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ORIGINAL PAPER

Measuring Teacher Talk and the Behavior of Autistic Students in Preschool Through Third-Grade Special Education Mathematics Activities

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Abstract

Objectives Teacher talk provides the medium for teaching and learning. However, there has been little emphasis on conceptualizing and measuring teacher talk within specific contexts and populations or the influence that child behavior has on teacher talk. We described and investigated varying models of teacher talk directed individually toward autistic students within 96 special education mathematics activities drawn from larger mathematics lessons. We also examined child behavior within mathematics contexts measured through observation and via teacher report.

Methods Our participants included 39 preschool–third-grade teachers across 14 districts in California and their 66 autistic students ($M_{age} = 6.74$ years, $SD = 2.04$). We utilized archival video observations from the start of the school year collected as part of a longitudinal study examining a classroom-based intervention for autistic students.

Results Our findings provide support for a five-factor model of teacher talk (instructional talk, questioning techniques, responsive language, directive language, and foundational talk) and shed light upon teachers' overuse of directive language to direct or redirect autistic students' behavior relative to the other talk dimensions. We also documented a significant positive association between teachers' use of non-task-related directives and student emotion dysregulation.

Conclusions This detailed evaluation of teacher talk provides a promising means for gauging the quality of instructional talk and the experiences of elementary-aged autistic students within special education mathematics contexts. Tailoring professional development for educators that centers on understanding developmental characteristics associated with autism and highlighting teacher talk as a targeted intervention is an area for further study.

Keywords Teacher talk · Autism · Emotion regulation · Instructional talk · Directive language · Mathematics activities

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Gauging the quality of mathematics instructional opportunities for autistic learners, who evidence differences in social communication and sensory processing, is highly understudied (American Psychiatric Association, D. S. M. T. F. & American Psychiatric Association APA, 2013). Teacher talk provides the medium for instruction and student learning (e.g., Connor et al., 2020). Thus, observing the talk teachers use with their autistic students within mathematics activities provides insight into students' experiences and the quality of the mathematics learning opportunity. Turning toward the general education literature, teacher talk has consistently been linked with students' developmental and academic outcomes (Milburn et al., 2014; Pianta, 2016), and teachers' responsiveness to their students' contributions and use of open-ended language have been marked as features in high-quality teacher-student interactions (Burchinal et al., 2008; Hamre & Pianta, 2007; Lee & Kinzie, 2012; Massey et al., 2008). Teachers' use of instructional talk within mathematics lessons, such as providing opportunities for students to demonstrate their thinking and monitoring students' understanding of concepts, has been identified as a recommended instructional practice linked to mathematics learning and achievement (Crosnoe et al., 2010).

Studies examining teacher talk with autistic learners are limited overall; however, teachers' use of responsive or "following" language with their autistic learners has been identified as an important feature of talk linked with child spontaneous communication and responses, language development, joint attention, and decreased perceived "problematic behavior" (Koenen et al., 2019; Qian, 2018; Sparapani et al., 2020). Providing students with choice and following their attentional focus has been linked with increased engagement (Ennis et al., 2021; Lane et al., 2015; Tiger et al., 2010; Wong, 2013). Furthermore, teachers' use of mathematics instructional talk with their autistic learners has been associated with student active engagement within special education mathematics activities (Sparapani et al., 2023). Despite this, descriptive studies have identified non-task-related directives, talk used to direct or re-direct attention and/or behavior, as one of the most frequently observed types of talk teachers use with their autistic students, and furthermore, teachers' use of open-ended questions with their autistic learners in classrooms has rarely been observed (Sparapani et al., 2022).

These findings suggest the relationship between teacher talk and student experiences within classrooms might be reciprocal. Studies have outlined predictive associations between teacher talk and student outcomes (Connor et al., 2020); at the same time, students' developmental characteristics and perceived behavior within classrooms appear to influence teachers' talk (Dykstra et al., 2013; Klibanoff et al., 2006). The literature suggests teachers vary the types of talk they use based on their students' language abilities, cognitive skills, degree of autism features, and capacity for emotion regulation (Dykstra et al., 2013; Dobbs et al., 2004; 2009). For example, studies have documented teachers' use of close-ended talk and non-task-related directives to discipline, manage, or control student behavior, particularly with students who exhibit more needs across development (de Kruif et al., 2000). Within early childhood and special education settings, studies have documented higher frequencies of non-task-related directives with students who exhibit less developed language and cognitive skills and more perceived "problematic" or "off-task" behavior (Dobbs & Arnold, 2009; Qian et al., 2018). In contrast, teachers are more likely to use responsive language with students who exhibit better developed expressive and receptive language, and they are more likely to ask open-ended questions that require generative responding to students who exhibit fewer autism symptoms (Qian et al., 2018; Sparapani et al., 2022).

Studies have conceptualized and measured teacher talk differently across classroom contexts and populations (Hadley et al., 2022), making it difficult to draw connections. Hence, the purpose of this study was to propose a measure of teacher talk, drawn from both the general education mathematics and autism literature, to describe and investigate the talk teachers used with their autistic students within special education mathematics contexts. The literature has suggested that specific features of teacher talk are linked to mathematics learning within general education settings (Chapin et al., 2003; Franke et al., 2007), and although not directly studied in autistic learners, this could generalize to autistic populations. At the same time, autistic learners, who exhibit vast heterogeneity across development, present a range of behaviors within the classroom that influence the talk they receive from their teachers—all of which may impact mathematics learning.

Our study extends the work of Sparapani et al. (2022), who conceptualized a six-factor unidimensional model to broadly measure teacher talk within six categories of classroom activities (i.e., literacy, mathematics, snack, recreation and leisure, other academics, and arts and crafts). The general talk dimension included open-ended questions, language models, close-ended question, directives, indirect requests, and fill-ins. We propose 12 features of talk comprising five distinct dimensions: instructional talk, questioning techniques, responsive language, directive language, and foundational talk. Instructional talk, questioning techniques, and responsive language have been identified as important for academic learning (Connor et al., 2020; Wiebe Berry & Kim, 2008). Elements of foundational talk, such as providing students with choice, making instructional comments, and following their attentional focus, have been associated with positive engagement in autistic students (Lane et al., 2015; Rispoli et al., 2013; Trussell et al., 2018). Finally, we included directive language because it has been frequently observed in educational contexts involving learners on the autism spectrum.

