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The Link Between Student-Perceived Teacher Talk and Student Enjoyment, Anxiety, and Discursive Engagement in the Classroom

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Abstract

This study seeks to understand the emotional connection of teachers' academically productive talk (APT) with student learning from the students' perspective. Using a sample of 2,225 students ($N_{7th\ grade}$ = 1,146 and $N_{8th\ grade}$ = 1,079) from 16 middle schools in a city of China, we investigate the relationship between students' perceptions of their teachers' APT, student emotions (enjoyment and anxiety), and their discursive engagement with others in the mathematics classroom. Results from structural equation modelling and mediation analysis show that after controlling for gender, family resources, and mathematics achievement, student-perceived teacher APT was positively associated with their discursive engagement with classmates. Furthermore, student enjoyment and anxiety in class mediated the relationship between student-perceived teacher APT and student discursive engagement with classmates. Multi-group analysis revealed that the model was invariant across genders and grades, indicating that the associations were applicable to male and female students as well as to seventh and eighth graders. These findings shed light on the emotional relationship of teacher APT with the discursive engagement of their students. Although prior research observes a positive relationship between teacher productive classroom talk and student discursive engagement primarily through classroom observations and teacher reflections, this study provides evidence from the students' perspective and highlights the mediating role of student emotions in the relationship.

Keywords: classroom talk, academically productive talk, enjoyment in class, discursive engagement

The Link Between Student-Perceived Teacher Talk and Student Enjoyment, Anxiety, and Discursive Engagement in the Classroom

Although past studies from the perspectives of teachers and researchers show how teachers' guidance of productive classroom talk supports students' cognitive processes, few have investigated the social and emotional relationship between teacher talk and student classroom engagement from the perspective of students. To fill this gap, this study examines how students' perceptions of the teacher's use of classroom talk are linked to their emotions (enjoyment and anxiety) and discursive engagement with classmates. Specifically, we examine the academically productive talk (APT) of teachers from the students' perspective. APT is a form of dialogic instruction that teachers use to position students as active thinkers in classroom conversations (Michaels & O'Connor, 2015; Resnick, Asterhan, & Clarke, 2015).

In the existing literature, a variety of terms are used to conceptualise dialogic instruction (e.g., academically productive talk, accountable talk, dialogic inquiry, dialogic teaching, and productive classroom dialogue; Alexander, 2017; Pehmer, Gröschner, & Seidel, 2015; Resnick, Michaels, & O'Connor, 2010; Wells & Ball, 2008). A central principle underlying dialogic instruction is that teachers can guide students to verbalise, share, and co-construct knowledge about the subject matter not only individually but also by thinking and interacting with others (Resnick et al., 2015; Webb et al., 2014).

In addition, the literature on classroom interaction finds reciprocal links between teacher behaviour and student engagement that is mediated through the students' perceptions of their teachers' behaviour (e.g., Frenzel, Becker-Kurz, Pekrun, Goetz, & Lűdtke, 2018; Frenzel, Goetz, Lűdtke, & Pekrun, 2009; Hughes & Chen, 2011). A frequently cited case is the reciprocation of emotion between teachers and students, with the teachers' enjoyment of teaching "infecting" their students, who subsequently "catch" the enjoyment and engage in learning with their peers (Hatfield, Cacioppo, & Rapson, 1994). However, there are few studies regarding classroom talk, a large part of classroom activities, that consider the associations of teachers' productive classroom talk with student emotions and discursive engagement with others. Therefore, the purpose of the present study, drawing on the conceptual frameworks of the reciprocal links between teacher and student classroom behaviours (Frenzel et al., 2009, 2018; Skinner & Belmont, 1993; Skinner, Furrer, Marchand, & Kindermann, 2008), is to understand the relationship between student-perceived teacher APT, student academic achievement, their enjoyment or anxiety, and their discursive engagement with others in the classroom.

Teacher Academically Productive Talk (APT) in the Classroom

Researchers have found that certain forms of classroom talk are beneficial for student learning and skill development (Alexander, 2017; Gillies, 2017; Howe & Abedin, 2013; Littleton & Mercer, 2013; Michaels, O'Connor, & Resnick, 2008; Resnick et al., 2015; Zwiers & Crawford, 2011). One essential element of such classroom talk—which the present study calls academically productive talk—is that it highlights the role of teachers in orchestrating student participation, argumentation, and evaluation (Resnick et al., 2010; Reznitskaya & Wilkinson, 2017).

Teachers use APT to structure and facilitate classroom discussions, opening up space for students to think for themselves and with others about school subject matters (Michaels et al., 2008). For example, teachers may allow "wait" or "thinking" time (e.g., "Think about this for a moment") after asking questions so that a greater number of students, not just those who raise

their hands first, have a chance to develop their ideas and contribute (Michaels, Shouse, & Schweingruber, 2008). Teachers can ask students to explain their reasoning (e.g., "Why do you think so?") and thus encourage individual student thinking. They can also ask students to apply their own reasoning to someone else's reasoning (e.g., "Do you agree/disagree, and why?") to share their thinking with others. In addition, teachers can help students listen carefully to others and try to understand them (e.g., "Who can restate what she just said?"). When students are guided to elaborate on their own thinking and respond to the ideas of others, they have increased opportunities to re-examine what they know, test their mental models, and evaluate other hypotheses (Mercer, Wegerif, & Louis, 2019; Resnick et al., 2015).

Given the findings about the influence of teacher APT in the classroom (Mehan & Cazden, 2015; Resnick et al., 2015), it is nonetheless surprising that few studies exist on student perceptions and behaviours under dialogic instruction (notable exceptions include Asterhan & Schwarz, 2016; Fisher & Larkin, 2008; Kiemer, 2017; Pratt, 2006; Rop, 2003). For example, Asterhan and Schwarz (2016), in "Three-Node Argumentation for Learning Framework", include individual learner characteristics (e.g., the student's cognitive status, motivation, and epistemological beliefs) as influential factors that might inhibit or enable the implementation of argumentation dialogue. Kiemer (2017) interprets a teacher's productive classroom talk as providing supportive social context to develop students' motivational learning outcomes and explores teacher professional development circles that can promote such a link. Moreover, most studies that have investigated the importance of teacher APT have focused on the cognitive process of classroom interaction from the researchers' and the teachers' perspectives. Few reports on the students' perceptions of teacher talk or, in particular, on how those perceptions are associated with the social-emotional process of classroom interaction and engagement.

