as Wolf and colleagues (2005) demonstrate, TMs can vary in quality from substantive to more formulaic use, with strong teacher TMs eliciting rich discussion and weak TMs eliciting only surface level information.

Another important finding from this study is that both the amount of talk in a lesson and the percentage of student talk were either negative or null predictors of instructional quality ratings. This indicates that the quality and nature of TMs in math lessons is more important than simple quantifications of overall talk. Nathan and Knuth (2003)'s work helps to explain this finding by highlighting the distinction between teacher-student talk and student-student talk. They argue that students are more likely to attend to information that flows from the teacher to students, likely because fellow students are perceived as lacking authority to support coherent and accurate mathematical understandings. Our results support this distinction. Therefore, with respect to determining instructional quality, basic metrics such as percent of student talk may not sufficiently capture the subtleties involved.

Conclusion

This study affirms the importance of identifying how particular talk moves, such as those derived from theories regarding academically productive discourse, are related to high quality mathematics instruction. Further, by employing the unique methodological approach of using AI models to classify TMs from classroom transcripts, this study demonstrates the relative ease and promise of connecting automated discursive information with existing data such as instructional quality or student achievement. This effort offers new insights into how to study teaching and what aspects to study, which may ultimately be useful for improving teaching at scale (Correnti et al., 2015).

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Table 1. MQI indicators used in this study, by instructional domain

Richness of the Mathematics					
Linking and Connections	Explanations	Multiple Procedures or Solution Methods	Developing Mathematical Generalizations	Mathematical Language	Overall Richness of Mathematics
Working with Students and Mathematics					
Remediation of Student Errors and Difficulties		Responding to Student Mathematical Productions in Instructions		Overall Working with Students and Mathematics	
Errors and Imprecision					
Major Mathematical Errors	Imprecision in Language or Notation		Lack of Clarity in Presentations of Mathematical Content		Overall Errors and Imprecision
Student Participation in Meaning-Making and Reasoning					
Students Provide Explanations	Student Mathematical Questioning and Reasoning		Enacted Task Cognitive Activation	Overall Student Participation in Meaning-Making and Reasoning	

NOTE: This study used NCES data for which an early version of the MQI was applied to most lessons. This early version had three rating options: low, mid and high for each coded lesson segment. In an updated version of the MQI, a "not present" score option was added. For our analyses, we removed 347 NCES lessons in which raters applied the updated version of the MQI. Additionally, in the updated version of the MQI, Student Participation in Meaning-Making and Reasoning was renamed Common Core Aligned Student Practices.

Table 2. Talk moves by category

	Learning Community	**Content Knowledge**	**Rigorous Thinking**
Teacher Talk Moves	● Keep Everyone Together ● Getting Students to Relate ● Restating	● Pressing for Accuracy	● Pressing for Reasoning ● Revoicing
Student Talk Moves	● Relating to Another Student ● Asking for More Information	● Making a Claim	● Providing Evidence

Table 3. Correlations between talk moves and MQI constructs for each dataset

	Learning Community					Content Knowledge		Rigorous Thinking			
	Keep Everyone Together	Getting Students to Relate	Restating	Relating to Another Student	Asking for More Information	Press for Accuracy	Making a Claim	Press for Reasoning	Revoicing	Providing Evidence	Percent Student Talk
Human Coded (N=119)											
Overall Richness	0.17+	0.18+	-0.04	0.00	-0.04	0.07	0.06	0.28**	0.11	0.19*	0.04
Overall Working With Students	0.22*	0.33***	0.00	0.07	0.03	0.18+	0.13	0.40***	0.17+	0.30**	0.05
Overall Student Participation in Meaning-Making and Reasoning	0.20*	0.32***	-0.1	0.16+	0.15	0.02	0.09	0.40***	0.12	0.45***	0.19*
(Reverse) Overall Errors and Imprecision	0.05	0.18+	-0.22*	-0.1	-0.04	-0.05	-0.21*	0.16+	-0.07	0.12	-0.25**
Whole-Lesson MQI (5-Point Scale)	0.18+	0.29**	-0.04	-0.02	-0.05	0.12	0.04	0.44***	0.13	0.26**	-0.05
AI Coded (N=119)											
Overall Richness	0.24**	0.27**	0.02	-0.03	-0.02	0.09	0.03	0.31***	0.1	0.24**	0.03
Overall Working With Students	0.25**	0.40***	0.03	-0.04	0.09	0.17+	0.06	0.41***	0.11	0.31***	0.06
Overall Student Participation in Meaning-Making and Reasoning	0.23*	0.31***	-0.09	0.00	0.20*	0.02	0.00	0.43***	0.03	0.48***	0.20*
(Reverse) Overall Errors and Imprecision	0.08	0.18+	-0.20*	-0.19*	-0.1	-0.05	-0.24**	0.15	-0.08	0.09	-0.26**
Whole-Lesson MQI (5-Point Scale)	0.23*	0.29**	-0.02	-0.12	-0.05	0.1	-0.03	0.43***	0.13	0.30**	-0.05
AI Coded (N=1313)											
Overall Richness	0.18***	0.20***	0.07**	-0.02	0.02	0.16***	0.10***	0.26***	0.24***	0.20***	0.01
Overall Working With Students	0.21***	0.26***	0.02	0.03	0.15***	0.16***	0.13***	0.34***	0.20***	0.32***	0.11***
Overall Student Participation in Meaning-Making and Reasoning	0.17***	0.27***	-0.06*	0.06*	0.17***	0.04	0.05+	0.36***	0.12***	0.43***	0.19***
(Reverse) Overall Errors and Imprecision	0.04	0.08**	-0.11***	-0.02	-0.02	-0.07*	-0.10***	0.08**	-0.05+	0.06*	-0.05+
Whole-Lesson MQI (5-Point Scale)	0.18***	0.19***	0.00	0.00	0.02	0.12***	0.05+	0.28***	0.16***	0.23***	-0.01

