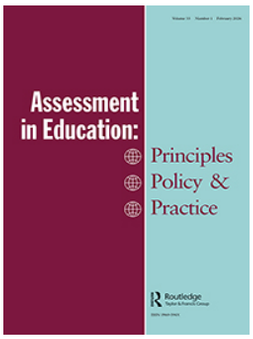

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Relationship between formative assessment practices and students' academic achievement: the mediating role of student engagement

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ABSTRACT

Theoretical benefits attributable to formative assessment of students' academic achievement are widely recognised. Empirical evidence has, however, shown that this positive relationship is not straightforward, prompting investigations into factors that may influence such a relationship. In the current study, we examine the mediating role of student engagement in the relationship between formative assessment practices and students' academic achievement in mathematics. The survey sample consisted of 379 tenth-grade students from mainland China. Structural equation modelling revealed that formative assessment practices did not directly impact students' academic achievement. Rather, the analysis indicated that student engagement mediated formative assessment practices' indirect and positive impact on academic achievement. The findings suggest that student engagement plays an important mediating role in the relationship between formative assessment practices and students' academic achievement.

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Formative assessment practices; student engagement; academic achievement

Formative assessment is known for its positive impact on learning (Hattie & Timperley, 2007; OECD, 2015). Transitions from theory to practice for formative assessment have not, however, always been straightforward (Browne, 2016; Marshall & Jane Drummond, 2006; Swaffield, 2011; Yan et al., 2022) and the empirical evidence of its effect on academic performance has been reported to be mixed (Chen & Andrade, 2018; Randel et al., 2016; Yan et al., 2021, 2023; Yin et al., 2014). Furthermore, researchers' understanding of the mechanisms by which formative assessment influences academic achievement remains limited.

Effectiveness has been reported in formative assessment practices though various factors affect it. For example, quality of feedback has been identified as an important component of effective formative assessment (Hattie & Timperley, 2007). Drawing on national data from PISA 2009 in the United States, Li (2016) demonstrated that formative assessment practices contribute to the development of positive teacher–student relationships, which in turn support students' academic success. Similarly, Monteiro et al. (2021)

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used multilevel modelling with classroom-based data from middle school and early secondary education students in Portuguese public schools, and found that supportive classroom environments operationalised through teachers' use of effective feedback were associated with higher levels of students' behavioural engagement. Notably, research in this line has tended to focus on factors external to learners themselves, like instructional and contextual conditions surrounding the assessment process. Previous studies have shown that one barrier to successful formative assessment is the lack of student engagement during assessments (Guo & Yan, 2019; Yan & Brown, 2021). The role of student involvement in assessments has been highlighted as an important aspect of formative assessment (Black & Wiliam, 1998). These findings suggest that the mixed evidence regarding the effectiveness of formative assessment may reflect insufficient attention to learners' active engagement in the assessment process. Against this backdrop, student engagement, which refers to the extent to which students actively and productively participate in learning, can be considered critical to effective formative assessment. Since student engagement is central to learning success (Hiver et al., 2021), linking student engagement to formative assessment may provide useful insights into a better understanding of formative assessment's impact mechanisms (Yang et al., 2021). Evidence from a quantitative study involving university students across public and private higher education institutions in the United Arab Emirates has shown that highly engaged students tend to invest greater effort in their studies (Shomotova et al., 2025). This study extends prior research by explicitly examining student engagement as a mediating mechanism linking formative assessment practices to academic achievement. In this vein, student engagement could potentially act to mediate the relationship of formative assessment practices to academic achievement. Prior research has not yet confirmed this relationship which sets the scene for the current study. Consequently, the mixed evidence regarding the effectiveness of formative assessment may partly reflect insufficient attention to students' active involvement in assessment processes. We address the gap in available literature by exploring relationships among formative assessment practices, student engagement, and academic achievement. As motivational factors and cognitive demands vary across disciplines, which can impact student responses to formative assessment and interactions with the material, the implementation of assessment methods and teaching strategies is contingent upon specific subject content (Wiliam & Leahy, 2015), and varies significantly between subjects (Black & Wiliam, 2004). Thus, focusing on a single subject to link formative assessment, engagement, and academic achievement provides a more nuanced understanding of these interrelationships. By narrowing the focus to a single subject, students are able to be more accurate in their responses to questionnaires about formative assessment practices and engagement.