Student Emotion in the Classroom

Students' positive emotions, such as enjoyment in class, are an important part of the school experience and influence learning and achievement (Frenzel et al., 2009, 2018; Pekrun et al., 2002b). Positive emotions help facilitate problem-solving, resiliency, self-regulation, positive group behaviour, and attachments to others (Fredrickson, 2001; Mainhard, Oudman, Hornstra, Bosker, & Goetz, 2018; Pekrun et al., 2002a). In contrast, negative feelings such as sadness, anxiety, and confusion may inhibit or discourage students' participation in class activities and their engagement with others (Do & Schallert, 2004).

Teacher-student classroom interactions play an important role in building these emotions. According to the social-cognitive learning theory by Bandura (1986), teacher behaviour in the classroom (e.g., cognitive modelling) is associated with the students' task performance. When students sense positive emotions such as enjoyment, interest, and intrinsic motivation in their teachers, their task-relevant engagement and academic effort often increase (Deci & Ryan, 1985, 2011; Mainhard et al., 2018; Pekrun, 2006; Ryan & Deci, 2000).

While previous research highlights the general relationship between teacher classroom practice and student emotions, the present study examines the relationship between teacher APT and student enjoyment and anxiety in the classroom. It seeks to understand how student emotions mediate the relationship of teacher APT with student discursive engagement with other students. We hypothesise that teacher APT, which creates space for students to actively think and participate, is related to students' higher enjoyment and lower anxiety, which in turn should benefit the students' discursive engagement with others.

Student Discursive Engagement with Others in the Classroom

Student engagement is a robust predictor of student learning, achievement, and fulfilment of long-term educational goals (Christenson, Reschly, & Wylie, 2012; Klem & Connell, 2004). Engaged students do more than just attend class; they self-regulate their behaviour, challenge themselves, and enjoy challenges in learning (Christenson et al., 2012; Klem & Connell, 2004). Proposed by Fredricks, Blumenfeld, and Paris (2004), a frequent measurement of student engagement is the interrelated behavioural, emotional, and cognitive dimensions of their engagement.

Recently, two lines of development have emerged. First, researchers have argued for a more domain-specific, environmental, and situated way of theorising and measuring engagement (Azevedo, 2015; Salmela-Aro, Moeller, Schneider, Spicer, & Lavonen, 2016; Sinatra, Heddy, & Lombardi, 2015). Second, social-behavioural engagement, which concerns the quality of the students' social interactions, has received considerable attention due to a growing emphasis on learning through social and collaborative activities (Fredricks et al., 2016; Pekrun & Linnenbrink-Garcia, 2012; Shernoff et al., 2016; Stahl, 2006; Wang, Fredricks, Ye, Hofkens, & Linn, 2016). As the interactive-constructive-active-passive (ICAP) framework suggests, learning conditions and activities are more effective in interactive (e.g., collaboratively co-constructing solutions) and constructive (e.g., asking questions and providing explanations) environments of engagement than they are in active (e.g., underlining text sentences) and passive (e.g., listening) ones (Chi & Wylie, 2014).

With this in mind, the present study defines student discursive engagement with others as the degree to which students are involved with others in conversational interactions to learn about the subject matter within a domain-specific context, such as a mathematics classroom (though students can certainly learn without discursive engagement). Further, the literature identifies two dimensions of student discursive engagement: (1) elaborating one's own thinking and (2) engaging with others' ideas (Resnick et al., 2010; Webb et al., 2014). Engagement with others' ideas is worth noting because interactions between students are beneficial for learning and achievement. Webb et al. (2014) explain the potential benefits of engaging with others' ideas. First, when students engage in discourse, they benefit from monitoring their own thinking by offering ideas and listening to other students. Second, they benefit from the process of having their own ideas challenged and defending them. Furthermore, students benefit rhetorically from interacting with peers by spreading useful argument stratagems in discussions, as Anderson et al. (2001) suggest. Webb et al. (2008), who investigate the relationship between the teacher's facilitation of the students' explanations and levels of student explanation to others, find that when the teacher asks students to explain and give follow-up explanations in class and in small groups, they often give correct and complete explanations, and this in turn, leads to improved academic achievement. Therefore, based on this rationale, we argue that by promoting student thinking and collaborative reasoning, teacher APT likely influences student discursive engagement with others not only within the classroom as a whole but also within small group settings (Khong, Saito, & Gillies, 2017; Mercer & Dawes, 2014).

In the present study, we do not distinguish between cognitive, emotional, behavioural, or social engagements since the literature suggests that these dimensions may be interrelated and sometimes difficult to differentiate (Eccles, 2016). We see student discursive engagement as a construct of student academic discourse participation, having a single one or a combination of the above engagement dimensions, being interrelated and not easy to differentiate (as Eccles mentioned), and more importantly, being characterised by student talk moves of sharing,

explaining, arguing, justifying, constructing, and building on the ideas of one another in the process of learning. Such student discursive engagement has been less focused on in empirical studies, which may be due to the tendency of seeing it as peripheral or a natural product of teacher-guided discourse (Hardman, 2019)—a common perspective that is likely to be influenced by the tradition of studying the triadic classroom discourse structures, such as initiation-response-follow-up (IRF; Sinclair & Coulthard, 1975) and initiation-response-evaluation (IRE; Mehan, 1979; Mehan & Cazden, 2015). However, understanding student discursive engagement is not peripheral but important, especially in relation to teacher talk moves. Does it have a direct association with perceived teacher talk, as one may assume, or are there any other variables that mediate the transmission from perceived teacher talk to student discursive engagement? Researchers recently have set some examples of investigating this question in the context of teacher professional development. They have established the possible connections between teacher professional development focused on teacher classroom dialogue and improved student learning interest and motivation in mathematics and science (e.g., Kiemer, 2017; Kiemer et al., 2015), but the study of student emotions regarding their enjoyment or anxiety in class remains a research gap to be filled.