Situated within a neurodiversity framework, which highlights the importance of the environment on learning, we measured the talk teachers directed toward preschool through third grade autistic students during mathematics activities as well as evaluated the association between teacher talk and child behavior as measured through direct observation and via teacher report. We feel that developing a means to gauge teacher talk within mathematics contexts will provide insight into mathematics opportunities presented to autistic learners. In addition, a measure of teacher talk designed for mathematics contexts would generate specific information on the features of talk that teachers are or are not using with their students or features that might be overused. This information will be foundational for teacher professional development. We used confirmatory factor analysis (CFA) to examine the fit of this five-factor model of teacher talk to our data, along with three alternative models. The following three research objectives guided this study: To describe the talk teachers individually direct toward preschool through third grade autistic children during special education mathematics activities, to examine the dimensionality of teacher talk within mathematics contexts using confirmatory factor analysis, and to evaluate the association between teacher talk and child behavior measured through direct observation and via teacher report.

This work is grounded in a neurodiversity perspective, which highlights the interplay between children and their environment and views autistic learners as capable and contributing members within their communities (Acevedo & Nusbaum, 2020; Lambert et al., 2020; Lord et al., 2022). Historically, neurodevelopmental inquiry has viewed autism through a deficit lens, and research and diagnostic efforts have predominantly focused on identifying and rectifying these deficits with the goal of enhancing individuals' quality of life (Sonuga-Barke & Thapar, 2021). The implications of this deficit-oriented model are now coming to light, entering mainstream discussions and academia alike (Pellicano & den Houting, 2022). The rising shift toward a neurodiversity paradigm, recognizing the assets and voices of neurodivergent individuals, has gained prominence in education research and has marked a significant change in both research and practice (White et al., 2023). While in a continual state of development, the neurodiversity perspective fundamentally urges researchers, advocates, educators, school administrators, and the general public to contextualize autism within the lived experiences of individuals. Moreover, it prompts us to reflect on the influence of the environment and how well it aligns with the needs of neurodivergent individuals (Sonuga-Barke & Thapar, 2021).

Classroom environments play a critical role in how autistic children learn (Sonuga-Barke & Thapar, 2021; Vidal et al., 2022). Features in the classroom environment might be effective in shaping learning, or they might create barriers to accessing learning opportunities (Pellicano & den Houting, 2022). The design of a classroom environment, including the opportunities presented to students and the types of talk teachers use within mathematics activities, may be a "match" or "mismatch" with an individual's needs. Improving alignment, or the "match" between learners and their environment, helps to reduce instructional barriers, enabling students' access to the learning opportunity and shaping their classroom experiences and learning outcomes (CAST, 2018).

We consider the interplay between the classroom environment and autistic children's emotion regulation. Emotion regulation is a complex and multi-faceted developmental process that is heavily influenced by one's environment, such that individuals use a range of cognitive, communicative, and/or behavioral strategies to manage physiological arousal and emotional responses to match the demands in their environment (Jahromi et al., 2012; Laurent & Fede, 2021; Mazefsky et al., 2013). Emotion regulation occurs when there is a match between an individual's internal state and their environment. In contrast, dysregulation is observed when one's physiological arousal and/or emotional state appear too high or too low in relation to the demands of the environment (Laurent & Fede, 2021).

Classrooms might be a particularly overstimulating environment for autistic learners who experience heighted sensitivity to sensory input (i.e., sound, visual stimuli, smell, and/or touch), as classrooms are often noisy, lively, bright, and busy (Nuske et al., 2017). In turn, autistic children may present a range of regulatory behavior, such as covering their ears to reduce sound, looking away to avoid visual overstimulation, or moving away from others who are in proximity (Laurent & Gorman, 2018). Vestibular motions such as swaying, flapping, or rocking are often used as calming or comforting strategies. Proprioceptive stimulation, such as tensing, pushing, or squeezing might also be used as coping strategies (Kirby et al., 2017). The presence of dysregulation within classroom activities is indicative of a mismatch between learner and environment, and regardless of whether students' regulatory behavior is effective, it is often misinterpreted within classrooms as "problematic" or "off-task" behavior that needs redirection (Brown et al., 2021). This is evident in the current research literature, as dysregulation has been described as "naughty" or "unmanageable" behavior (Goodall et al., 2022).

The talk that teachers use with their students within academic lessons provides insight into instructional quality of the opportunity and the views teachers have regarding their students as learners (Wiebe Berry & Kim, 2008). Observing teachers' use of responsive language, or how they take up and respond to students' communication and ideas, provides information on how relevant and important they feel the contribution is. Furthermore, teachers' high-frequency use of directive language with their autistic students as a means to manage, extinguish, or redirect off-task behavior (Sparapani et al., 2020; Wilkenfeld & McCarthy, 2020) provides further evidence for the misconception that teachers may have regarding the function of autistic children's behavior and emphasizes views to "fix" behavior rather than reduce instructional barriers within the environment. In fact, words such as "controlling," "punitive," "harsh," and "dismissive" have been used to characterize language environments where there is limited balance between directive language and other types of talk (de Kruif et al., 2000; McWilliam et al., 2003; Reeve, 2009). Studies have also suggested that too many directives relative to other types of talk disrupt the learning process by shifting attention away from instructional goals to focus on compliance, decrease interaction quality by reducing opportunities for students to productively engage in an activity, and contribute to environmental overstimulation for autistic learners (Hart & Whalon, 2013; Keen et al., 2005; Sparapani et al., 2020).

The literature on teacher talk within mathematics contexts for autistic learners is divided. Researchers who draw from the neurodiversity perspective have highlighted both the limited nature of learning opportunities provided to autistic learners and the need for conceptually based mathematics instruction (Lambert & Sugita, 2016; Sparapani et al., 2023). Teacher's use of conceptually oriented talk, which focuses on the underlying concepts of mathematical content (Blazar & Pollard, 2022), provides opportunities for students to demonstrate their understanding of mathematics concepts by thinking deeply, grappling with, and explaining their thinking (Hiebert & Grouws, 2007). Yet, studies have suggested that autistic students are often presented with procedurally based learning opportunities, with a focus on following predetermined steps to carry out mathematics problems without understanding the underlying concepts of an activity (Barnett & Cleary, 2015). Procedurally oriented talk, such as reciting mathematics rules and exercises involving rote practice and memorization, is often characterized by low-cognitive demand, as this type of talk is intended for review and practice (Blazar & Pollard, 2022).

The tension within the literature lies at the intersection between instruction and disability. Drawing from behavioral-based theories, researchers argue for the need to simplify mathematics instruction for autistic learners, who present language-based difficulties that interfere with their capacity to engage in the higher-level mathematics thinking that is involved in conceptual mathematics (Cox & Root, 2020). Yet, without opportunities for both procedural and conceptual mathematics, autistic learners are not provided with active, critical thinking opportunities that translate into becoming mathematical thinkers and doers in the classroom (Lambert et al., 2020).