Mathematics is selected in this study because it is a fundamental subject and a critical tool across various disciplines, taught from kindergarten through to university and beyond (Su et al., 2021). In China, mathematics is a mandatory subject from primary school to high school (Wang et al., 2017). It plays a central role in high-stakes examinations such as the high school entrance examination (Zhongkao) and the National College Entrance Examination (Gaokao), which substantially influence students' educational trajectories. Recognising its importance for their children's academic and career prospects, Chinese parents place significant emphasis on mathematics education and have

high expectations for their children's performance in this subject (Cao et al., 2006). Given the importance and attention mathematics receives, we selected it as a target subject for academic achievement in this study.

Building on this rationale, the present study examines the relationship between formative assessment practices, student engagement, and academic achievement within the context of mathematics education, aiming to provide a clearer understanding of how formative assessment influences academic outcomes through student engagement.

Formative assessment and academic achievement

There exist various definitions of formative assessment. According to Black and Wiliam (1998), when teachers use assessments during learning activities while adjusting their efforts to better meet students' needs, this type of assessment is called formative assessment. According to the OECD (2005), formative assessment is a frequent and interactive assessment of students' progress; it supports the identification of students' needs as well as the adjustment of teachers' instructions. In general, formative assessment emphasises that information obtained during the learning process can be helpful for both teachers' teaching and students' learning. Similarly, some scholars have further conceptualised formative assessment as assessment conducted within the instructional process with the explicit purpose of improving teaching or learning (Shepard, 2008; Shepard et al., 2005). Recent research and meta-analyses have reinforced that formative assessment functions as an ongoing process integrated within instruction to support learning growth (Goertzen et al., 2025; Xuan et al., 2022).

According to Wiliam and Leahy (2015), five main practical strategies are implemented in the classroom: (1) explain, share, and allow students to understand success criteria and learning intentions; (2) design effective classroom tasks, such as classroom discussions; (3) provide feedback to drive the learning process; (4) activate learners as teaching resources; and (5) activate learners as owners of their own learning.

For the first strategy, student learning is promoted if learning intentions and success criteria are clear, shared, or understood. Wiliam and Leahy (2015) demonstrated that students need to know the direction of their learning and what constitutes high-quality work. The second strategy emphasises the role of teachers as they collect evidence of students' learning, which may inform feedback so that teachers can quickly and effectively adjust instructions to meet students' needs as related to learning. The third strategy involves harnessing the power of feedback to improve student learning. Feedback should be effective, thought-provoking, focused, and relevant to the students' learning goals. Effective feedback on assessments is considered an important tool for improving learning (Hounsell et al., 2008). The fourth strategy refers to the fact that student learning can improve substantially when students are activated as learning resources. Wiliam and Leahy (2015) argue that one will never truly understand something unless one tries to teach it to others. When students provide feedback, they face simultaneous needs to internalise their intentions for learning and criteria for success. For the fifth strategy, only students can create learning, and better students can manage their learning; thus, they will also learn better. Students can improve how they manage their learning processes and become owners of their own learning styles.

The five-strategy framework presented above is intended as a unified base on which to understand formative assessment practices. This framework covers a wide range of aspects essential to formative assessment. These five strategies may also be seen to provide a clear basis for evaluating the formative assessment of teaching practices. The current study consequently draws on these strategies to evaluate formative assessment in classroom practice.