Note: +p<0.1;*p<0.05;**p<0.01;***p<0.001

Table 4. OLS regression predicting MQI domains and overall MQI score using talk moves

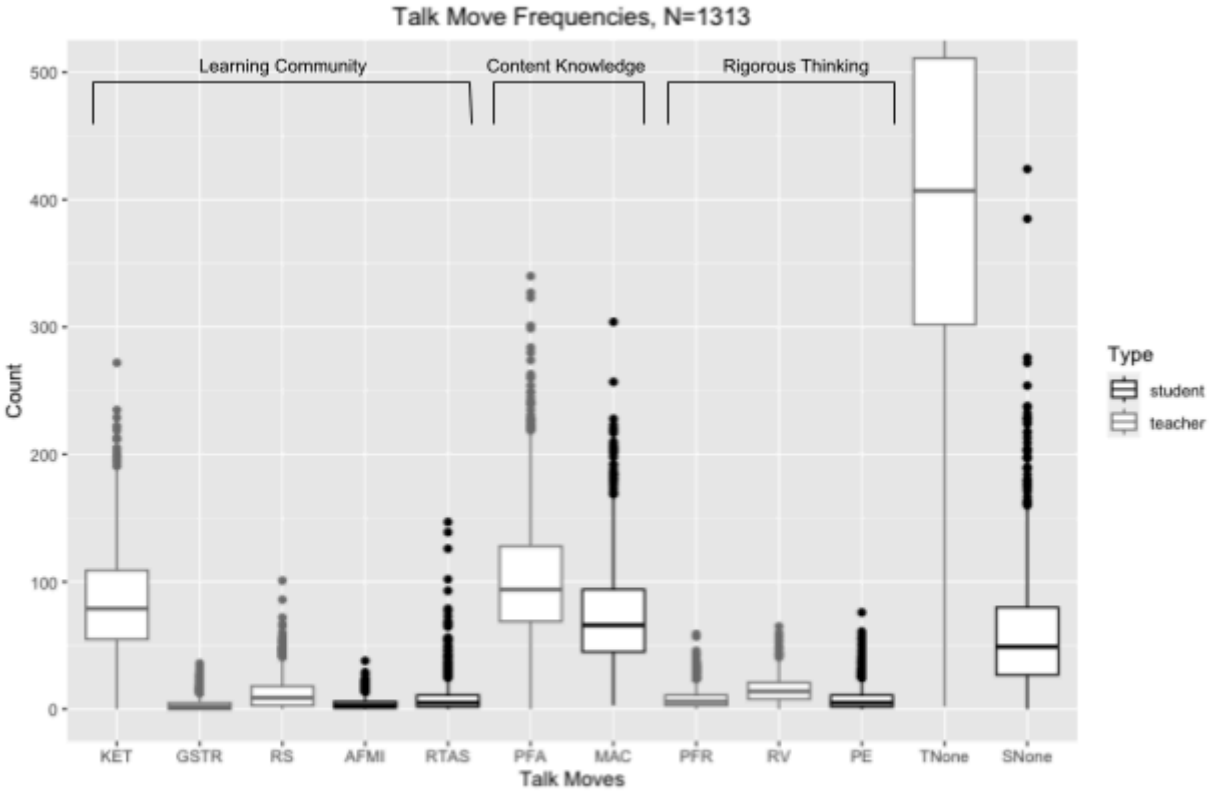
	Overall Richness	Overall Working with Students	Overall Errors and Imprecision (Reversed)	Overall Student Participation in Meaning-Making and Reasoning	Overall MQI
Learning Community					
Keep Everyone Together 2	0.06*	0.08***	0.00	0.08***	0.13*
	(0.02)	(0.02)	(0.02)	(0.02)	(0.05)
Keep Everyone Together 3	0.08**	0.11***	0.00	0.11***	0.22***
	(0.03)	(0.03)	(0.02)	(0.02)	(0.06)
Getting Students to Relate 2	-0.02	-0.03	0.01	0.00	0.07
	(0.02)	(0.02)	(0.02)	(0.02)	(0.05)
Getting Students to Relate 3	0.06*	0.07**	0.05*	0.08***	0.21***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.05)
Restating 2	0.03	0.00	-0.05*	0.01	-0.06
	(0.02)	(0.02)	(0.02)	(0.02)	(0.05)
Restating 3	0.02	-0.05+	-0.07**	-0.05*	-0.09
	(0.03)	(0.02)	(0.02)	(0.02)	(0.06)
Relating to Another Student 2	0.00	0.00	-0.02	0.00	-0.08
	(0.02)	(0.02)	(0.02)	(0.02)	(0.05)
Relating to Another Student 3	0.01	-0.02	-0.04+	0.00	-0.09
	(0.03)	(0.03)	(0.02)	(0.02)	(0.06)
Asking for More Information 2	-0.03	-0.01	0.01	-0.02	0.04
	(0.02)	(0.02)	(0.02)	(0.02)	(0.05)
Asking for More Information 3	-0.01	0.04*	0.00	0.01	0.05
	(0.02)	(0.02)	(0.02)	(0.02)	(0.06)
Content Knowledge					
Pressing for Accuracy 2	0.03	0.01	0.01	-0.02	0.00
	(0.02)	(0.02)	(0.02)	(0.02)	(0.06)
Pressing for Accuracy 3	0.06+	0.02	-0.01	-0.03	0.02
	(0.03)	(0.03)	(0.03)	(0.03)	(0.08)