Similarly, framing questions in an open-ended manner provides opportunities for students to share their ideas and craft generative responses—both of which are central to development and learning (Braun & Hughes, 2020; Hadley et al., 2022; Pentimonti et al., 2017; Wasik & Hindman, 2013). Despite this, closed-ended questions, such as simple questions that require fixed responses, have been documented as the most prevalent type of question provided to autistic learners in classrooms (Milburn et al., 2014). By simplifying interactions and opportunities within mathematics contexts, autistic students may miss opportunities to engage in rich learning experiences that deepen their understanding of mathematical content. This raises concerns about the quality of mathematics instruction that autistic students receive within classrooms and highlights the need to further evaluate teachers' instructional talk and the educational experiences of autistic learners within classrooms—goals of the current study.

Method

Participants

This study used archival data drawn from a 4-year classroom intervention project. Participants included 39 preschool–third-grade special education teachers across 14 districts in California and their 66 autistic students ($M_{age} = 6.74$ years, $SD = 2.04$). University Institutional Review Board approval was granted prior to the start of the larger intervention project, and all participating teachers and families completed the consent process. Teachers had between one and two participating autistic children within their classrooms. Participating teachers were primarily female (85%) and ranged in teaching experience ($M = 9.53$ years; $SD = 6.68$). Seventy-four percent of the teachers identified as Non-Hispanic/Non-Latinx, White/Caucasian. All participating teachers taught within special education contexts: 39% in moderate/severe, 31% in mild/moderate, 23% in autism, and 7% in resource classrooms. Six teachers reported having an autism-specific certification.

Participating students were primarily male (85%) and diverse regarding racial and ethnic background (Table 1). Thirty-two percent (32%) of the participants identified as White/Caucasian; 44% identified as Non-Hispanic/Non-Latinx. Students met classification criteria for having autism spectrum disorder measured via the Autism Diagnostic Observation Schedule, Second Edition (ADOS-2; Lord et al., 2012). Forty-eight percent of the participating students had a cognitive score above 70 and 45% below 70—the clinical cut-off for intellectual disability (APA, 2013). Data appeared to be missing at random. Student demographic information and scores for the standardized and teacher report measures used in the study are reported in Table 1.

Procedures

As part of the larger study, trained diagnosticians confirmed autism diagnoses on all participating students and administered a battery of standardized measures at the beginning of each school year. Participating teachers completed questionnaires outlining their students' developmental and skill profiles, and classroom video observations were collected across the school year. Data for the current study included baseline information from the beginning of the school year (years 1–4), prior to the start of the intervention. Specifically, we included standardized measures of students' cognitive functioning, teacher-rating measures of child behavior, and classroom observations of mathematics lessons. University Institutional Review Board approval was granted prior to the start of the larger intervention project, and all participating teachers and families completed the consent process.

Table 1 Student demographic information and standardized and teacher report measures

	Mean (*SD*)
Hispanic ethnicity	
Hispanic or Latinx	31%
Non-Hispanic or non-Latinx	44%
Unspecified	25%
Race	
African American/Black	7%
Asian American/Pacific Islander	2%
White/Caucasian	32%
Native American	1%
Mixed race/bi-racial	13%
Other	18%
Unspecified	27%
Standardized measures	
ADOS-2 ($n=66$)	7.68 (1.61)
DAS-2 ($n=37$)	84.16 (16.74)
MSEL ($n=25$)	21.16 (4.80)
PDDBI ($n=57$)	53.34 (10.44)

$N=66$. Autism Diagnostic Observation Schedule, Second Edition, (ADOS-2) was used to measure autism severity within our sample. Differential Ability Scales, Second Edition (DAS-II) and the Mullen Scales of Early Learning (MSEL) were used to measure students' cognitive abilities. The MSEL was used with younger children, chronologically or developmentally ($n=25$). Teacher rating measures of behavior were measured using the Pervasive Developmental Disorder Behavior Index (PDDBI). There were no missing data for the ADOS-2 and four missing scores on the cognitive assessment. There were 10 missing scores for the PDDBI from seven different teachers in six different districts

The mathematics lessons were previously coded at the level of the individual student using Stein and Lane's (1996) conceptual framework for differentiating mathematics activities by level of cognitive demand (Sparapani et al., 2023). Most students had one to three identified activities within the larger mathematics lessons; two students had four, one had five, and one had six identified activities. Once the varying activities were identified, five consecutive minutes of each activity were sampled for further coding. See Sparapani et al. (2023) for details on these procedures.

Measures

Observational Measures In the current study, we examined 96 identified mathematics activities drawn from 66 special education mathematics lessons. We used Noldus Observer® Video-Pro Software (Noldus Information Technology XT 14 and 15, 2017) to code the 12 features of teacher talk as well as student emotion regulation. See Table 2 for definitions and examples. All mathematics activities centered on math-related concepts including numbers, time, patterns, and measurement; transitional and other non-instructional time were not included. We used a multiple pass procedure in which we coded one individual at a time (Yoder et al., 2018). Two trained undergraduate research assistants coded teacher talk, and four coded emotion regulation within the 5-min sampled activities. Interrater agreement was calculated on 10% of the emotion regulation data at random and yielded an average agreement score of 98.8%. Interrater agreement for teacher talk was calculated at the level of the individual variables on 10% of the data at random and yielded an average agreement score of 88% (79–94). In addition, 18% of the observations were consensus coded by both raters.

We adapted the coding definition of emotion regulation outlined in the *Classroom Measure of Active Engagement* (CMAE; Sparapani et al., 2016) to include the use of self-regulatory strategies. We identified the amount of time students spent *well-regulated*, in which we observed a match between students' physiological arousal and emotional states and the expectations of the activity (Laurent & Fede, 2021). Being in a well-regulated state also included times when students used adaptive, self-regulatory behaviors (i.e., tapping foot gently, holding a fidget) to maintain a regulatory state for successful activity participation. We also identified the duration of time that students spent within a *dysregulated* state, in which we observed a mismatch between students' physiological and/or emotional states and their learning environment. See Table 2.