As another gap, evidence of the association between teacher talk and student discursive engagement has come principally from the interpretation of classroom discourse data and/or from teachers' and researcher's perspectives. Little is known about how students perceive the emotional and discourse benefits of their teachers' APT, that is, whether students see teacher APT as beneficial or distracting or how such perceptions may be associated with their emotions and discursive engagement with others in the classroom (Clarke, 2015; Fisher & Larkin, 2008; Howe, 2017; Pratt, 2006; Rop, 2003). This study contributes to the literature by filling the aforementioned two gaps: (1) investigating the association between teacher talk and student discursive engagement in the classroom from student perspectives and (2) investigating student emotions in the classroom (i.e., enjoyment and anxiety) as a possible mediator of the relationship between teacher talk as perceived by students and student discursive engagement with others.

The Present Study

In sum, this study conceptualises the relationships between student-perceived teacher APT, student enjoyment or anxiety, and their discursive engagement with others as part of the reciprocal model of classroom talk (see Figure 1). The model is based on the reciprocal model of classroom behaviour (Frenzel et al., 2018; Skinner & Belmont, 1993), which posits that teacher behaviour is associated with student behaviour via the students' perceptions of the former and vice versa (Frenzel et al., 2009; Skinner et al., 2008). Furthermore, emotions mediate the relationship between the teacher's and the student's behaviour (Frenzel et al., 2018; Hatfield et al., 1994). The present study focuses only on the part indicated by the solid rectangles and arrows (the shaded area) in Figure 1. We argue that student-perceived teacher talk is associated with student discursive engagement in the classroom. Further, student emotions (enjoyment or anxiety) in class mediates this relationship. In Figure 1, the part indicated by dashed rectangles and arrows suggests that teacher-perceived student discursive engagement is associated with teacher talk via the teacher's emotions in the classroom. However, due to the present study's scope and data constraints, this part has been left for future research. Ideally, a full model incorporates both parts to test the reciprocal links, which may provide a more comprehensive understanding of the mechanisms of teacher-student interactions in the classroom.

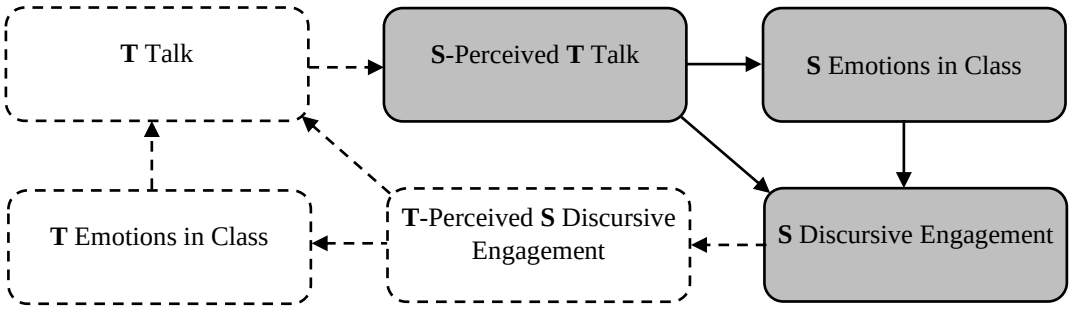

Figure 1. The reciprocal model of classroom talk. **T**: Teacher; **S**: Student. The model is based on Skinner and Belmont (1993) and Frenzel et al. (2018), but the study focuses only on the part indicated by solid rectangles and arrows (the shaded area). The dashed rectangles and arrows show ideas and links for future studies.

The present study mainly contributes to the literature by answering the following research questions: (1) To what extent is student-perceived teacher APT related to student discursive engagement with others in the classroom? (2) To what extent is student-perceived teacher APT related to student emotions in the classroom, in particular to their enjoyment or anxiety? (3) To what extent do students' emotions mediate the relationship between student-perceived teacher APT and student discursive engagement with others in the classroom? Previous research suggests that student academic achievement, gender, and family backgrounds may relate to their levels of engagement in classroom discussions (Borg, 2015; Kelly, 2008), so the present study examines these factors as well. By examining these research questions, the study will contribute to the literature in three distinctive ways. First, as discussed earlier, student discursive engagement should not be regarded as peripheral or as a natural product of teacher classroom talk. Unravelling the relationship between the form of teacher dialogic instruction, APT, and student discursive engagement with others should help to reveal the mechanisms of effective dialogic pedagogy. Second, the study expands the line of research from attending chiefly to the associations between teacher talk and student learning outcomes to a process-oriented inquiry with respect to student discursive engagement in the classroom. Third, the study investigates the connections between the use of instructional dialogue by teachers and students' enjoyment and anxiety in the mathematics classroom, which is still a conspicuous research gap in the literature.

Method

Participants

This study was conducted in a school district in a city of China. Students, teachers, principals, and parents completed and submitted consent forms before the project began. Stratified random sampling was used to select 16 schools and their 2,290 seventh (N = 1,211) and eighth grade (N = 1,079) students. In total, 2,225 student participants provided information for data analyses (response rate: 97.2%; $N_{7\text{th grade}}$ = 1,146, $N_{8\text{th grade}}$ = 1,079). The mean age of participants was 11.87 years (SD = .73), with 52.4% males and 47.6% females. The mathematics test and the student questionnaire were both administered in paper-and-pencil format in classrooms.

