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Enhancing mathematics achievement through teacher support: The mediating role of student feedback literacy

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ABSTRACT

Teacher support has been widely recognized as beneficial for academic achievement, but the underlying mechanism remains unclear. Recently, student feedback literacy has gained attention as a key factor explaining how teacher support enhances academic outcomes. While teacher support creates a conducive environment, its effectiveness depends on students' ability to use teacher feedback. This study examined the relationship between perceived teacher support and students' mathematics achievement, focusing on the mediating role of feedback literacy. Participants were 230 students from southern China (ages 14–18, mean = 16.15, *SD* = 0.033). The results showed that teacher support affects students' academic achievement both directly and indirectly. Feedback literacy among students showed statistical significance as it mediated effects attributable to teachers' support on academic achievement. Our results highlight that enhancing students' feedback literacy, especially their ability to grasp applicable feedback, strengthens the positive impact of teacher support on academic achievement.

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Academic achievement; mediation; structural equation modeling; student feedback literacy; teacher support

Introduction

Teacher support and its effect on academic performance have attracted considerable research attention because supportive teacher behaviors are critical for a learning environment. However, the empirical evidence of effects attributable to teacher support on student academic achievement is mixed (Ahmed et al., 2010). Several researchers have suggested a positive impact of teacher support on academic achievement (Affuso et al., 2023; An et al., 2023; Chen, 2005; Fu et al., 2023; Martin et al., 2024; Peng et al., 2022; Wang & Eccles, 2012), while some researchers have not found significant results (Havik & Ertesvåg, 2019; King & Ganotice, 2014). These mixed findings indicate the necessity of understanding the internal mechanisms through which teacher support affects academic achievement. Feedback literacy may be a potential mediator because teacher support often involves providing guidance, encouragement, and constructive feedback, which students must interpret and utilize effectively to improve their learning outcomes. While teacher feedback has a well-known positive effect on academic achievement (Hattie & Timperley, 2007), its effectiveness is closely linked to students' feedback literacy (Yan & Chiu, 2022; Yan et al., 2021). One key barrier to effective feedback utilization is students' lack of feedback literacy. Drawing insights from the conceptualizations of Carless and Boud (2018) and Sutton (2012), student feedback literacy is operationally defined in this study as an individual's ability to effectively receive, understand, evaluate, and use teacher feedback.

Teachers have significant roles when it comes to cultivating students who can use teacher feedback to good effect (Carless & Boud, 2018). Teacher support, as a crucial contextual factor, helps create the conditions in which student feedback literacy can develop. By fostering a supportive learning environment, encouraging active student participation, and providing guidance, teachers can enhance students' feedback literacy (Carless & Boud, 2018). Therefore, teacher support may influence student academic achievement by promoting the development of student feedback literacy. This area suggests an avenue for further investigation.

Therefore, we aimed to explore the relationship between student-perceived teacher support and student academic achievement in mathematics through the mediation of students' feedback literacy. The results have the potential to illuminate internal mechanisms by which perceived teacher support influences academic achievement.

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Literature review

Teacher support and academic achievement

According to the social support model, the support provided by teachers is a multidimensional structure (Anderman et al., 2011; Tennant et al., 2015) that can be divided into four dimension: instrumental, informational, emotional, and appraisal (House, 1981; Kerres Malecki & Kilpatrick Demary, 2002; Tardy, 1985). Instrumental support refers to perceived resources provided by the teacher, such as spending time helping students and providing them with materials or money. Emotional support denotes that love, trust and empathy are provided. Appraisal support refers to providing feedback support and social comparison. Informational support refers to providing information, such as advice and suggestions, to students (House, 1981; Tardy, 1985). As a key factor in frequent interactions and the formation of relationships with others, educators have important roles when it comes to promoting students' growth and learning (Tao et al., 2022). Regarding teachers' appraisal support, one of the most significant indicators is the feedback teachers provide to students (Kelly & Antonio, 2016). Feedback's effect has also been widely discussed in terms of academic achievement (Hattie & Timperley, 2007; Wisniewski et al., 2019).

Many empirical studies have shown that teacher support facilitates academic achievement (Leon et al., 2017; Sakiz et al., 2012) and student engagement (Roorda et al., 2011, 2017). Tao et al. (2022), meta-analyzing 71 articles, noted minor to moderate correlations of teacher support to achievement. The buffering hypothesis model by Cohen and Wills (1985) proposes that social support can promote psychological and behavioral adaptation by buffering stress. Support from teachers is one of the major channels for social support, as it can reduce negative impacts due to academic pressure on students, thereby improving academic achievement.

Additionally, the importance of teacher support is also acknowledged in microsystem theory, which emphasizes the impact of the interaction between individuals and their surroundings on their development and achievement (Bronfenbrenner, 1979). As important components of the student microsystem, teachers' emotional support, academic guidance, and encouragement can promote students' learning enthusiasm and self-confidence and enhance their investment and effort in learning (Pianta & Stuhlman, 2004).