Autism Features The ADOS-2 is a semi-structured, standardized play-based assessment used to measure reciprocal

Table 2 Teacher talk and student emotion regulation definitions

Instructional talk. Teachers' use of instructional talk and practices within mathematics activities that help to convey mathematical meaning. This dimension includes the following three features:
Conceptually oriented talk. Teachers provide opportunities for students to develop conceptual knowledge of mathematics content. Conceptually oriented talk requires higher cognitive demand as the focus is on conceptual understanding of concepts. Teachers might encourage students to think about, grapple with, and explain their thinking to develop a deeper understanding of mathematical concepts (Hiebert & Gruows, 2007)
Procedurally oriented talk. Teachers provide opportunities for review and practice of mathematics concepts with a focus on rote memorization and recall. Teachers might also scaffold the learning process by giving students step-by-step direction to complete a mathematics problem. Procedurally oriented talk requires low cognitive demand. Attending to where students are and then building upon their understanding with these types of scaffolding procedures have been found to be important parts of the learning process, especially when combined with conceptual learning opportunities (Van de Pol & Elbers, 2013)
Remediation. Teachers provide opportunities for students to learn from mathematics errors. They may correct a mistake or scaffold the learning opportunity to help students address the misconception
Questioning techniques. Teachers' use of questions to encourage activity participation. This dimension includes the following three features:
Open-ended questions. Content-related questions that do not have fixed responses, allowing students to generate creative responses
Close-ended questions. Content-related questions that elicit fixed responses, such as simple 1–2 words in response to simple "wh" questions, yes/no, or choice questions. Close-ended questions also include questions that require non-verbal responses
Fill-ins. The teacher uses a pause to encourage the student to "fill-in the blank" with practiced, rote responses. Fill-in responses require very low cognitive demand, as responses are typically rote or memorized answers that follow familiar questions and phrases
Responsive language. Teacher's immediate, affectively positive verbal responses that follow students' communicative contributions (Landry et al., 2006). Responsive language is often used to acknowledge students' ideas, encourage continued interaction, and/or provide meaningful feedback to students (Brock et al., 2018). Teachers might also ask for clarification or express genuine enthusiasm in response to students' contributions (Connor et al., 2020)
Directive language. Teacher's use of non-task-related talk to discipline, manage, or control student behavior, such as stopping a behavior or redirecting students to stay on task (de Kruif et al., 2000; Reeve, 2009). This dimension includes the following two features:
Directing behavior. Directing or redirecting behavior to comply with non-task-related commands. These directives center on behavior management and are not related to the learning goal or activity
Directing attention. Directing or redirects students' attention by calling their names when they are not oriented towards the activity. Non-verbal gestures (tapping, pointing), demands ("look here"), and physical contact (moving student's hand, turning student's face) can also be used to bring students' attention back to the activity
Foundational talk. Teachers' use of language and instructional strategies to prepare students for upcoming activities. This involves explaining the upcoming activity and directions in order to provide structure and predictability for the student. This dimension captures the following three features:
Following attention. The teacher makes comments or asks questions about what the student is experiencing. These comments or questions do not have to be related to the activity, but are in response to what the student is doing, seeing, or experiencing
Instructional comments. Teachers makes comments that are content specific or makes instructional observations without expecting for the students to join in
Providing choice. The teacher offers students a choice of materials during activities in order to increase motivation, access, and participation
Emotion regulation: The emotion regulation dimension captures students' capacity to monitor and manage their physiological arousal, emotional states, and behavior, to match the demands of an activity or the environment
The emotion regulation dimension yields the duration of time that students spend in well-regulated (with or without the use of self-regulatory strategies) and dysregulated states within individual mathematics tasks
Well-regulated. When students are in a well-regulated state, their emotional state and physiological arousal align with the demands of the activity. They may appear to be in an active alert or quiet alert state. Students may or may not use observable strategies to stay in an active or quiet alert state, such as lightly tapping their foot, fidgeting with an object, lightly rubbing the table, gently swaying or rocking, humming, or quietly using self-talk
Dysregulation. Dysregulation occurs when there is a mismatch between students' interstate states (emotions and physiological arousal) and the environment. When students are in a dysregulated state, they may appear overaroused/overstimulated or underaroused/understimulated. This might include high-state behaviors, such as extreme excitement, anger/frustration, stress, or hyperactivity or low-state behaviors such as drowsiness and fatigue. Students may experience mild signs of dysregulation or more extreme dysregulation

The features of teacher talk derive a frequency count of the number of instances that teachers directed language toward an individual student. Student emotion regulation yields the amount of time spent in the varying states. The variables are mutually exclusive, such that they cannot occur at the same instance

interactions and repetitive behaviors. The ADOS-2 yields three standard scores: the Overall Calibrated Severity Score (CSS), the Social Affect Calibrated Severity Score (SA-CSS), and the Restricted and Repetitive Behavior Calibrated Severity Score (RRB-CSS). We used the Overall CSS score as a measure of overall autism symptomatology, which is assessed using a 10-point scale. Scores of 4 and above indicate the presence of autism features, meeting classification criteria for autism spectrum disorder (ASD). The ADOS-2 has strong psychometric properties, with high interrater reliability and test–retest reliability as well as strong validity.

Cognitive Functioning Information on students' cognitive functioning was gathered using two different measures based on chronological and developmental age. The *Differential Ability Scales*, *Second Edition* (DAS-II; Elliott et al., 2007) is an examiner administered test to assess cognitive abilities for children aged between 30 months and 17 years, 11 months. Thirty-seven students in this study received the DAS-II based on their cognitive ability (Bishop et al., 2011; Farmer et al., 2014). The assessment yields scores for four scales (Verbal, Non-verbal Reasoning, Spatial Reasoning, and Special Non-verbal Composite) and one composite score (General Conceptual Ability). We used the Non-verbal Reasoning standard score, which has a mean of 100 and a standard deviation of 15. Scores range from 30 to 170. The DAS-II is a widely used measure of cognitive abilities. It was standardized using a normative sample of children that is representative of the general population and has strong psychometric properties.

The *Mullen Scales for Early Learning (MSEL*; Mullen, 1995) is a standardized developmental test designed for use with children between the ages of 30 and 68 months. Children who were not able to establish basal scores on the DAS-II were instead given the MSEL ($n = 25$), in accordance with recommendations given by the Autism RUPP network (Arnold et al., 2000). The assessment is composed of five subscales: gross motor, fine motor, visual reception, expressive language, and receptive language. The MSEL provides T-scores for each of the subscales ($M = 50$, $SD = 10$), as well as age equivalents for receptive and expressive language. Unlike the DAS-II, the MSEL does not yield a NVIQ score. We therefore followed the procedures of previous studies, deriving the NVIQ score by extrapolating the T-scores from the two non-verbal scales outlined above (Bishop et al., 2011). The MSEL has been found to have good internal consistency and test–retest reliability, as well as established construct, criterion and concurrent.