Many studies have explored formative assessment's positive impact on academic performance. Black and Wiliam (1998) reviewed a wide range of studies in school and college settings and reported substantial achievement gains associated with formative assessment. In an analysis of more than 800 meta-analyses, Hattie (2009) reported an impact on academic achievement due to formative assessment ranked third among 138 learning activities affecting student performance and the effect size was .9. A recent meta-analytical review of 48 studies, their combined sample consisting of 116,051 K-12 students, attributed a positive but limited effect to formative assessment in terms of students' reading achievement, with an effect size of 0.19 (Xuan et al., 2022). However, some formative assessment strategies have been shown to have no significant impact on academic performance (e.g., Bennett, 2011; Briggs et al., 2012; Yan et al., 2021). In general, since formative assessment's impact on academic performance is supported by theory and relatively large amounts of experimental evidence, we propose the first hypothesis:

H1: Formative assessment is significantly and positively related to academic achievement.

Student engagement and academic achievement

Student engagement usually refers to the extent to which students actively and productively participate in learning activities and is conceptualised in many studies as the ABC types of engagement, where A is affective engagement, B is behavioural engagement, and C is cognitive engagement (Ben-Eliyahu et al., 2018; Christenson et al., 2012; Fredricks et al., 2004, 2019). Affective engagement is the degree to which students feel activated during learning activities (Wong & Liem, 2022). This includes activating positive emotions while deactivating negative ones. Positive emotions may include senses of vitality, interest, or enjoyment (Skinner et al., 2009). Negative emotions may include tiredness, boredom, frustration, anger, and anxiety (Skinner et al., 2008). Activating emotions with positive valence has been shown to have a demonstrable relation to academic progress (Heddy & Sinatra, 2013; Pekrun et al., 2002), and students' higher emotional involvement reflects intrinsic motivation to learn, to act with a sense of belonging in the classroom (Lam et al., 2014). However, it should be noted that the effects of academic emotions are context-dependent and cannot be determined solely by emotional valence. Some positive emotions (e.g., relief) may have deactivating effects on subsequent engagement, whereas certain negative emotions (e.g., anxiety) can be activating and facilitate academic effort and performance under specific conditions (Pekrun et al., 2002).

Behavioural engagement refers to observable behaviours (Birch & Ladd, 1997; Wong & Liem, 2022) that students take in making an effort to complete learning tasks or

extracurricular activities (Finn et al., 1995). Students' high behavioural engagement is reflected in diligence towards their learning tasks, as well as engagement in extracurricular activities (Lam et al., 2014). These efforts and participation often predict learning progress, such as improved skills and grades (Ericsson et al., 1993; Ladd & Dinella, 2009).

Cognitive engagement is defined in actions that might optimise one's thought process (Wong & Liem, 2022) and refers to the strategies selected and applied by students (Walker et al., 2006). This involves self-managed thinking, for example, in exercising control over one's strategies for attentiveness, self-regulation, critical thinking, and problem-solving. These thinking-optimising behaviours primarily arise from students' motivational states and have been shown to predict academic progress (Greene et al., 2004).

The majority of studies have demonstrated student engagement as critical to academic success. For example, the meta-analysis of Chang et al. (2016), which synthesised studies conducted primarily in the United States and spanning elementary, secondary, and higher education levels, reported significant positive correlations between behavioural, cognitive, and emotional engagement and academic achievement. Across 58 articles, these three types of engagement were found to show significant and positive correlation towards academic achievement, with effect values of 0.299, 0.232, and 0.238, respectively (Chang et al., 2016). Another recent meta-analysis by Wong et al. (2024), drawing on studies conducted predominantly in North America, Europe, and Australia, with a smaller number of studies from Asia, examined 137 studies involving 158,510 participants and found that academic achievement was strongly related to emotional, cognitive, and behavioural engagement. Given the practical evidence of a relationship between student engagement and academic achievement, we propose a second hypothesis:

H2: Student engagement is significantly and positively related to academic achievement.

Formative assessment and student engagement

Reciprocal determinism in *Social Learning Theory* states that behaviour, human factors, and environmental factors function as interconnected and interacting determinants (Bandura, 1977, 2001). In the current study, these three factors are reflected by students (human factors) being able or unable to get help from teachers' formative assessment strategies and related course activities (the environment), and then taking action (behaviour). The environment affects the way we think, feel, and behave, and can therefore promote or hinder us from taking the desired actions (Ponton & Carr, 2016). Effective learning environments have been shown to promote students' engagement while allowing teachers and students to ensure the progress of learning as intended (Wiliam & Leahy, 2015). Formative assessments may involve teachers monitoring learning progress or providing feedback, both of which are environmental factors that may enhance student engagement as well as learning outcomes (Yang et al., 2021). Hence, we argue that formative assessments embedded in classroom practices affect students' thinking, feeling, and actions, which, in turn, promote students' participative behaviour.