On the other hand, several researchers have found no significant relationship between teacher support and academic achievement. For example, Havik and Ertesvåg (2019) collected trajectory data on the perception of teacher teaching support from 815 eighth- and ninth-grade students in nine schools in Norway over a period of three rounds within one and a half years and found no significance in the direct relation of teaching support to students' mathematics achievement. As this Nordic study found, teachers' teaching support may affect students' academic performance more through nonacademic factors such as behavior and motivation rather than directly affecting their academic performance. In a study by King and Ganotice (2014) with a sample of 1,026 Filipino middle school students, teacher support was not significantly related to academic achievement, although a positive correlation linked it to positive achievement goals. In summary, despite some studies citing no relationship, much of the existing literature has found teacher support affects academic achievement.

Student feedback literacy and academic achievement

Student feedback literacy, initially defined by Sutton (2012) as relevant skills for reading, interpreting, and using feedback written by teachers, has evolved to encompass broader competencies. The concept now includes the necessary knowledge, skill, and attitude required to process feedback and apply it to improve academic achievement (Carless & Boud, 2018). Han and Xu (2021) emphasized the cognition and social affect that are components of feedback literacy, which prepare students for meaningful engagement with feedback.

There are four key facets to feedback literacy: appreciation, judgment, affect management, and action (Carless & Boud, 2018). These elements emphasize not only recognizing the value of feedback but also actively using it to enhance academic performance. Molloy et al., (2020) identified seven elements within a feedback literacy framework, further highlighting impacts due to emotions, reciprocal feedback processes, and active application of feedback information. Overall, feedback literacy may be summarized as a student's skill in engaging with feedback processes while using them in improved learning (Zhan, 2022).

The framework proposed above (Carless & Boud, 2018) is widely applicable; it provides a strong foundation for theoretical models and empirical research (Karunarathne et al., 2024; Molloy et al., 2020; Zhan, 2022). An appreciation of feedback, for example, underscores learners' recognition of its importance, which in turn can foster their willingness to adjust strategies and improve academic outcomes (Hattie & Timperley, 2007). This can cultivate both autonomous learning and a lifelong learning mindset (Carless, 2015). The act of making judgments involves critical self-reflection on one's performance and applying feedback to improve future work (Carless & Boud, 2018). Reflecting supports understanding of concepts (Pei et al., 2020) while boosting learner confidence (Wang et al., 2018) and can positively influence academic performance (Zhai et al., 2023). Emotional engagement with feedback is also vital. Students with feedback literacy can manage their emotions, seek help, and maintain a positive approach to using internal and external feedback for learning improvement (Carless & Boud, 2018). Taking action, an essential part of feedback literacy, means a student has the initiative to examine the contents of written feedback and then apply the feedback for improved outcomes (Sadler, 1989). Effective feedback relies on learners viewing themselves as agentic with respect to their learning processes, not as inert subjects in the process (Boud & Molloy, 2013).

Student feedback literacy and self-regulated learning are closely interconnected, playing essential roles in enhancing academic outcomes. Feedback literacy is a fundamental skill

for students' self-regulated and co-regulated learning (Yan & Carless, 2022). Developing feedback literacy enhances students' ability to recognize relevant feedback from teachers or peers and integrate it into their monitoring process. In addition, feedback literacy supports effective self-assessment, helping learners compare their work against learning objectives and identify areas that need improvement (Yan & Carless, 2022). This not only fosters students' self-awareness but also boosts their sense of competence and motivation to manage their learning actively. Students with high feedback literacy are better equipped to interpret feedback accurately and translate it into meaningful actions (Carless & Boud, 2018; Han & Xu, 2020). For example, they are more likely to identify specific areas for change—whether in study techniques, time management, or cognitive strategies—and implement adjustments accordingly. This adaptability enables students to respond to challenges proactively, further enhancing their self-regulation abilities. Student feedback literacy is closely related to the self-regulated learning process, helping learners regulate their learning independently and gain benefits.

Despite the theoretical benefits of feedback literacy on academic achievement, empirical evidence remains limited. Karunarathne et al. (2024) investigated the relationship between 130 freshman economics and business undergraduates' acceptance of tutor feedback and their performance on assessment tasks and observed direct correlations of student feedback literacy to task performance. Rad and Mirzaei (2024) investigated the impact of feedback literacy in terms of developing feedback literacy along with writing skills and resilience among 44 undergraduate students of an additional language. Their findings revealed significant improvements in student feedback literacy and their writing and resilience following their participation in a program that was focused on writing and enhanced with feedback literacy. However, a cross-sectional study indicated that there was no correlation between students' feedback literacy and writing performance (Zhang, 2023).