The *PDD Behavior Inventory* (PDDBI; Cohen et al., 2003) is an informant-based rating scale completed by teachers to access their perceptions of their autistic students' behavior and social pragmatic skills. The PDDBI was designed to assess intervention response in autistic children, as it measures aspects of adaptive and maladaptive behavior associated with autism. The PDDBI includes subtests that yield composite scores (T-scores with $M = 50$; $SD = 10$). The Autism composite provides a summation score of children's perceived behavior by measuring how adaptive behavior offsets maladaptive behavior. Higher scores are indicative of more perceived maladaptive behavior relative to adaptive behavior. The PDDBI was normed on a sample of autistic children and has shown good criterion-related validity by comparing this rating scale with other measures, including the Childhood Autism Rating Scale and the Autism Diagnostic Interview—Revised.

Data Analyses

Confirmatory Factor Analysis We evaluated four competing models of teacher talk. See Fig. 1. The conceptualization of each model was guided by and extends the current literature. A one-factor model was tested because it represents the most parsimonious model. We used confirmatory factor analysis (CFA) with Mplus software (Muthén & Muthén, 1998-2017) to evaluate the fit of each model; the "complex" feature in Mplus was used due to the nested nature of the data (Kline, 2016). All tested models met the recommended identification assumptions. The models including a single indicator factor were identified by fixing the error term of the single indicator factor to equal $1 - r$ (S^2), where r equals reliability.

Correlations Between Teacher Talk and Student Behavior We first ensured that our data were normally distributed by examining skewness and kurtosis values and histograms. We used Pearson correlations to examine the association between teacher perceived ratings of student behavior measured with the PDDBI and an observational measure of student emotion regulation (the amount of time students spent well-regulated and dysregulated in activities). We then used partial correlations, controlling for the influence of cognitive abilities, to examine associations between the dimensions of teacher talk based on the results of the CFA and student behavior (perceived and observed). We z-scored scores from the two cognitive measures (MSEL and DAS-2) to have a common scale for analysis. Results of the partial correlations were adjusted for multiple analyses by applying the FDR correction (Benjamini & Hochberg, 1995).

Results

Descriptive Information

We examined the number of occurrences that teachers used the varying types of talk as well as the duration of time students spent within well-regulated and dysregulated states within the 5-min samples of mathematics activities. The means and standard deviations below represent the average number of occurrences teachers used specific features of talk within the sampled activity as well as the average duration of time students spent well-regulated within the sampled activities. We identified three outliers within the data and brought the scores within three standard deviations of the mean. After doing this, all the variables were normally distributed. See Table 3.

Within the 5-min sampling of activities, teachers most frequently used behavioral directives ($M = 7.53$ occurrences; $SD = 8.48$) followed by instructional comments ($M = 6.61$ occurrences; $SD = 7.30$) and responsive language ($M = 4.26$

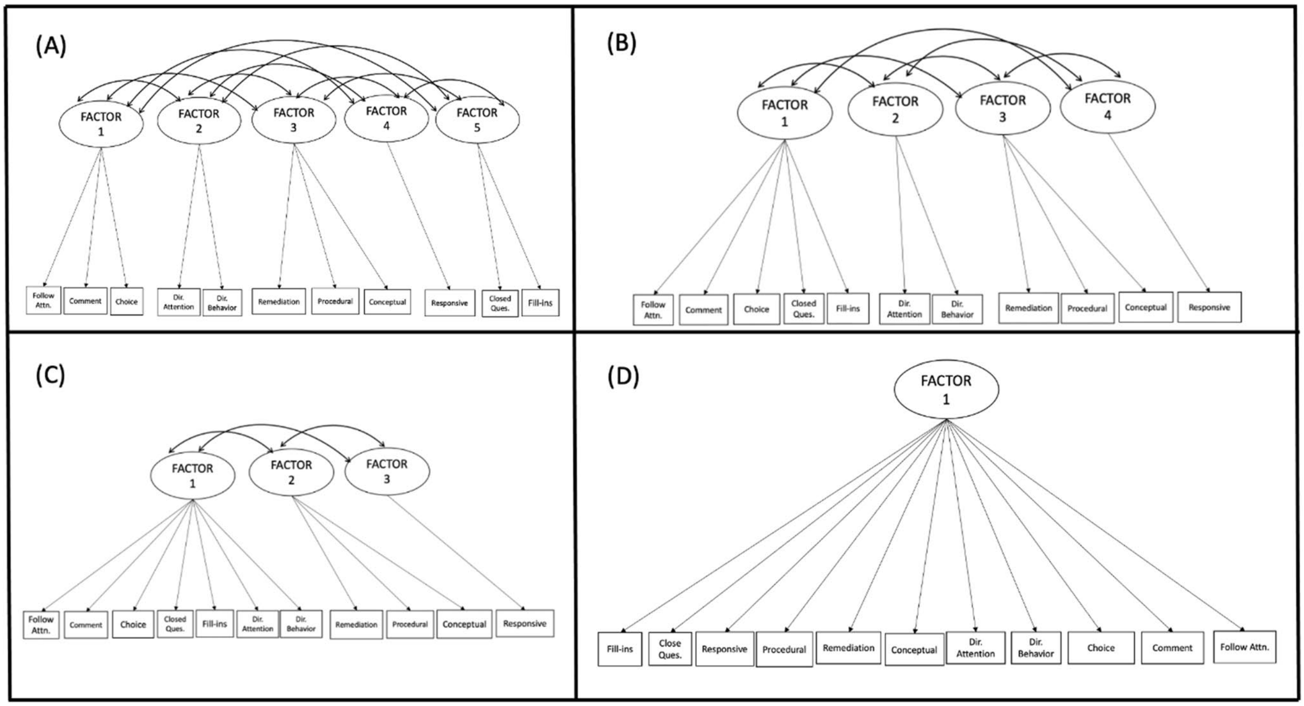

Fig. 1 The 5-factor model consisted of 11 indicators loading onto 5 distinct factors (**A**). The 4-factor model consisted of 11 indicators loading onto 4 distinct factors (**B**). The 3-factor model consisted of 11 indicators loading onto 3 distinct factors (**C**). The 1-factor model consisted of 11 indicators loading onto 1 distinct factor (**D**)