According to Bonwell and Eison's (1991) conception of active learning, students' learning is enhanced if they are able to participate actively, as opposed to the passive

reception of information. Hence, student engagement is likely to improve their academic performance. Active learning can promote deeper understanding, critical thinking, and memory of materials, thereby improving learning outcomes.

Both student engagement and formative assessment play important roles in learning as collaborative and interactive processes. While student engagement, as a psychological process, mediates the effect of environmental factors on academic performance (Lam et al., 2014), assessment plays central to teachers' creating a successful learning environment.

Theoretically, formative assessment practices that focus on learning strategies may lead to students' greater engagement in learning activities. From a behavioural perspective, for example, when teachers design classroom discussion activities to make students more behaviourally involved in learning, providing more opportunities for students to respond during instruction is associated with higher engagement in the lesson (Meyer et al., 2022). In terms of emotional engagement, moreover, when teachers provide feedback or encourage students to become each other's learning resources, they may experience positive feelings, thereby promoting emotional participation (Reschly et al., 2020). With respect to cognitive engagement, some research has suggested that students' cognitive engagement is affected by factors such as course structure goals (Ames & Archer, 1988; Meece et al., 2006), which echo the first formative assessment strategy – clarifying and sharing learning intentions and success criteria (Wiliam & Leahy, 2015).

In addition to this direct influence, student participation, in turn, influences the practices of formative assessment. By assessing students' engagement while considering emotional factors, teachers may organise or arrange activities more effectively, encouraging students to become more actively involved in learning (Jennings & Angelo, 2006; Mandernach et al., 2011). Understanding students' engagement levels, teachers may adjust their teaching practices as they respond to variable degrees of motivation or engagement as well as fluctuations in attitude (Mandernach et al., 2011). Nevertheless, there is limited evidence concerning the links between formative assessment and student engagement. Accordingly, we proposethe third and fourth hypotheses:

H3: Formative assessment has a significant and positive relationship to student engagement.

H4: Student engagement mediates the relationship of formative assessment to academic achievement.

Pulling together the issues presented and discussed thus far, a hypothesised model is presented in Figure 1, with age and gender included as demographic covariates. Age and gender were included as covariates because prior research has shown that both variables are associated with variations in student engagement and academic outcomes. For example, Santos et al. (2021) found that female students show higher engagement than male students. Hartono et al. (2019) also reported significant differences in student engagement by gender and grade. Their results indicated that female students are generally more engaged than male students, and that younger students tend to be more engaged than older students. Previous studies have also reported differences in academic