Teacher support, student feedback literacy, and academic achievement

Vygotsky's (1978) social development theory states that learning is fundamentally a social production wherein interactions with more experienced others promote cognitive development and learning. Teacher support is crucial in this process because it helps bridge the gap between students completing tasks independently and achieving goals with guidance—the so-called zone of proximal development. Successful development of students' feedback literacy is possible only if teachers create the right environment for learners' active participation and provide relevant guidance support (Carless & Boud, 2018). Strong feedback relies on a partnership, on teachers and students sharing responsibility, to develop research-based practices in feedback provision (Carless, 2022; Yang et al., 2021). Additionally, scaffolding, proposed by Wood et al. (1976), reinforces relations of teacher support to students' feedback literacy. Scaffolding involves providing students with temporary support structures to help them reach a higher level of understanding and skill mastery than they could achieve on their own. Strong and effective scaffolding requires teachers to adjust their level of support based on student's current performance. Molloy and Boud (2013) proposed that tailored feedback and guidance provided by teachers enable students to gradually internalize feedback and become more self-regulated learners. As students receive scaffolding support in interpreting and applying feedback, they gradually build their feedback literacy and become more adept at seeking, understanding, and using feedback independently. Therefore, teacher support not only helps achieve immediate learning outcomes but also promotes the long-term growth of feedback literacy, which is essential to continued academic and professional growth. Teachers' scaffolding of cognition, like their social-affective support, plays a key role when it comes to developing feedback literacy in students and serves as a bridge between educators' and learners' feedback literacy (Xu & Carless, 2017).

In Vygotsky's (1978) theory of social development, social interaction is considered essential for cognitive development. Building upon this framework, attachment theory offers an additional layer of understanding. According to attachment theory, individuals develop internal relationship working models based on early interactions with their primary caregivers, which influence their expectations, beliefs, and behaviors in subsequent social interactions, including those in educational settings (Bowlby, 1969). Teachers' emotional support plays a vital role in cultivating secure attachment relationships with students and fosters safe, supportive learning situations in which learners perceive that they are valued, respected, and understood. Pianta and Stuhlman (2004) found that supportive student-teacher relationships showed an association when it came to increasing students' motivation, engagement, and academic achievement. Given positive support, students develop trust and confidence with respect to teachers, which enables them to seek feedback, accept criticism, and understand that feedback can support development and learning, thereby improving their feedback literacy. Simultaneously, teachers' emotional support can alleviate students' anxiety during the feedback process (Xu & Carless, 2017).

Feedback literacy can influence the connection between teacher support and academic achievement by improving students' ability to use feedback effectively, which is critical for learning improvement because feedback literacy transforms teacher support into actionable insights that students can apply to academic tasks (Yan & Chiu, 2022). In other words, students with feedback literacy are better able to interpret and take action according to teachers' feedback, thereby promoting academic growth. The supportive environment created by effective teacher-student communication encourages students to actively engage in feedback, and this engagement allows students to view feedback as a constructive tool that enhances their learning process (Winstone et al., 2017). Therefore, feedback literacy may be a mechanism through which the positive effects of teacher support can be translated into improved academic performance.

When students possess feedback literacy, they are better equipped to interpret these comments and implement changes in their work, thereby linking the support from teachers to improved academic outcomes.

Professional development programs can change teachers' feedback beliefs and practices (Brooks et al., 2021; To et al., 2023; Van Ha & Murray, 2021), and teacher feedback literacy interacts with student feedback literacy (Carless & Winstone, 2023). Training teachers to enhance their feedback literacy may also support the development of student feedback literacy. Professional development programs have been shown to improve teacher feedback literacy (Van Ha & Murray, 2021). To et al. (2023) proposed three approaches to achieving this: first, using diary writing prompts to guide teachers in exploring the relationship between their practices and students' feedback engagement in depth; second, leveraging co-teaching arrangements to observe each other's practices and reflect on challenges; and third, encouraging teachers to evaluate their own practices and brainstorm improvement strategies during professional development meetings. However, research on the developmental process of teacher feedback literacy remains limited (To et al., 2023).

Therefore, relations of teacher support to academic achievement may be enhanced if students have strong feedback literacy. Teacher support is conducive and encourages students' participation in feedback. However, without the necessary feedback literacy, students may not fully utilize the support provided by teachers. Efficacious feedback depends on delivery as well as design in feedback processes that promote student participation (Dawson et al., 2019). Therefore, feedback literacy can be viewed as a key skill that enables a student to bridge gaps when receiving teacher support as well as when achieving success.

This study aims to explore the relationships among teacher support, student feedback literacy, and mathematics academic achievement. Specifically, it seeks to investigate how student feedback literacy connects teacher support to mathematics academic achievement.

The specific research hypotheses for this study include:

H1: Perceptions of teacher support have a significant, positive relationships to mathematics academic achievement.

H2: Student feedback literacy is significantly and positively related to mathematics academic achievement.

H3: Perceptions of teacher support have significant, positive relationships to student feedback literacy.

H4: Students' feedback literacy has a mediation effect on the relationship with perceptions of teacher support when it comes to mathematics academic achievement.