Table 3 Summarized statistical information for the 12 features of teacher talk

Teacher talk	Mean	Range	Observed cases
Following attention	0.75 (1.61)	0–8	27
Instructional comments	6.01 (7.30)	0–34	79
Providing choice	0.42 (1.07)	0–6	19
Directing behavior	7.53 (8.48)	0–37	82
Directing attention	1.80 (2.55)	0–12	47
Conceptually oriented talk	0.78 (1.77)	0–9	25
Procedurally oriented talk	3.34 (3.87)	0–16	68
Remediation	0.91 (1.40)	0–6	38
Responsive language	4.26 (3.78)	0–15	80
Open-ended questions	0.09 (0.52)	0–4	4
Close-ended questions	3.36 (4.97)	0–26	67
Fill-ins	0.86 (2.05)	0–13	33

Reported means, standard deviations, and range reflect the frequency, variability, and range of teacher talk features within the 5-min sampled observation. The observed cases reflect the number of instances that each of the teacher talk features appeared across the total 96 activities. For example, directing behavior was observed in 82 of the 96 mathematics activities

occurrences; $SD = 3.78$) relative to all other features of talk. In fact, we observed behavioral directives in 82 of the 96 activities, instructional comments in 79 activities, and responsive language in 80 activities. The following six features of talk had an average mean below one occurrence per activity: following attention, providing choice, conceptually oriented talk, remediation, open-ended questions, and fill-ins. Five of these were observed in less than 35 of the 96 activities: following attention (27 activities), providing choice (19 activities), conceptually oriented talk (25 activities), open-ended questions (4 activities), and fill-ins (33 activities). In addition, students spent an average of 3:48 ($SD = 1{:}39$) minutes of the mathematics activities in a well-regulated state, accounting for 69% of the observed time. Teachers perceived students as well-behaved overall, with an average reported composite score on the PDDBI of 54.34 ($SD = 10.44$). See Table 1.

Confirmatory Factor Analysis

Prior to running the CFA, we dichotomized the five features of talk that were rarely observed across the activities (following attention, providing choices, conceptually oriented talk, and fill-ins) and excluded open-ended questions from the analyses since they only occurred in four activities. The five-factor model evidenced excellent fit to the data overall (RMSEA = 0.03 [0.00–0.08]; CFI = 0.97; $\chi^2/df = 1.09$) and the best relative fit when compared to alternative models ($p < 0.01$). See Table 4 and Fig. 2. The model of teacher talk included the following latent factors, instructional talk, questioning techniques, responsive language, directive language, and foundational talk. All loadings contributed a significant amount of variance to the latent factors ($p < 0.05$). We observed moderate to strong, positive associations among each of the latent variables ($r = 0.30$–0.77), excluding the directive language latent factor which was not significantly associated with instructional talk or responsive language.

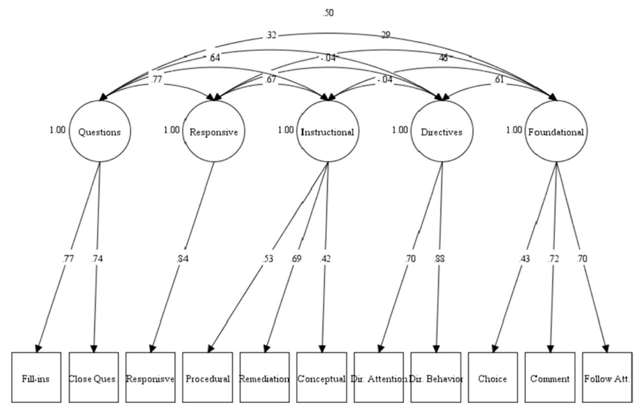

Fig. 2 Confirmatory factor analysis of teacher talk within mathematics activities**.** Instructional talk (Instructional), questioning techniques (Questions), responsive language (Responsive), directive language (Directives), and foundational talk (Foundational). Close-ended questions (Close Ques.), procedurally oriented talk (Procedural), conceptually oriented talk (Conceptual), directing attention (Dir. Attention), directing behavior (Dir. Behavior), providing choice (Choice), instructional comment (Comment), following attention (Follow Att.)

Teacher Talk, Student Behavior, and Cognitive Functioning

We first examined associations among teacher ratings of student behavior outlined on the PDDBI with the classroom observation measure of emotion regulation. There was a negative, significant correlation between perceived behavior and observed emotion regulation ($r = -.279$, $p = 0.01$), suggesting that teachers reported less perceived behavior problems during times when students were observed to be in a well-regulated state. Furthermore, we observed a strong, significant negative association between teacher perceived behavior (PDDBI) with student cognitive functioning ($r = -.706$, $p < 0.001$) as well as a small correlation between emotion regulation and cognitive functioning ($r = -.276$; $p = .007$). We also documented a negative significant correlation between teachers' use of directive language ($r = -.347$, $p < 0.001$) and a positive association between use of responsive language ($r = .314$, $p = 0.003$) with students' cognitive functioning. This suggests that cognitive skills, in part, influenced the amount of directive and responsive language teachers used with their students as well as perceived and observed behavior within the classroom.

Partial Correlations Between Teacher Talk and Student Behavior We next examined partial correlations between the five dimensions of teacher talk with students observed and perceived behavior, controlling for the influence of cognitive functioning. See Table 5. There was a significant, positive association between being in a dysregulated state with teachers' use of directive language ($r = .501$, $p < 0.001$) and foundational talk ($r = .304$, $p = 0.004$). We also observed a small, positive association between teacher perceived behavior with instructional talk ($r - 285$, $p = .012$). These correlations remained significant after performing the robust FDR correction procedure.

Table 4 Model fit statistics using WLSMV estimation and difference testing

Model fit indices	5-Factor	4-Factor	3-Factor	1-Factor
χ^2/df	1.09	1.42	1.94	1.99
RMSEA	0.03	0.07	0.10	0.10
C.I	.00–0.08	.01–0.10	.07–0.13	0.07–0.13
Pclose-fit H_0	.68	.25	.10	0 < .001
CFI	.97	.85	.63	0.59
$\Delta\chi^2$	5-Factor and 4-factor 22.88 ($df = 4$), $p < 0.01$	5-Factor and 3-factor 49.71 ($df = 7$), $p < 0.001$		5-Factor and 1-factor 52.92 ($df = 9$), $p < 0.001$

All models were compared against the 5-factor model using the DIFFTEST option in Mplus Software ($\Delta\chi^2$). Weighted least squares-mean and variance adjusted (WLSMV), root mean square error of approximation (RMSEA), 90% confidence interval, probability RMSEA ≤ .05 (Pclose-fit H_0), comparative fit index (CFI)

Discussion

We discuss three primary contributions that this study makes. Our detailed examination of teacher talk provides a promising means for measuring the quality of teacher talk within special education mathematics activities as well as insight into the learning opportunities presented to autistic students and the experiences they have within these opportunities. We outline commonalities and differences in conceptualizing and measuring perceived behavior through teacher report versus observational measures of emotion regulation. Our findings link teacher talk with child behavior, highlighting the need for professional development centering on talk as a targeted intervention. We discuss these contributions in detail below as well as outline educational implications and future directions.