Measures

Student mathematics achievement. Students completed a mathematics achievement test in the class, composed of 29 items (37 sub-items, with a maximum total score of 47) adapted from the released mathematics test items by the Trends in International Mathematics and Science Study (TIMSS) for middle school students (Mullis & Martin, 2013). The mathematics achievement test instructed students to complete two types of questions (i.e., multiple-choice questions and constructed-response questions) within 40 minutes, aiming to measure the students' general mathematics achievement in three cognitive domains (i.e., knowing, applying, and reasoning; Mullis & Martin, 2013). All test items had undergone a rigorous process of validation by TIMSS.

The original test items of TIMSS were designed for eighth grade students internationally. To develop the test paper for the seventh and eighth grade students in the study, we applied the following procedure three months before the start of the project. First, by adapting the released items of the Chinese versions of the TIMSS mathematics tests (administered in Taiwan and Hong Kong, with item difficulties available), the researchers designed a pool of 64 items, upon which they agreed on the appropriateness of content, difficulty level, and cultural and item understanding. Second, eight experienced local mathematics teachers, who each had at least eight years' experience of teaching middle school mathematics and did not participate in the main study, reviewed the item selection process and adjusted the selection and phrasing of items with the researchers to produce 46 items. Third, the researchers conducted a pilot study using the 46 items with a sample of 14 students (7 seventh grade and 7 eighth grade) in the same school district who had similar backgrounds to the main study students. Based on the test results and by checking the expert and concurrent validity conducted by the pilot students' mathematics teachers, we finalised the mathematics test with the remaining 29 items. Since the TIMSS mathematics test has not been administered in the city, the items were not previously exposed to the students, which was also confirmed by the participating teachers.

The psychometric analysis of the 37 sub-items with the 2,225 participating students showed good difficulty and discrimination parameters. The item difficulty indices ranged from 0.11 to 0.87 (M = 0.50, SD = 0.15) and the discrimination power ranged from 0.19 to 0.80 (M = 0.58, SD = 0.15). Out of the 37 sub-items, three were relatively easy (P > 70%), three were difficult (P < 30%), and the remaining 31 were within a recommended range (84%; P = 30% to 70%; Linn, 2008). As for the discrimination power, one item showed poor discrimination power (D = 0.19; < 0.20), one item showed acceptable discrimination power (D = 0.25; 0.20 to 0.29), four were within the acceptable range (0.30 to 0.39), and the remaining 31 items (84%) exhibited excellent discrimination power (> 0.39; Ebel & Frisbie, 1986).

Student-perceived teacher APT in class. Student-perceived teacher APT was assessed from the students' perceptions using six items developed in this study based on the relevant literature on APT (e.g., Anderson, Chapin, & O'Connor, 2011; Hennessy et al., 2016; Michaels & O'Connor, 2015; Resnick et al., 2015; van der Veen, de Mey, van Kruistum, & van Oers, 2017; Webb et al., 2014). Although several studies have investigated classroom talk from the teacher's perspective, few, if any, have measured their discourse from the perspective of the students. This study developed and validated the student-perceived teacher classroom talk scale to evaluate the students' perceptions of their mathematics teachers' APT in the classroom. The scale was in line with the four essential goals for facilitating classroom discussions, namely (1) helping students share their own thoughts, (2) helping students listen carefully to one another, (3) helping students deepen their reasoning, and (4) helping students think with others (Anderson et al., 2011; Michaels & O'Connor, 2015).

We asked students how frequently their mathematics teachers facilitated APT in class (six items; e.g., "My mathematics teacher asks us to explain our thoughts in class," "My mathematics teacher allows enough time for us to answer questions in class," and "My mathematics teacher asks us to evaluate one another's ideas in class."). The answers were rated using a four-point Likert scale ranging from 1 (*rarely*) to 4 (*frequently*). The higher score indicated the higher frequency that the mathematics teacher used APT to engage students in productive classroom talk, as perceived by the students. The scale has good internal consistency (Cronbach's *alpha* = .820 in this study).

Student emotions in class. We developed the scale of student self-reported emotions in class by adapting items from the class-related items of the Achievement Emotions Questionnaire (AEQ) — Mathematics (Pekrun, Goetz, Frenzel, Barchfeld, & Perry, 2011). First, we measured the students' enjoyment of their mathematics class by asking them to indicate how they feel about attending mathematics class (four items; e.g., "I look forward to my mathematics class" and "I enjoy my mathematics class"). Answers were rated using a four-point Likert scale ranging from 1 (*strongly disagree*) to 4 (*strongly agree*). The higher the subscale score, the stronger the enjoyment. The enjoyment subscale is highly internally consistent (Cronbach's *alpha* = .916 in this study).

Second, we measured the students' anxiety in mathematics class (four items). Sample items were "I feel anxious in mathematics class," and "I worry that I'm not able to follow what is being taught in mathematics class." Answers were rated using a four-point Likert scale ranging from 1 (*strongly disagree*) to 4 (*strongly agree*). The higher the anxiety subscale scores, the more anxious the students were. The anxiety subscale is highly internally consistent (Cronbach's *alpha* = .848 in this study).

Student-perceived discursive engagement with others in class. We developed and validated the student discursive engagement with others in class scale based on the literature (Hennessy et al., 2016; Webb et al., 2014). To assess the students' self-reported discursive engagement behaviour with others, the study asked students how frequently they engaged with their classmates in productive classroom talk (five items; e.g., "In mathematics class, I listen to different views by my classmates," "In mathematics class, I discuss with my classmates to learn about the subject matter," and "In mathematics class, I discuss with my classmates to solve problems."). Answers were rated using a four-point Likert scale ranging from 1 (*rarely*) to 4 (*frequently*). Higher scores indicated a higher level of discursive engagement with others in the mathematics classroom, based on self-reporting. The scale has good internal consistency (Cronbach's *alpha* = .821 in this study).

Student gender and family resources. Previous research suggests that student backgrounds might contribute to their discursive engagement in the classroom (Kelly, 2008). We included student gender in the investigation and measured the students' family resources by using yes or no questions adapted from TIMSS assessment (e.g., "Do you have your own computer or tablet?"; Mullis & Martin, 2013). A higher score of affirmative answers indicates better family resources for the child's educational development.