Methods

Participants and measures

Through convenience sampling, we collected data from two public schools in Guangdong Province, China. Altogether, there were 234 participants. All students independently completed a questionnaire lasting approximately 10–15 min. After removing invalid responses (e.g., the answers to all questions were the same or more than 50% of the answers were missing), there were 230 valid responses retained, including 119 from boys (51.74%) and 111 from girls (48.26%). The total proportion of missing values was 5.65%. Because there was no multivariate normal distribution, we used multiple imputations to fill in data gaps (Sterne et al., 2009). The participants' average age was 16.15 years old; the age range spanned from 14 to 18.

Measuring instruments

The data measures used in this study included students' perceived teacher support, students' feedback literacy, and mathematics academic achievement, each of which is obtained from their following respective scales, described below.

Perceived Teacher Support Scale

Perceived teacher support was measured on Wu et al.'s (2024) Perceived Teacher Support Scale (see Appendix B). This scale assesses four dimensions of teacher support: instrumental Support ($\alpha = 0.915$; 7 items, e.g., "My teachers will take time to help me when I need help for my study"), emotional Support ($\alpha = 0.933$; 6 items, e.g., "My teachers trust me"), informational Support ($\alpha = 0.950$; 7 items, e.g., "My teachers provide information to assist me in solving problems myself"), and appraisal support ($\alpha = 0.913$; 5 items, e.g., "My teachers will inform me when I make mistakes"). All items measured students' perceptions of teacher support based on their responses. Subjects needed to rate these items using a 6-point scale of 1 (*strong disagreement*) to 6 (*strong agreement*). High totals indicate higher perceived teacher support. Cronbach's α for the entire scale in this study was 0.977, with the α coefficients for each of the four dimensions, in the order listed above, being 0.933, 0.954, 0.967, and 0.934.

Student Feedback Literacy Scale

We measured students' feedback literacy according to Zhan's (2022) Student Feedback Literacy Scale, which covers most of the content of feedback literacy and has been used and validated in China. In this scale, students' feedback literacy is divided into six dimensions, namely "eliciting," "processing," "enacting," "appreciation of feedback," "readiness to engage," and "commitment to change." The first three are related to students' abilities, while the last three are related to students' dispositions. "Eliciting" includes the ability to seek information from various sources to enhance learning ($\alpha = 0.910$; 4 items, e.g., "I am good at communicating with others to elicit useful information about what is good work."). "Processing" includes the ability to understand and evaluate feedback received ($\alpha = 0.916$; 4 items, e.g., "I am good at comprehending others' comments."). "Enacting" includes abilities to establish goals, devise plans, and oversee actions to complete a feedback cycle ($\alpha = 0.927$; 4 items, e.g.,

"I am good at adjusting or setting goals for my later learning to respond to suggestions."). "Appreciation of feedback" includes recognition of the significance of feedback in the learning process (α = 0.914; 4 items, e.g., "I have realized that feedback from other people can make me recognize my learning strengths and weaknesses."). "Readiness to engage" includes managing emotions to constructively respond to negative or critical feedback (α = 0.896; 4 items, e.g., "I am always ready to receive hypercritical comments from others."). "Commitment to change" includes students' willingness to actively engage with feedback and dedicate time and effort to ongoing improvement (α = 0.918; 4 items, e.g., "I am always willing to overcome hesitation to make revisions according to the comments I get."). We used a 6-point Likert scale ("completely disagree"–"completely agree"), and used the average score for the 24 items to indicate a learner's feedback literacy score. The α coefficients for each dimension, in the order listed above, are 0.909, 0.941, 0.962, 0.951, 0.915, and 0.946, which are similar to the values reported by Zhan (2022) for each dimension, indicating high reliability. The α coefficient of the six dimensions for the entire scale in this study is 0.977.

Academic achievement

In this study, we will use mathematics scores as an indicator to measure student academic achievement in mathematics. In Guangdong province, where this study was conducted, a unified municipal assessment test for students is conducted in concluding each academic year. Mathematics scores for the participants on this standardized test were obtained from their school records. Mathematics is considered a major subject in China, from elementary to high school, and is frequently of importance in demonstrating high school students' mathematics performance. Overall, the mathematics rating was 150 points, and 90 points marks the passing score.

All surveys were conducted after students completed a unit called the "First Round Knowledge Review." This timing was chosen deliberately because a standardized test is administered shortly after the unit to assess students' mastery of the content. Conducting the survey at this point gives students an opportunity to reflect retrospectively on their understanding of feedback and the teacher support they received throughout the unit. The timing also ensures that students' perceptions of feedback literacy are grounded in recent experiences, allowing for a clearer exploration of the relationships among perceived teacher support, student feedback literacy, and academic achievement in mathematics.

Data analysis

We used SPSS software (v. 26; IBM SPSS) to calculate descriptive statistics, including Cronbach's α as well as correlation coefficients. In testing the structure of factors, we conducted confirmatory factor analysis (CFA) via R software; using structural equation modeling (SEM), we tested structural relations within the hypothesized model (R Core Team, 2019).