The good fit we observed in our model of teacher talk overall as well as the relative fit when compared to other models provide preliminary validation for measuring teacher talk within special education mathematical contexts using five distinct, yet related dimensions. The five dimensions are composed of 12 features of talk drawn from the mathematics and autism literature, extending the work of Sparapani et al. (2022) who proposed a one-factor general model of teacher talk for measuring autistic children's participation in a range of general and special education classroom activities. Observing the correlations among the dimensions provides insight into the interconnectedness of the teacher talk features within mathematics contexts. Directive language, for example, was only linked with questioning techniques and foundational talk; the other dimensions were all interconnected. This suggests that directive language is fundamentally different from instructional talk and responsive language. How each of the talk features loaded onto the dimensions is also insightful, as conceptual talk contributed less variance to the instructional talk dimension than procedural talk and remediation. This might be specific to learners on the autism spectrum, as studies have documented limited opportunities for autistic students to participate in conceptual mathematics opportunities (Lambert et al., 2020). Future research is needed to understand whether the teacher talk dimensions differentially predict student outcomes and, furthermore, how generalizable the five-dimensional model is to other populations and contexts.

Quality of the Learning Experience Examining teacher talk as a five-dimensional model provides insight into the quality of mathematical learning opportunities provided to autistic learners within special education classrooms. We observed strong relationships among teachers' use of instructional talk, responsive language, and questioning techniques—talk that has been linked with higher quality interactions and more rigorous mathematical learning opportunities (Suh et al., 2021; Whittaker et al., 2018). We also documented a strong relationship between directive language and foundational talk, which is associated with classroom management and preparation procedures. Although overuse of directives within the classroom has been outlined as problematic in the literature (de Kruif et al., 2000), embedding directives into classroom routines and procedures with limited disruption contributes to a consistent and systematic classroom flow (Connor et al., 2014). Hence, it is possible that the presence of all five dimensions within an instructional opportunity, when frequency of occurrence is balanced, is indicative of a higher quality instructional opportunity—The activity is well managed and offers choice as well as includes responsive language, focused talk centered on learning mathematics, and questioning techniques to facilitate participation.

In our study, it was notable that the dimensions of teacher talk were not well balanced. We documented a limited range of talk overall, primarily observing five of the 12 features of talk we set out to examine: directing behavior, instructional comments, responsive language, close-ended questions, and procedurally oriented talk (respectively). Most of the features of talk were either rarely observed (i.e., following attention) or they were observed within activities but with low frequency (i.e., providing choice). In addition, teachers rarely asked their autistic students open-ended questions to tap into generative knowledge or conceptually oriented

Table 5 Partial correlations between dimensions of teacher talk and student behavior

Variable	1	2	3	4	5	6	7
1. Instructional talk	—						
2. Questioning techniques	0.391***	—					
3. Directive language	0.011	0.214*	—				
4. Foundational talk	0.268**	0.187	0.423***	—			
5. Responsive language	0.404***	0.577***	0.037	0.246*	—		
6. Dysregulated	−0.135	0.042	0.501***	0.304**	0.040	—	
7. Well-regulated	0.207	0.108	−0.169	−0.075	0.055	−0.608***	—
8. PDDBI ($n=83$)	0.285*	−0.102	−0.100	−0.092	−0.107	−0.121	0.061

*$p < .05$; **$p < .01$; ***$p < .001$

talk, which facilities deeper engagement with mathematics beyond rote memorization and procedural learning—features of talk that encourage participation and promote mathematics learning (Hiebert & Gruows, 2007). What we observed instead were high frequencies of directive language, which most likely interrupted instruction, as they are non-task-related talk used to direct or redirect individual student behavior. In fact, 26 of the 96 activities included 10 or more directives within the 5-min sample; 10 of the observations included 20 or more directives during this time.

Overuse of Directive Language Like previous studies, we found that students who exhibited less developed cognitive abilities were likely to receive more directive language, whereas stronger cognitive abilities were linked with more responsive language. This is problematic for several reasons. The literature suggests that teachers' use of responsive language is most critical with vulnerable learners and, furthermore, high frequencies of directive language tend to create controlling, authoritative learning environments. Such environments could hinder positive classroom experiences, engagement within equitable learning opportunities, and overall academic and developmental outcomes (Williford et al., 2017). The potentially negative impact that high frequencies of directives have is clearly illustrated within a study by Sparapani et al. (2022) who examined a reading intervention that utilized a scripted language approach. The authors provided example transcripts of the talk interventionists used with autistic elementary students. Consistent with our findings, the authors outlined high frequencies of directives used to redirect student behavior with students who exhibited co-occurring language and cognitive impairments—showing multiple back-to-back directives within a short period. The authors interpreted this constant verbal redirection to stay on task as an indicator to better prepare educators who are instructing autistic learners with higher support needs. Solely relying on oral language approaches or language-based activities without providing students with multiple means to access the learning materials or express their thinking points to a mismatch between the child and the environment (Meyer et al., 2014)—as these data indicate that learners are not fully accessing the learning opportunity if they need constant redirection. Furthermore, the rapid pace of directives may feel bombarding to autistic students and lead to decreased engagement and dysregulation.

Viewing Behavior as a Developmental Skill It has been suggested that common features of autism, such as sensory sensitivity, differences in the expression of emotion regulation, or limited capacity for joint attention, are often misunderstood as problematic behavior within classrooms (Mundy, 2016). Our findings provide evidence to support this. Teachers may be misinterpreting regulatory behavior in autistic children as "problematic" or "off-task behavior" that needs redirection. This may be more pronounced in students who exhibit more need, as we found that teachers' ratings of their students' behavior were highly inflated by cognition. This, in turn, might lead to an increase in directive language in attempt to redirect students back "on task." Consider the following example that we documented within our mathematics observations. A teacher is teaching a mathematics lesson to a small group of students, but an autistic student in the group keeps standing up, turning away, or even leaving the group. The teacher repeatedly redirects the student to come back and sit down. To the teacher, this may look like poor behavior, but in actuality, there is a mismatch between the student and the demands of the activity—The student is experiencing dysregulation, and these observable behaviors are intended to be self-regulatory.