Construct Validity of the Three Scales

To gain evidence of construct validity of the three scales discussed above (i.e., student-perceived teacher APT, student emotions in class, and student discursive engagement with others in the classroom), we first conducted exploratory factor analysis (EFA) using 489 participants' data randomly sampled from the whole dataset, a sample size selected to meet the criteria of the

minimum ratio of participants to items (10:1; Worthington & Whittaker, 2006). Then we conducted confirmatory factor analysis (CFA) using a data set including the rest of 1,736 participants. For the EFA, we applied maximum likelihood with the geomin oblique rotation based on Browne's (2001) recommendation. Missing values were initially handled by the full information maximum likelihood (FIML) method when conducting exploratory and confirmatory factor analysis, since FIML is demonstrated to be a viable method for handling missing values (Schlomer, Bauman, & Card, 2010). We conducted the data analyses using Mplus 7.4 (Muthén & Muthén, 2015).

The EFA results suggested acceptable construct validity of the three scales. All factor loadings of items were higher than .40 and all cross-factor loadings were lower than .30 (Hinton, McMurray, & Brownlow, 2014). Moreover, the primary loadings of all the items were at least 0.2 greater than any cross-loadings between the two subscales (Bedford, 1997). These results suggested that the three scales had sound psychometric properties for further CFA.

The CFA results (with the rest of the data: N = 1,736) are presented in Table 1. The values of comparative fit index (CFI) and Tucker-Lewis index (TLI) of the three scales were all higher than .95, and the root mean square error of approximation (RMSEA) and standardised root mean square residual (SRMR) were all lower than or approximate to .80, indicating good model fits for all three scales (Hu & Bentler, 1999). Table 2 summarises the items and factor loadings for the three scales.

Table 1
CFA Results of the Three Scales Used in this Study (N = 1,736)

		χ^2	*df*	RMSEA	90% CI	CFI	TLI	SRMR
1.	Student-perceived teacher APT	54.19***	7	0.063	.048, .079	0.99	0.97	0.020
2.	Student emotions in class	232.664***	19	0.071	.063, .079	0.98	0.97	0.037
3.	Student-perceived discursive engagement with others in class	29.79***	4	0.062	.042, .084	0.97	0.98	0.016

Notes. APT: Academically Productive Talk; RMSEA: Root Mean Square Error of Approximation; CI: Confidence Interval; CFI: Comparative Fit Index; TLI: Tucker-Lewis Index; SRMR: Standardised Root Mean Square Residual. ***p < .001.

Table 2
Items and CFA loadings for the Three Scales Used in this Study (N = 1,736)

Item	**Standardised Coefficient**	**S.E.**
Scale 1: Student-perceived teacher APT		
1. My mathematics teacher allows enough time for us to answer questions in class.	0.76***	0.01
2. My mathematics teacher stops to leave us time for thinking after asking us questions in class.	0.77***	0.01
3. My mathematics teacher asks us to listen to one another in class.	0.75***	0.01
4. My mathematics teacher asks us to explain our thoughts in class.	0.68***	0.01
5. My mathematics teacher asks questions to test our understanding of what has been taught.	0.58***	0.02

6. My mathematics teacher asks us to evaluate one another's ideas in class.	0.45***	0.02
Scale 2: Student emotions in class		
Sub-scale: Student enjoyment in attending class		
1. I look forward to my mathematics class.	0.80***	0.01
2. I enjoy my mathematics class.	0.89***	0.01
3. I have lots of fun from mathematics class.	0.85***	0.01
4. Learning in mathematics class is very exciting to me.	0.86***	0.01
Sub-scale: Student anxiety in attending class		
1. I feel anxious in mathematics class.	0.93***	0.01
2. I feel uneasy when thinking of mathematics class.	0.75***	0.01
3. I feel nervous in mathematics class.	0.87***	0.01
4. I worry that I'm not able to follow what is being taught in mathematics class.	0.52***	0.02
Scale 3: Student-perceived discursive engagement with others in class		
1. In mathematics class, I listen to my classmates when they speak.	0.70***	0.02
2. In mathematics class, I listen to different views by my classmates to get inspiration.	0.73***	0.02
3. In mathematics class, I discuss with my classmates to learn about the subject matter.	0.75***	0.01
4. In mathematics class, I discuss with my classmates to solve mathematics problems.	0.57***	0.02
5. In mathematics class, I discuss with my classmates to stimulate thinking.	0.70***	0.02

Notes. APT: Academically Productive Talk; *** $p < .001$.

Analysis

Variables. In the structural model, the exogenous latent variable (i.e., the independent variable) was student-perceived teacher APT in class. The mediating variables (latent variables) were student enjoyment and anxiety in class. The endogenous latent variable (i.e., the dependent variable) was student-perceived discursive engagement with others in class. The observed variables were student mathematics achievement (standardised z-scores), gender, and family resources. We considered the associations of the observed variables with both the mediators and the dependent variable.

Common method bias. We conducted Harman's single-factor test to assess the issue of common method variance in the present study (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003). A single-factor CFA using all the items presented in Table 2 revealed an extremely poor fit, with χ^2 (152) = 9240.502, CFI = .600, TLI = 0.549, RMSEA = .164, and SRMR = 0.128. This indicates that common method bias was unlikely to be a serious concern in the data set.

Mediation. To assess mediation, we used Baron and Kenny's (1986) method to examine whether the following conditions hold: (1) the link between the independent variable on the mediator is significant; (2) the mediator's link with the dependent variable (controlled for the independent variable) is significant; and (3) the link between the independent variable and the dependent variable is smaller when controlling for the mediator than without it (Baron & Kenny, 1986; Fritz & MacKinnon, 2007). We used the Sobel test to estimate the indirect mediation (Preacher & Hayes, 2004; Sobel, 1982).