Accordingly, the hypothesized mediation model (Figure 1) was tested using robust maximum likelihood estimation (MLR), which accounts for departures from normal distribution by adjusting fit indices for a given model of the data. This is common in data based on a Likert-type scale (Li 2016; Zhong and Yuan 2011). To assess how well the data fit our model, we examined several goodness-of-fit indexes (GFIs). The GFI is generally demonstrated with reference to values for comparative fit index (CFI) and Tucker-Lewis Index (TLI) near or exceeding .90, by root mean square error of approximation (RMSEA) under .08, and by standardized root mean square residual (SRMR) under .10 (Kline, 2016). We recalculated the indirect impacts using percentile bootstrap confidence intervals (CIs) based on 1,000 resamples, where each resample was drawn with replacement from the original data set of 230 participants. This standard resampling approach ensures robust estimates of the sampling distribution and reliable confidence intervals (Preacher & Hayes, 2008). While doing this, we based indirect effect on a distribution of resampled estimates rather than any one product value, therefore seeking greater reliability in comparison to other estimations (Tibbe & Montoya, 2022).

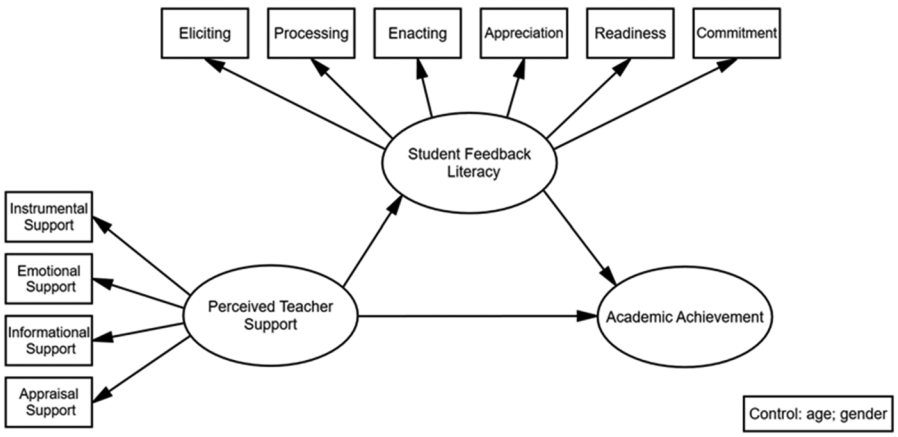

Figure 1. Hypothesized structural model.

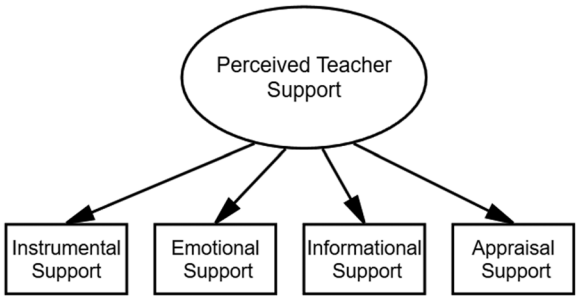

Figure 2. Modified model of perceived teacher support.

Results

This section presents our findings. First, we describe the descriptive statistics, scale reliability, and bivariate correlations to provide an initial overview of the relationships among the variables. Next, we present the CFA conducted to validate the measurement model, including the steps taken to optimize model fit. Finally, we report the main analysis of the hypothesized mediation model using SEM, followed by an assessment of mediation effects through bias-corrected bootstrapping.

Preliminary analyses

In Table A1 we present means, *SD*s, α coefficients of the scales, and bivariate correlations among the variables. Cronbach's α coefficients for all scales were satisfactory (all α > .900). All correlations obtained support the hypotheses: perceived teacher support had significantly positive correlations to students' feedback literacy ($.345 < r < .901$), student feedback literacy had significant positive correlations with mathematics academic achievement ($.183 < r < .272$), and perceived teacher support had significant positive correlations to mathematics academic achievement ($.264 < r < .366$).