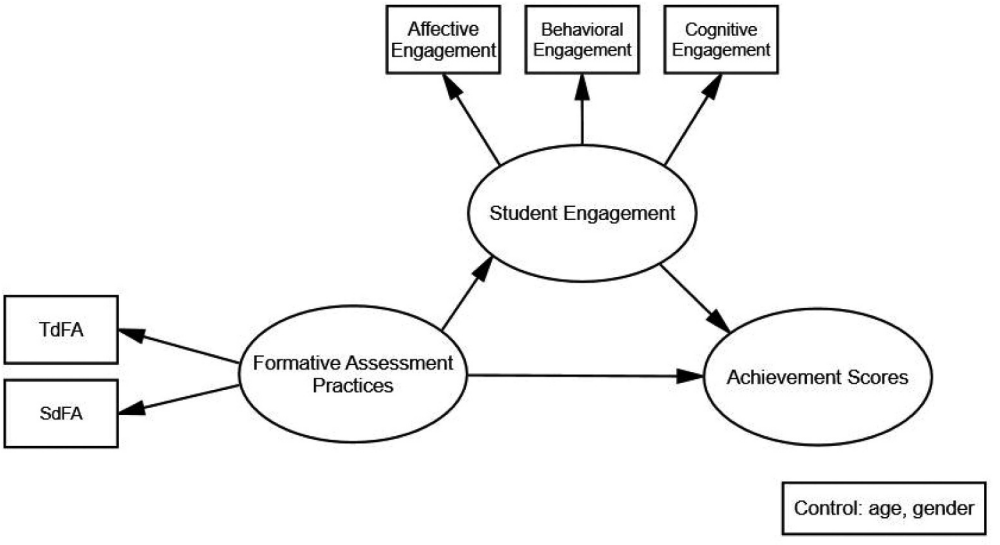

Figure 1. The hypothesised model. Note. TdFA: Teacher-directed formative assessment, SdFA: Student-directed formative assessment.

achievement related to gender and age (e.g. Douglas et al., 2020; Eze et al., 2015; Richardson & Woodley, 2003).

Context of the study

This study is set against the backdrop of high school education in mainland China. Classroom teaching in this context aims for high scores on summative examinations while also emphasising formative assessment (Brown & Gao, 2015; Xiao et al., 2023; Yu, 2023). Therefore, formative assessment often takes place concurrently with high-stakes summative assessment, which may limit students' active participation in the evaluation process. In such contexts, students' examination performance and corresponding scores are often prioritised, sometimes at the expense of their engagement in meaningful learning (Carless & Lam, 2014). Given this educational context, studying the relationship between formative assessment, student engagement, and academic achievement is particularly important. Understanding the role of student engagement may help explain why formative assessment does not always lead to improved academic performance in high-pressure educational environments like Chinese high school classrooms.

Methods

Research participants

A convenience sampling method was used. A total of 434 tenth-grade students in two high schools in Guangdong Province, China, were invited to participate in the survey, and 430 completed questionnaires were returned. After excluding invalid questionnaires (e.g., selecting the same option for all items), 379 valid responses

were retained for the subsequent analyses. Respondents' mean age was 16.16 (SD ± 0.46), the range was 14–18. There were 176 females (46.4%) and 203 males (53.6%). Of the full sample, 320 (84.4%) gave complete answers, while 50 (13.5%) had missing values (less than 5%). The remaining 9 (2.4%) had missing values between 6.5% and 65.2%. We then used the MICE package in R to perform multivariate imputation on the missing data (R Core Team, 2019; Van Buuren & Groothuis-Oudshorn, 2011).

Research instrument

Formative Assessment Practices

Formative assessment practices were measured using a student version of Yan and Pastore's (2022) Teacher Formative Assessment Practice Scale. The original scale consisted in 10 items that measured two types of teacher formative assessment practices from a teacher perspective: teacher-directed formative assessment (TdFA; α = 0.70; 6 items such as 'I share the learning intention before students start working in class') and student-directed formative assessment (SdFA; α = .75; 4 items such as 'I ask students to provide feedback to help peers improve'). The questions were transformed to align with a student's perspective (see Appendix). For example, Item 2 ('I clarify what is valued for each assessment task') was changed to 'My teacher clarifies what is valued for each assessment task'. The answer was given using a six-point scale where 1 indicated 'Never' and 6 indicated 'Very frequently'. An elevated score indicated more frequent implementation of formative assessment. The reported cronbach's α was at .95 and .90 for TdFAs and SdFAs, respectively. Cronbach's α for the whole scale was .94.

Student engagement

Student engagement was measured using an adaptation of Lam et al.'s (2014) Student Engagement Scale, which contains three engagement dimensions: affective (α = .84; 9 items; e.g. 'I am very interested in leaming'), behavioural (α = .80; 12 items; e.g. 'I try hard to do well in school'), and cognitive (α = .89; 12 items; e.g. 'When I study, I try to understand the material better by relating it to things I already know'). These items were rated using a six-point Likert scale. Affective and behavioural dimensions ranged from 1 (strongly disagree) to 6 (strongly agree). The cognitive dimension, given in terms of frequency, ranged from 1 (never) to 6 (very frequently). The reported reliability of the scale was high (Cronbach's α = .96).