Multi-group SEM. To consider the possible grade differences in the relationship between the variables, we applied multi-group structural equation modelling (SEM) to examine the structural invariance across genders and grades (i.e., seventh and eighth grades). Following

the steps in Vandenberg and Lance (2000), we firstly conducted three hierarchical processes for examining measurement invariance (MI), namely, configural, metric, and scalar invariance. In configural invariance, factor loadings and thresholds are set free across groups. If configural invariance is identified, metric invariance is tested, in which factor loadings are equally constrained across groups. After metric invariance is confirmed, scalar invariance is assessed, in which factor loadings and intercepts of all items are equally constrained across groups (Cheung & Rensvold, 2002). MI is established if (a) the overall model fit is acceptable (Little, 1997) and (b) a value of ΔCFI between two nested models is smaller than or equal to 0.01 (Cheung & Rensvold, 2002).

Results

Descriptive Statistics and Correlations

Table 3 shows the descriptive statistics and correlations between the variables (independent: student-perceived teacher APT; mediators: student enjoyment and anxiety in class; dependent: student-perceived discursive engagement with others in class; and other variables: student mathematics achievement, gender, and student-reported family resources). The mathematics achievement of each grade (i.e., seventh and eighth) was converted into standardised z-scores before conducting subsequent analyses.

Table 3
Descriptive Statistics and Correlation Matrix of the Variables (N = 2,225)

		1.	2.	3.	4.	5.	6.	7.
1.	Gender[a]	-						
2.	Student-reported family resources	.144***	-					
3.	Mathematics achievement[b]	.030	.283***	-				
4.	Student-perceived teacher APT	.033	.178***	.165***	-			
5.	Student enjoyment in class	-.151**	.148***	.237***	.315***	-		
6.	Student anxiety in class	.034	-.097**	-.343**	-.191**	-.490**	-	
7.	Student-perceived discursive engagement with others in class	-.058**	.217***	.245***	.446***	.646***	-.386**	-
M		1.474	13.358	.000	3.425	2.933	2.039	3.203
SD		.499	3.243	.999	.562	.827	.840	.602
Cronbach's $\alpha^{\wedge}$		-	-	-	.820	.916	.848	.821

Notes. APT: Academically Productive Talk; [a] Gender: Male = 1; Female = 2; [b] Mathematics achievement was standardised z-scores at each grade (i.e., seventh and eighth). $^{\wedge}$ Cronbach's $\alpha >$ 0.70 (Nunnally & Bernstein, 1994). $^{**}p < .01$; $^{***}p < .001$.

Examining the Structural Model

First, we tested the links between student-perceived teacher APT, the three observed variables (the z-scores of student mathematics achievement, gender, and family resources), and student discursive engagement with others in mathematics class. The results indicated good model fits, with χ^2 (70) = 651.809, CFI = .932, TLI = .915, RMSEA = .061, and SRMR = .034. There were significant associations of student-perceived teacher APT (β = .479, *SE* = .021, and *p*

< .001), mathematics achievement (β = .149, *SE* = .021, and p < .001), student gender (β = -.103, *SE* = .021, and p < .001), and family resources (β = .126, *SE* = .022, and p < .001) with student discursive engagement with others in class.

Next, we added the two mediators (student enjoyment and anxiety in class) into the model. Again, we obtained good model fits, with χ^2 (189) = 1514.637, CFI = .939, TLI = .926, RMSEA = .056, and SRMR= .043 (Figure 2). Sobel test results showed significant mediation. Student enjoyment (β = .299 × .662 = .198, *SE* = .015, z = 9.604, and p < .001) and anxiety (β = -.215 × -.045 = .010, *SE* = .005, z = 2.080, and p < .05) mediated the relationship between student-perceived teacher APT and student discursive engagement with others. After accounting for mediation, the link between student-perceived teacher APT and student discursive engagement with others decreased from β = .479 and p < .001 to β = .269 and p < .001, indicating significant partial mediation. Overall, indirect links accounted for 43.4% of the relationship between student-perceived teacher APT and student discursive engagement with others, with a stronger link through student enjoyment (41.3%) than through student anxiety in class (2.1%), which was also reflected by the small mediation of student anxiety (β = .010).