CFA

The measurement model consisted of two second-order latent variables and 10 first-order latent variables. Given the high covariance among the four types of perceived teacher support (ranging from .745 to .901) (Hair et al., 2019), we performed second-order CFA to simplify our model and quantify the total effect by merging the four subconstructs: instrumental, emotional, informational, and appraisal support. The second-order factor approach allows us to quantify the total effect of teacher support while reducing potential multicollinearity and maintaining the conceptual coherence of the construct. While the measurement model has been adjusted, the core theoretical framework and hypotheses remain consistent. The second-order factor model captures the shared variance among the sub-constructs, reflecting their collective contribution to the overall construct. This ensures that the relationships hypothesized in the model are still represented, albeit through a streamlined structure. We have included an updated diagram of the modified model in Figure 2. To improve the model fit in CFA, we sequentially eliminated items based on the error covariance values identified through the modification indices (MI). The decisions were guided by the following substantial arguments in the meantime: (1) construct clarity: items that extended beyond the academic focus (e.g., addressing nonacademic growth or advice) were removed to sharpen the construct definitions and ensure alignment with the theoretical framework of perceived teacher support; (2) conceptual overlap: items that risked blending with other subscales (e.g., emotional support and informational support) were excluded to maintain distinctiveness among the dimensions of support; And (3) measurement redundancy: generic or overly broad items that introduced redundancy with more specific items within the same construct were eliminated to enhance precision and reduce conceptual noise. After deleting the items, SEM obtained an acceptable model fit: S-Bχ^2/df = 1.827, CFI=.954, TLI=.946, SRMR=.035, RMSEA=.087. Although RMSEA is at the threshold boundary, it is still below 0.1 (Browne & Cudeck, 1992). These items are: two items from the Instrumental support subscale (#05: "My teachers will take time to help me when I meet problems other than study" and #07: "My teachers create conditions to promote my growth in areas other than study"); one item from the emotional support subscale (#10: "My teachers encourage me to study hard"); two items from the informational support subscale (#15: "My teachers teach me how to handle things through demonstration" and #17: "My teachers give me advice on topics other than study when I meet problems in my campus life"); and one item from the appraisal support subscale (#22: "My teachers give me feedback about my learning tasks"). We recalculated the internal consistency of the adjusted constructs. The results showed that reliability indicators remained within the accepted range: teacher instrumental support (α = 0.933), teacher emotional support (α = 0.954), teacher informational support (α = 0.967), and teacher appraisal support (α = 0.934). We also examined the convergent validity and content validity of the constructs. By calculating the average variance extracted (AVE), we ensured that the revised constructs effectively capture their theoretical essence. The AVE values for teacher instrumental support, teacher emotional support, teacher informational support, and teacher appraisal support were 0.742, 0.808, 0.861, and 0.789, respectively. All values exceeded the recommended threshold of 0.50, indicating that a substantial proportion of the variance in each construct is explained by its respective indicators (Hair et al., 2019). Although some items were removed, the core definitions and measurement dimensions of the constructs remain unchanged. The retained items adequately cover the primary content and key dimensions of the original constructs, thereby ensuring conceptual consistency. The revised scale is attached in Appendix A. According to the baseline, the modified SEM of the Student Feedback Literacy scale (i.e., removing item #8 [I am good at recognizing different standing points of other people when they give comments on my work]) showed a satisfactory model fit: S-Bχ^2/df= 1.686 CFI = .955, TLI = .949, RMSEA = .077, SRMR = .039.

Primary analysis—mediational model

Using SEM, we analyzed our hypothesized model. The findings indicate our model surpasses standard criteria; it effectively represents the relationships within the sample. Our proposed theoretical model, displayed in Figure 1, fitted the data well: S-Bχ^2/df = 1.551, CFI = .980, RMSEA = .062, TLI = .974, and SRMR = .042. The model's standardized regression weights are shown in Figure 3.

H1: Perceptions of teacher support have a significant, positive relation to mathematics academic achievement.

The results confirmed that perception of teacher support positively predicts mathematics academic achievement (β = .371, p < .001), supporting H1.

H2: Student feedback literacy is significantly and positively related to mathematics academic achievement.

The analysis demonstrated that perceived teacher support positively predicts student feedback literacy (β = 0.166, p < 0.05), supporting H2.

H3: Perceptions of teacher support have significant, positive relations to student feedback literacy.

The findings showed that student feedback literacy positively predicts academic achievement (β = .300, p < .001), supporting H3.

H4: Students' feedback literacy has a mediation effect on relations between perceptions of teacher support when it comes to mathematics academic achievement.

Bias-corrected bootstrapping was used to test the mediation effects for significance. An indirect effect was considered significant if the 95% confidence interval (CI) did not include zero (Hayes, 2017). Table 1 shows that the indirect effect of perception of teacher support on mathematics academic achievement through student feedback literacy was significant (effect = .061, 95% CI [.249, 3.302]), supporting H4.

Discussion

We explored the relation of perceptions of teacher support and student feedback literacy to mathematics academic achievement among Chinese school students. The results showed support for a mediating effect due to students' feedback literacy relating perceptions of teacher support to academic achievement.

The relation of perceived teacher support to academic achievement shows partial directness. Consistent with our hypothesis H1, studies have found that, as students perceive more teacher support, students achieve higher grades (Danielsen et al., 2010; Tao et al., 2022). This is also consistent with microsystem theory, which states that teacher support, as part of the microsystem, plays a significant role in adolescent achievement (Fairless et al., 2021). Teacher support helped students become more resilient, especially in how they handled academic pressure and setbacks emotionally (Fang et al., 2020).