Achievement scores in mathematics

Academic achievement in mathematics uses a grading system based on standards and competencies, in which grades show weighted raw scores based on student summative assessments. In some provinces of China, including the province where this study was conducted, a city-level unified examination is administered once during the school year for the teaching quality assessment of basic education. The scores for each subject were calculated separately for each participant. The current study uses mathematics learning scores for the 2022–2023 school year, where the mean student score was 68.71, out of 150.

Data analysis

Structural equation modelling (SEM) was used to test relations linking formative assessment, academic achievement, and student engagement. This approach allowed simultaneous estimation of relationships among latent variables and testing of mediation effects within a single integrated model. First, Pearson's correlation coefficient was used to examine the relationships between the variables. The measurement model was tested, and if the measurement model showed acceptability, the structural model was estimated using R. As tests for multivariate skewness as well as kurtosis demonstrated violations of assumed multivariate normality, we used a robust maximum likelihood estimation and calculated Satorra-Bentler's scaled $\chi 2$ (S-B$\chi 2$). Finally, the study used bootstrap estimation with 1,000 resamples to test for mediation effects, and an indirect effect was considered statistically significant if its 95% bootstrap confidence interval did not include zero. To assess how well our empirical data fit our hypothesised model, we used CFI ≥ .90, TLI ≥ .90, RMSEA ≤ 0.08 and SRMR ≤ 0.08 (Browne & Cudeck, 1993; Hu & Bentler, 1999).

Results

Descriptive statistics and bivariate correlations, and structural equation modelling

Table 1 outlines descriptive statistics, including correlations between variables. Students demonstrated high behavioural engagement (4.43/6), cognitive engagement (4.50/6), and TdFA (4.55/6). Results from correlation analysis suggested formative assessment practices were moderately correlated with each variable and weakly correlated with academic achievement. Following conventional guidelines for interpreting correlation coefficients (Cohen, 1988), correlations around .30 were considered moderate, whereas correlations around .10 were considered weak.

Measurement model

To simplify our model and quantify a total impact of formative assessment practices, a second-order CFA was conducted by merging two sub-constructs, TdFA and SdFA. In this study, after deleting Item #06 and Item #07, the SEM obtained acceptable model fits: S-B$\chi 2/df = 2.389$, CFI = .983, TLI = .985, SRMR = .032 and RMSEA = .085. According to the benchmark, the modified SEM for the student engagement scale (i.e., removing items

Table 1. Correlations among latent variables.

	Mean	SD	BE	CE	TdFA	SdFA	Academic achievement
AE	3.88	1.09	.63***	.55***	.45***	.42***	.21***
BE	4.43	1.04	–	.60***	.41***	.33***	.16**
CE	4.49	0.99		–	.49***	.37***	.21***
TdFA	4.55	1.10			–	.68***	.20***
SdFA	4.01	1.31				–	.11*
Academic achievement	68.71	29.18					–

Note. AE: Affective engagement, BE: Behavioural engagement, CE: Cognitive engagement, TdFA: Teacher-directed formative assessment, SdFA: Student-directed formative assessment. ***p< .001. **$p < .01$. *$p < .05$.

#9, #10, #12, and #14) showed an accepted model fit: S-Bχ2/df = 2.284, CFI = .947, TLI = .939, SRMR = .075, RMSEA = .079.

The measurement model consisted of two second-order latent variables, six first-order latent variables, and 30 items. A preliminary evaluation of the model demonstrates that the model has a good fit: S-Bχ2/df = 1.330, CFI = .993, TLI = .987, RMSEA = .031, and SRMR = .022. The factor loadings of each latent variable indicator are all between 0.75 and 0.91, which are statistically significant, indicating that the corresponding indicator can represent each latent variable. Furthermore, correlations among latent variables showed the expected directions, as illustrated in Table 1.