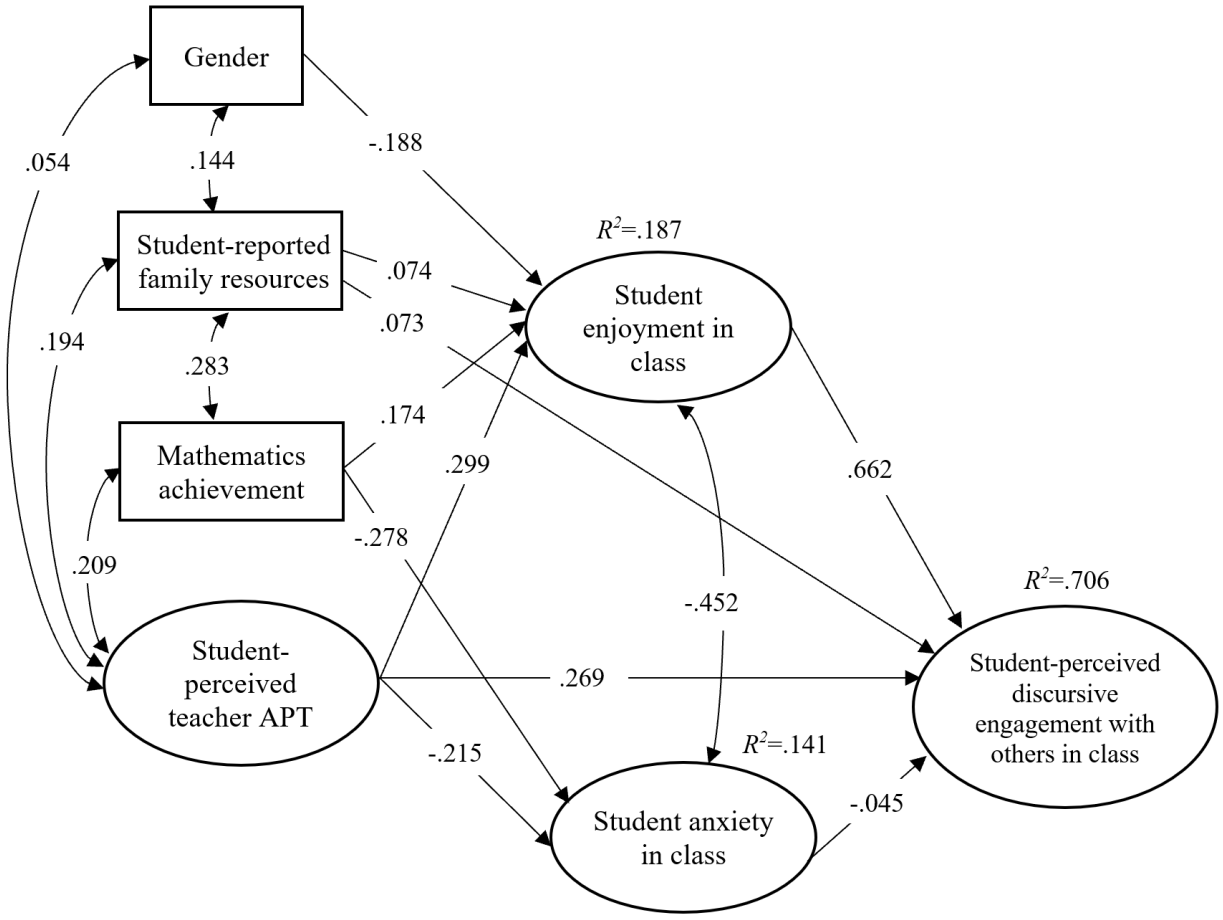

Figure 2. Structural equation model testing the relationship between student-perceived teacher APT, student emotions (enjoyment, anxiety), and student-perceived discursive engagement with others in mathematics class. Gender: *Male* = 1, *Female* = 2. To simplify the view, the observed indicators of each latent variables are not shown in the figure. All the correlations and path

coefficients shown in the figure are standardised and statistically significant ($p < .05$). Goodness of fit: $\chi^2 = 1514.637$; $df = 189$; CFI = .939; TLI = .926; RMSEA = .056; SRMR = .043.

As for the observed variables, the students' mathematics achievement was positively related to their enjoyment ($\beta = .174$ and $p < .001$) and negatively related to their anxiety ($\beta = -.278$ and $p < .001$) in attending mathematics class (see Figure 2). Gender (male = 1 and female = 2) was negatively related to student enjoyment ($\beta = -.188$ and $p < .001$), showing that female students were less likely to enjoy mathematics class. Student family resources were positively related to student enjoyment ($\beta = .074$ and $p < .001$) and student discursive engagement with others ($\beta = .073$ and $p < .001$) in mathematics class.

Structural Invariance Across Genders and Grades

Multi-group SEM was used to examine the possible gender and grade differences in the relationships between student-perceived teacher APT, student emotions, and student discursive engagement with others in the classroom across genders and grades (i.e., seventh and eighth). The structural invariance could only be evaluated under the precondition of the measurement invariance across groups. Results of testing measurement invariance showed that the overall model fits were good, and ΔCFIs were .003 or smaller between two nested models (Table 4), which were smaller than .01, indicating that configural, metric, and scalar invariances were established in the proposed model for gender and grade. Therefore, structural invariance was examined next.

Table 4

Fit Indices for Measurement Invariance Tests of the Model across Genders and Grades (N_{total} = 2,225)

Model	χ^2	*df*	CFI	ΔCFI	TLI	RMSEA	SRMR
M1: Baseline model	1416.910	144	.944	-	.933	.063	.046
M2 [a]: Configural invariance	1589.267	288	.943	.001	.932	.064	.048
M3 [a]: Metric invariance	1638.397	303	.941	.002	.934	.063	.053
M4 [a]: Scalar invariance	1727.123	318	.938	.003	.933	.063	.056
M5 [b]: Configural invariance	1609.732	288	.942	.002	.931	.064	.047
M6 [b]: Metric invariance	1622.036	303	.942	.000	.935	.063	.049
M7 [b]: Scalar invariance	1673.416	318	.941	.001	.936	.062	.049

Notes. [a] Fit indices for measurement invariance tests of the model across genders (N_{male} = 1,166; N_{female} = 1,053). [b] Fit indices for measurement invariance tests of the model across grades ($N_{7th\ grade}$ = 1,146; $N_{8th\ grade}$ = 1,079). CFI: Comparative Fit Index (> .90); TLI: Tucker-Lewis Index (> .90); RMSEA: Root Mean Square Error of Approximation (< .10); SRMR: Standardised Root Mean-square Residual (< .08) (Hu & Bentler, 1999; Marsh, Hau, & Wen, 2004).

We then examined the null hypothesis of equality of path coefficients in the proposed model across genders and grades with the "Model test" command in Mplus 7.4 (Muthén & Muthén, 2015; Wang & Wang, 2012). If the Wald chi-square test was significant, we constrained one specific structural path to be equal at a time to identify paths with significant grade differences. If no significance was identified, we stopped the analysis.

The differences in path estimates of the SEM model across genders and grades were assessed by equally constraining the corresponding path coefficients for each group. The results of omnibus Wald tests across genders (in which gender as a control variable was excluded; Wald $\chi^2(9) = 7.654$ and $p = .57$) and across grades (Wald $\chi^2(10) = 13.794$ and $p = .18$) showed that there was no significant difference in the path coefficients, indicating that all paths were equal for male and female students as well as for seventh and eighth graders.

Discussion

The study's findings show that student-perceived teacher APT was positively related to student discursive engagement with other students in class. Furthermore, student-perceived teacher APT was significantly associated with student emotions (i.e., higher enjoyment or lower anxiety in class), which further mediated the relationship between student-perceived teacher APT and student discursive engagement with others in class. In addition, student mathematics achievement was not directly related to their discursive engagement with others. Rather, students with higher mathematics achievement tended to report experiencing higher enjoyment and lower anxiety, which in turn were linked to more discursive engagement with others in mathematics class. Extending prior research that has observed a positive relationship between teacher productive talk and student discursive engagement primarily through classroom observations and teacher reflections, this study provides evidence from the students' perspective and highlights the mediating role of student emotions in the relationship. We discuss the findings and implications below.