Our hypothesis H3 that students' feedback literacy would predict academic achievement was supported. Hence, stronger feedback literacy is linked to improvements in academic performance. This finding emphasizes the importance for learning that may be attributed to feedback. It indicates a critical role for feedback literacy in helping students effectively utilize feedback and adjust learning strategies while enhancing outcomes (Carless & Boud, 2018). These findings also show consistency in relation to earlier research demonstrating improving students' feedback literacy significantly positively impacts academic achievement (Karunarathne et al., 2024; Rad & Mirzaei, 2024).

Table 1. Bias-corrected bootstrap test results.

Effect path	Estimate	95% BCI
PTS → AA		
Direct effect	0.300	[4.409, 11.619]
Indirect effect		
PTS → SFL → AA	0.061	[0.249, 3.302]
Total: direct + total indirect	0.361	[6.373, 12.911]

Note. BCI, bootstrap confidence interval; PTS, perceived teachers' support; SFL, student feedback literacy; AA, academic achievement.

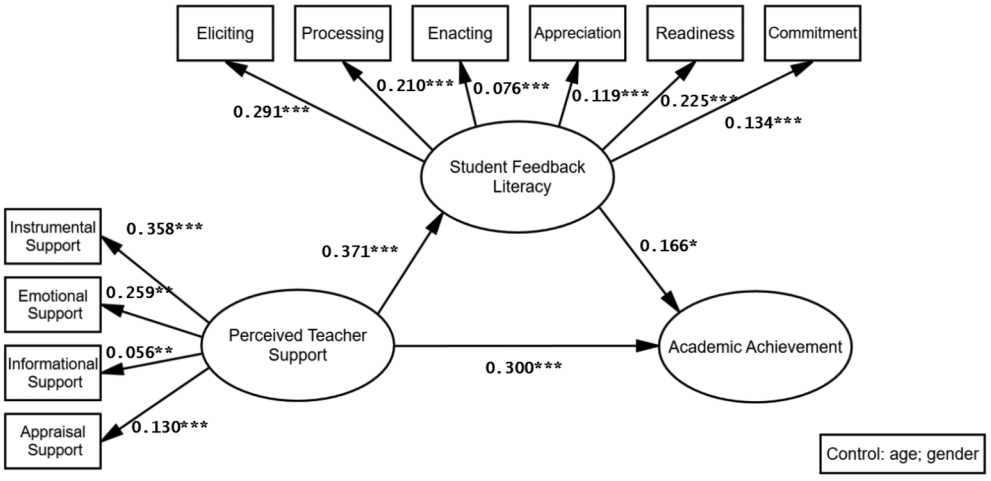

Figure 3. Structural model showing standardized direct effects *** p < 0.001, ** p < 0.01, * p < 0.05.

Our analysis found that students' perceptions of teacher support may enhance academic achievement by fostering feedback literacy. A mediating role for students' feedback literacy could be attributable to students' greater likelihood of demonstrating higher feedback literacy when they report greater teacher support. This is then relatable to greater academic achievement. This result echoes the importance attached to students' feedback literacy in influencing learning (Carless & Boud, 2018) and learning ability (Nieminen & Carless, 2023).

That is, teacher support is implemented through practices such as providing clear and constructive feedback and creating an environment that encourages students to view feedback as a learning tool rather than criticism, thereby enabling students to develop the skills needed to interpret and act on feedback. These practices align well with Carless and Boud's (2018) assertion that, by demonstrating how to interpret and apply feedback, teachers help students internalize these skills and use feedback autonomously.

Our findings also extend the literature, providing empirical evidence for the role of social learning theory in developing feedback literacy. As Vygotsky's (1978) social learning theory states, knowledgeable individuals, such as teachers, promote cognitive development.

In addition, our findings are consistent with Bandura's social learning theory, which emphasizes learning through observation and imitation (Bandura, 1986). By modeling effective feedback practices, teachers can serve as role models, demonstrating how to use feedback effectively. When students observe that teachers value and skillfully utilize feedback, they are more likely to adopt similar strategies, thereby improving their self-efficacy and academic performance.

In summary, teacher support is essential for developing feedback literacy, which can enhance academic achievement. By equipping students with the skills and positive attitudes to handle feedback, teachers enable them to become proactive and adaptable learners who can maximize the benefits of feedback, continuously improve, and achieve academic success.

Practical implications

By demonstrating that teacher support and academic achievement in mathematics have a relation, one mediated by student feedback literacy, this study offers several practical implications.

First, teachers provide important support for students' feedback literacy (Carless, 2022; Han & Xu, 2020). Thus, it is recommended that teachers provide students with occasions whereby they may foster willingness and ability as they effectively take part in feedback through various supportive and well-designed learning environments (such as using exemplars and peer assessment; Carless, 2022).

Second, teachers should improve their own feedback literacy because teacher feedback literacy is interactive and supportive, in a reciprocal relationship, with respect to student feedback literacy (Carless & Winstone, 2023), which helps teachers provide better support to students. For instance, teachers' relational sensitivity promotes students' feedback literacy because it actively encourages students to cope emotionally (Carless & Winstone, 2023). Therefore, teachers should not only receive training on how to encourage students to integrate feedback practices into learning but also provide specific implementation strategies.