Relationship between formative assessment, student engagement, and academic achievement

Figure 2 illustrates standardised path coefficients in the final model. The results demonstrated that an increase in formative assessment practices was associated with more student engagement ($\gamma = .640$, $p < .001$), while the direct effect of student engagement on achievement scores ($\beta = .204$, $p < .001$) is also significant. However, the direct impact of formative assessment practices and achievement scores ($\gamma = .079$, $p = .354$) did not show significance.

Mediating effect of student engagement

Table 2 reports direct, total indirect, and total effects. In the modelling process of this research, formative assessment was included as an independent variable predicting achievement scores. Student engagement was included as a variable mediating achievement scores. Through the mediation of student engagement, formative assessment shows a significant and positive indirect effect on achievement scores ($\beta_{indirect} = .130$, $p < .05$;

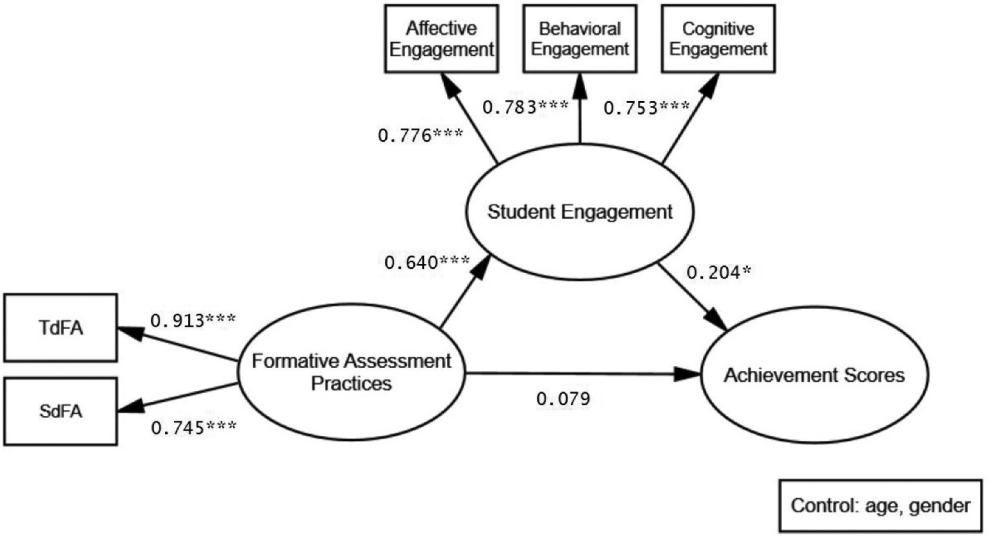

Figure 2. Structural model showing standardised direct effects. ***$p < .001$; **$p < .01$; *$p < .05$.

Table 2. Effect between variables.

Effect path	Estimate	95% BCIs.
TFAP → Achievement scores		
Direct effect	0.079	[−2.580, 7.20]
Indirect effect		
TFAP→Student engagement→Achievement scores	0.130	[0.373, 7.245]
Total: direct+total indirect	0.209	[2.699, 9.539]

$\beta_{total} = .209$, $p < .001$), indicating a full mediation effect. The indirect effect was calculated as the product of the path from formative assessment to student engagement and the path from student engagement to achievement scores, with significance assessed using bias-corrected bootstrap confidence intervals.

Discussion

This study examined the complex relations of formative assessment to student engagement and academic achievement. Data from 379 tenth-grade students in mainland China were used for testing the mediation model. The final model indicated that student engagement was a mediator in the link between formative assessment and academic achievement. The findings provide empirical evidence on how formative assessment practices and student engagement affect academic performance.