Teacher APT and Student Discursive Engagement with Others

The positive relationship between teacher APT and student discursive engagement with others is consistent with findings in the literature (Khong et al., 2017; Littleton & Mercer, 2013). Researchers have discussed the distinctive role of teacher talk in orchestrating and modelling the interactive environment of learning and cognition, together with the structures, features, and teacher professional development programs that align with it (Alexander, 2017; Gillies, 2016; Howe & Abedin, 2013; Osborne, 2010; Resnick et al., 2010). This study contributes to the literature by providing evidence from the students' perspective of teacher APT in the classroom. As Resnick et al. (2010) maintain, teachers may use questions to check the students' understanding by saying "Can you justify your answer?" and to encourage students to reason with one another (e.g., by saying "Do you agree or disagree, and why?", "Can you elaborate on what s/he has just said?"). After asking questions, teachers may allow thinking/wait time for students to have a chance to develop more complex ideas (Michaels et al., 2008). In our study, we find that according to analyses of students' self-perception data, if students perceive their teachers as using a higher frequency of APT talk moves, the students are more likely to report discursive engagement with others in the classroom (e.g., listening to others' ideas and discussing the topic with other students).

Teacher APT and Student Emotions in the Classroom

The associations between student-perceived teacher APT and student emotions in class (i.e., a positive association with student enjoyment and a negative association with student anxiety) indicate that when teachers use productive classroom talk to create space for students to think and reason, students are likely to experience higher levels of enjoyment and lower levels of anxiety in the classroom. These findings align with the literature regarding the links between

teacher supportive behaviours (e.g., teacher questions, feedback, scaffolding, and motivational discourse) and student emotions, interest, and motivation (e.g., Kiemer, Gröschner, Pehmer, & Seidel, 2015; Kiemer, 2017; Sakiz et al., 2012). It is likely that teacher APT helps create a social and cognitive environment that promotes positive emotions in their students in the classroom (Deci & Ryan, 2012; Pekrun, 2006; Pekrun et al., 2002a, 2002b; Stone, Deci, & Ryan, 2009).

The Mediating Role of Student Emotions

This study finds that student emotions significantly mediate the relationship between teacher APT and student discursive engagement with others in the classroom. While student enjoyment strongly mediates the relationship between student-perceived teacher APT and student discursive engagement with others, student anxiety weakly mediates the relationship. These results are consistent with Deci and Ryan's (2012) self-determination theory regarding the influence of social environment on the learners' intrinsic motivation (p. 416). Teachers use APT to encourage student thinking and participation, but they may also create a social and cognitive environment where students feel engaged, and these internally rewarded emotions are likely to trigger students' motivation to engage in discussion with others. The control-value theory of achievement also emphasises the significance of student emotions in influencing them to engage in discussions (Pekrun, 2006). Among other things, this theory proposes that having achievement goals, as well as achievement-related control and value beliefs (i.e., control-value appraisal), may affect student emotions, which are likely to impact academic engagement and performance via processes such as cognitive strategies, motivation, and self-regulation. This aligns with the mediating role of student emotions found in this study.

Significance, Limitations, and Directions for Future Research

This study has theoretical implications for the relevance of student-perceived teacher APT and student emotions to an enriched discursive engagement in the classroom. While teachers use APT to encourage student engagement and discussion, they may also create an environment that triggers positive emotions in their students to engage in discussion with others. This is an important finding. Although this study did not involve a teacher professional development (TPD) intervention, the results regarding the associations may indicate the potential benefits of having such TPD for promoting positive student emotions and engagement with others in class. As such, it may fill the gap in the literature by demonstrating that student-perceived teacher talk is not only associated with student discursive engagement but, more importantly, with student emotions in class. This carries implications for TPD focusing on dialogic instruction, as previous literature only explored the impact of such TPD on student learning interest and motivation (e.g., Kiemer, 2017; Kiemer et al., 2015), student higher-order learning (Pehmer et al., 2015), and classroom knowledge co-construction (Higham, Brindley, & Van de Pol, 2014). So far, little has been found on student emotions in class. Future studies could carry on with this line of research to conduct TPD studies and observe the emotional benefits for students (e.g., enjoyment and anxiety) and their dialogic engagement with others in the classroom.

Designed to understand the relationships between teacher talk, student achievement, their emotions, and their discursive engagement with others in class from the students' perspective, this study has a few limitations. First, we assessed the teachers' APT and student discursive engagement with others through student perceptions. Although this may close one gap in the literature, a hybrid multifaceted data collection method that depicts teacher productive talk

behaviour more comprehensively may help reduce concerns about the potential common-method variance. In future studies, observational data collected from students', teachers', and researchers' opinions of lessons would be helpful to address this issue. Second, as our study did not cover silent thinking, future studies might capture such individualised learning through other means such as individual homework, quizzes, and exams. Third, while this study proposed a reciprocal model of classroom talk, it did not investigate how students influence their teachers. Fourth, we did not address the issue of causality between the variables, given the study's use of between-person data (Hamaker, 2012). As for directions for future research, other studies might conduct longitudinal investigations to test the within-person associations of the reciprocal links. This should help to further our understanding of the mechanisms of teacher-student interactions in the classroom.

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Data Availability

The data that support the findings of this study are available on request from the corresponding author upon reasonable request. The data are not publicly available due to privacy or ethical restrictions.

Ethics

The project underwent a rigorous review and obtained approval from the University of Hong Kong's Human Research Ethics Committee (HREC) prior to the Hong Kong Research Grants Council's (RGC) funding of the project.

Conflict of Interest

No potential conflict of interest was reported by the authors.

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