Recent research coming from a neurodiversity perspective has called for educators to view observable behavior through an emotion regulation lens, understanding the match/mismatch between students' physiological arousal and emotional states with the demands of the environment rather than as problematic behavior that needs fixing. Findings from our study support this view, suggesting that viewing "problematic behavior" through an asset-based lens might prove to be a more successful approach to meeting the needs of autistic learners within classrooms. That is, teachers could adapt their talk and provide accommodations and scaffolds as needed to ensure the environment is a good match with their students' needs (Vidal et al., 2022). Incorporating visual supports within lessons to provide visual representation of oral content (Tay & Kee, 2019) is one such example.

Educational Implications and Future Directions

Findings from our study invite the larger question as to why dysregulation occurs in the classroom. This is important to understand since we know that dysregulation can interrupt learning (Laurent & Prizant, 2005; Nigg, 2017; Moffitt et al., 2013). In our study, we found that teacher talk, at least in part, is linked to student dysregulation in the classroom. By the time children enter formal schooling, they are expected to regulate their behavior to participate in classroom activities (Goodall et al., 2022). However, the mismatch between what the teacher expects and what the child is experiencing may result in a discrepancy between expectation and reality, perpetuating a cycle of increased dysregulation. Understanding dysregulation in the classroom is an area of future research, as it will bring forth insights into professional development that is centered on improving the experiences autistic children have within classrooms.

Furthermore, our findings raise concerns about the quality of mathematics learning opportunities provided to autistic students within special education classrooms, which is consistent with previous studies (e.g., Lambert et al., 2020). Like the tension in the literature regarding mathematical instructional opportunities for autistic learners (Sparapani et al., 2023), the lack of observed open-ended questions we documented in our study might reflect a difference in views. Educational and clinical practices designed for autistic individuals are steeped in a culture of highly structured behavioral interactions and based on reduced and simplified language, providing limited choices and increasing structure within interactions (Odom et al., 2021). The use of directive language and close-ended questions reflects a prevailing belief that autistic students require an imposed structure to communicate (Dart et al., 2023). This approach would suggest that students inherently lack the skills to be generative or creative in response to open interaction bids—that the communication and language differences observed in autistic learners interfere with their ability to understand, interpret, and respond to questions that require higher cognitive demand. These beliefs have come under scrutiny in recent years as being excessively rigid, limiting autistic individual's spontaneous interactions and potentially narrowing learning opportunities (Chapman & Bovell, 2020; Delprato, 2001; Hugh et al., 2022; Schuck et al., 2022) and restricting access to cognitively demanding curriculum (Howley et al., 2023). Researchers and advocates are increasingly pushing back on the fundamental belief that autistic students are unable to access creative, unstructured, or spontaneous learning opportunities (Hetzroni et al., 2019; Ten et al., 2015). This implies a misinterpretation of observed differences as a sign that students are "less" capable, and by doing so, educators are simplifying mathematics instruction and talk without first providing an opportunity to engage in higher-level learning opportunities. Indeed, Sparapani and colleagues (2022) found that asking autistic students open-ended questions elicited increased generative responding within a reading intervention. Future work is needed to further explore the interplay among teacher talk, mathematical instructional opportunities, and mathematics learning in autistic students and, furthermore, to understand how accommodations and scaffolds can be embedded into higher-level instructional opportunities to promote access and learning in autistics students within varying educational needs (Vidal et al., 2022).

Limitations

The current study has many notable strengths, including using classroom video observations to provide insight into the dynamic classroom environment and the complex transactional interactions that take place between teachers and their students. Analyses were performed at the level of the activity, equaling 96 activities in total. We sampled 5-min observations from a range of mathematics activities. However, all students did not have the same number of observations because the number of activities varied per lesson, with some but not all students participating in two or more different activities. In addition, we used archival baseline data from a larger intervention study, which limited our access to additional language and cognitive measures. Future research is needed to understand, in more detail, how children's communication, language, and varying cognitive abilities relate to the talk they receive from their teachers within a specific age range and grade level. Future research is also needed to explore teacher talk with autistic children who are minimally verbal or non-speaking and use assistive alternative communication (AAC) within classrooms. Furthermore, our study did not include a comparison sample of non-autistic children; as such, we referred to the existing literature to compare our findings to studies that included non-autistic children. As a next step, research is needed to explore whether and how the findings from our study generalize to non-autistic children within special and general education classrooms.

The relatively small sample size is a critical limitation that should be acknowledged. As such, readers should use caution when interpreting the results. A small sample size can affect the reliability and validity of the findings by increasing the margin of error, potentially overestimating effect sizes, and reducing the power to detect true effects. It also potentially limits the generalizability of the findings to a broader population. Our sample to parameter ratio was also small, which could increase the likelihood of type I and type II errors. Additionally, this study does not statistically account for teacher-student interactions, making it impossible to measure the reciprocity between teachers and students. Finally, video observations are useful because they provide a snapshot of real-world contexts in action; however, it is possible that the teachers and students within our study shifted their behaviors because they were aware of the video recording.

That being said, this study begins to elucidate the nature of talk used by teachers within mathematical learning opportunities and the degree to which teachers' talk may impact students' in-class behavior and learning. The descriptive and exploratory nature of this study provides foundational information for future research. Future work is needed to continue to untangle the reciprocity of teacher talk and student behavior among neurodiverse students and their teachers within dynamic classroom contexts as well as identify mediators and moderators of instructional interactions that influence one another and shape developmental and academic outcomes.

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Author Contribution All authors contributed sufficiently to the manuscript. The study used archival video observations that were collected as part of a longitudinal project evaluating a classroom-based intervention for autistic children in preschool through third grade. NS and NT conceptualized and operationalized the instructional practice and teacher language dimensions, and NS and LT conceptualized and operationalized the emotion regulation dimension. CP, NS, and LT conceptualized and crafted the theoretical framework that grounds the study. NS, JVG, SB, HF, and AD conceptualized the varying latent models based on the extant literature. SB and NS were involved in the data curation, and NS, SB, and AD were responsible for the methodology and data analyses. NS and LT were involved in supervision of the video coding. NS, SB, LT, and CP were responsible for writing the manuscript. All authors were involved in reviewing and editing the manuscript.

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Declarations

Ethics Statement This study used archival data from a larger intervention study. The original study was approved by the University of California, Davis IRB.

Informed Consent This study used archival data. As part of the original study, participants completed the consent process prior to the start of the study. NS and SB were involved in the data curation.

Conflict of Interest The authors declare no competing interests.

Disclaimer The opinions expressed are those of the authors, not of the funding agency, and no official endorsement should be inferred.

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