Third, feedback literacy not only equips students with the skills to interpret and apply feedback effectively but also supports essential self-regulated learning processes such as self-monitoring, self-assessment, and strategic adaptation. As students develop their feedback literacy, they become more capable of self-regulating their learning, leading to improved academic outcomes. Therefore, educators should prioritize the development of feedback literacy alongside self-regulated learning strategies, creating learning environments that foster both immediate academic achievement and long-term autonomy in learning.

Limitations and future directions

The study has several limitations. First, it is limited by its cross-sectional approach, which precludes any conclusions regarding causality among the associations identified. Second, we sampled two school populations in Guangdong. Given cultural differences between Western and Chinese contexts, this sample may not be adequately representative of relations linking perceptions of teacher support to school students' academic achievement across different mainland-Chinese regions, nor can it be generalized to Western contexts. Third, although the psychometric scales employed in this study have been validated for reliability and validity, we used self-reported measures that risked introducing common method bias.

In future, we hope that the results of this study will be verified through longitudinal experimental designs to expand the current findings. In addition, more extensive research should be conducted in other parts of China and other Asian countries beyond China. Implementing a multimethod research design to combine self-reported data with objective measures or other data sources (such as behavioral observations or teacher reports) can help validate self-reported data and identify potential biases (Creswell & Plano Clark, 2018).

Conclusion

Consistent with the hypothesized mediation model (Figure 1), this article reports on perceptions of teacher support as showing positive association to student feedback literacy. This relation was positive in its association to mathematics academic achievement. Teachers' support indirectly affected academic achievement via students' feedback literacy. These findings contribute to a body of literature that explores mechanisms through which teacher support affects academic achievement. Our findings also provide new insights into how to influence students' feedback literacy. This knowledge has both theoretical and practical implications for exploring the pathways and mechanisms that can promote learning through student

feedback literacy. It is important that educators support learners' development of feedback literacy, which can help students make better use of feedback practices, thereby improving their learning outcomes at school.

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Appendix A

Table A1. Descriptive statistics and correlations across latent variables.

	Mean	*SD*	Cronbach's α	1	2	3	4	5	6	7	8	9	10	
1. Eliciting	4.254	0.065	0.909	–										
2. Processing	4.352	0.064	0.941	.779**	–									
3. Enacting	4.170	0.068	0.962	.729**	.820**	–								
4. Appreciation	4.292	0.064	0.951	.735**	.826**	.869**	–							
5. Readiness	4.353	0.064	0.915	.724**	.786**	.779**	.784**	–						
6. Commitment	4.187	0.067	0.946	.742**	.790**	.879**	.867**	.814**	–					
7. Teacher Instrumental support	4.703	0.065	0.933	.345**	.354**	.375**	.376**	.417**	.353**	–				
8. Teacher emotional support	4.817	0.067	0.954	.387**	.385**	.378**	.395**	.350**	.366**	.745**	–			
9. Teacher informational support	4.739	0.070	0.967	.354**	.375**	.359**	.357**	.401**	.346**	.808**	.849**	–		
10. Teacher appraisal support	4.762	0.067	0.934	.387**	.392**	.395**	.405**	.392**	.388**	.797**	.797**	.901**	–	
11. Academic achievement	56.54	1.777	–	.257**	.183**	.250**	.248**	.272**	.231**	.319**	.334**	.366**	.264**	–

Note. $^{**}p < 0.01$.

Appendix B. Perceived Teacher Support Scale

My teachers

Instrumental support

Item 1: will take time to help me when I need help for my study,
Item 2: give me opportunities to show myself.
Item 3: organize activities for me to collaborate with others in learning.
Item 4: try their best to ensure the things I need for study.
Item 5: will take time to help me when I meet problems other than study.
Item 6: create conditions to promote my growth in study.
Item 7: create conditions to promote my growth in areas other than study.

Emotional support

Item 8: trust me.
Item 9: respect me.
Item 10: encourage me to study hard.
Item 11: are happy to listen when I want to talk about a question/problem.
Item 12: treat me fairly.
Item 13: believe that I have potential.

Informational support

Item 14: provide information to assist me in solving problems myself.
Item 15: teach me how to handle things through demonstration.
Item 16: give me study advice.
Item 17: give me advice on topics other than study when I meet problems in my campus life.
Item 18: provide information to assist me in identifying my strengths and weaknesses.
Item 19: tell me the focuses and the difficulties of my learning.
Item 20: provide information to assist me in thinking about my future goals.

Appraisal support

Item 21: will inform me when I make mistakes.
Item 22: give me feedback about my learning tasks.
Item 23: tell me how I perform in class.
Item 24: give me feedback about my behavior other than study.
Item 25: give me feedback on my areas of improvement.