	Overall Richness	Overall Working with Students	Overall Errors and Imprecision (Reversed)	Overall Student Participation in Meaning-Making and Reasoning	Overall MQI
Making a Claim 2	-0.06*	-0.01	-0.04	-0.02	-0.04
	(0.03)	(0.02)	(0.02)	(0.02)	(0.06)
Making a Claim 3	-0.09*	-0.04	-0.08**	-0.07*	-0.16+
	(0.04)	(0.03)	(0.03)	(0.03)	(0.09)
Rigorous Thinking					
Pressing for Reasoning 2	0.03	0.04+	0.02	0.03	0.10*
	(0.02)	(0.02)	(0.02)	(0.02)	(0.05)
Pressing for Reasoning 3	0.10***	0.11***	0.03	0.08***	0.21***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.06)
Revoicing 2	0.10***	0.08***	0.00	0.08***	0.22***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.05)
Revoicing 3	0.19***	0.12***	0.02	0.10***	0.32***
	(0.03)	(0.03)	(0.02)	(0.02)	(0.06)
Providing Evidence 2	0.01	0.02	0.00	0.04*	0.04
	(0.02)	(0.02)	(0.02)	(0.02)	(0.05)
Providing Evidence 3	0.06*	0.09***	-0.01	0.17***	0.16**
	(0.03)	(0.02)	(0.02)	(0.02)	(0.06)
Amount of Talk					
Total Sentences	-0.00012**	-0.00008+	0.00012**	-0.00011*	-0.0001
	(0.000047)	(0.000045)	(0.00004)	(0.000042)	(0.00011)
Percent Student Talk	-0.15	0.19	0.10	0.54***	-0.32
	(0.15)	(0.14)	(0.12)	(0.13)	(0.35)
Constant	1.25***	1.15***	2.67***	1.05***	2.66***
	(0.04)	(0.04)	(0.03)	(0.04)	(0.10)
R2	0.132	0.171	0.040	0.224	0.115
R2 Adj.	0.118	0.157	0.023	0.211	0.100
RMSE	0.29	0.28	0.25	0.26	0.70

+p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001

Note: The terciles are as follows: Keep Everyone Together (0-11, 11-97, 97-272), Getting Students to Relate (0-1, 1-3, 4-36), Restating (0-5, 5-14, 14-101), Relating to Another Student (0-3, 3-9, 9-147), Asking for More Information (0-2, 2-5, 5-38), Press for Accuracy (1-78, 78-114, 114-340), Making a Claim (3-50, 50-81, 82-304), Press for Reasoning (0-4, 4-9, 9-59), Revoicing (0-9, 10-17, 17-65), Providing Evidence (0-3, 3-9, 9-76).

Figure 1. Talk moves frequencies in the full dataset



Note. Talk moves are organized by construct. The abbreviations reference the following talk moves: KET: Keep Everyone Together; GSTR: Getting Students to Relate; RS: Restating; AFMI: Asking for More Information; RTAS: Relating to Another Student; PFA: Pressing for Accuracy; MAC: Making a Claim; PFR: Pressing for Reasoning; RV: Revoicing; PE: Providing Evidence; TNone*: Teacher utterance with no talk moves; SNone: Student utterance with no talk moves. *TNone continues beyond the range shown here.