Direct relationships between formative assessment, student engagement

The key variables in this analysis include formative assessment and student engagement, which are theorised to positively impact academic achievement. This suggests that students with greater experience in formative assessment practices and a higher sense of engagement tend to achieve better results. The SEM results indicated that formative assessment practices directly affect student engagement ($\beta = 0.640$), supporting hypothesis H_3. This also confirms that formative assessment practices are well suited to enhancing processes related to engagement (Nichols & Dawson, 2012). Student engagement was also found to significantly affect academic performance ($\beta = 0.204$) directly, supporting hypothesis H_2. These findings are consistent with *reciprocal determinism*, which conceptualises learning as the result of dynamic interactions among environmental factors (e.g., formative assessment practices), individual processes, and behavioural responses such as student engagement (Bandura, 2001). From an achievement goal perspective, student motivation is intricately tied to their learning environment, shaped by their perceptions of school values, achievement criteria, and success definitions (Anderman & Patrick, 2012). Classroom goal structures, as subjectively perceived by students, are closely related to the quality of student engagement (Anderman & Patrick, 2012).

The key goal in offering feedback is to encourage students to actively participate in the learning and assessment process. Furthermore, teacher feedback helps shape students' self-regulation abilities (Kyaruzi et al., 2018). From a self-regulation perspective, students play an active and constructive role in supervision, control, and regulation in their

cognition, motivation, and behaviour (Pintrich, 2000), making students the main body of learning, which ultimately leads to an increase in student engagement.

From a collaborative learning perspective, shared learning experiences such as in-group peer assessment promote engagement and decision-making (Shiu et al., 2012; Sridharan et al., 2018; Wimpenny & Savin-Baden, 2013). How students perceive their contributions, and their peers', drives participation and learning outcomes within groups (Adesina et al., 2022). Student engagement, a precursor to academic achievement, is crucial across various engagement models (Kahu & Nelson, 2018; Wang et al., 2019). Ultimately, increased engagement leads to enhanced attention, focus, and motivation, aligning with constructivist learning principles (Bransford et al., 1999).

Indirect relationships among formative assessment, student engagement, and academic achievement

Results showed no statistical significance in the direct effect due to formative assessment practices concerning academic performance ($\beta = .079$, $p = .354$), consistent with previous studies (Boström & Palm, 2023; Van den Berg et al., 2017; Yan et al., 2021, 2023). However, student engagement emerged as a significant mediator of the relation between formative assessment and academic achievement, with an indirect effect of 0.130 ($p = 0.035$) on academic achievement. This finding highlights that formative assessment practices alone may not guarantee improvements in academic achievement, underscoring the crucial role of student engagement as it mediates formative assessment's effect on academic performance.

Student engagement is a promising way of improving academic performance (Fall & Roberts, 2012; Maroco et al., 2016; Wu et al., 2010). Engagement is also essential for learning, and improved academic performance may in turn reinforce students' continued engagement in learning. (Christenson et al., 2012). Formative assessment relies on students' active participation in assessment processes, receiving and utilising feedback as they guide their learning (Black & Wiliam, 2009). If students receive feedback passively rather than engaging actively in evaluative and self-monitoring processes, its impact on learning may be limited (Merry, 2013). Similarly, self-assessment or peer assessment will be ineffective if students do not critically reflect on their own or peers' work and set goals for improvement (Andrade & Valtcheva, 2009; Nicol & Macfarlane-Dick, 2006). According to *reciprocal determinism*, students should take follow-up action after formative assessment practices to enhance academic achievement. This is an interactive process involving three elements (i.e., teacher's formative assessment practices, student, and engagement). Despite good intentions behind formative assessment practices, the desired effect will not be achieved if students cannot actively engage in it. This may explain why some formative assessment practices do not directly predict academic achievement.

Although the present study modelled student engagement as a mediator between formative assessment practices and academic achievement, the cross-sectional design limits strong causal interpretations. It remains possible that student engagement both supports and results from formative assessment processes. For example, students who experience success through formative assessment may report higher engagement as a consequence of positive learning experiences and a sense of achievement. At the

same time, students who are already more engaged may be more likely to benefit from formative assessment practices. Thus, engagement may function as both an antecedent and a consequence within the formative assessment–achievement relationship. Employing experimental or longitudinal designs is needed to more clearly disentangle the directionality of these relationships and to examine how engagement develops over time in response to formative assessment practices.

Theoretical and practical implications

This study deepens understanding of the theoretical mechanisms by which formative assessment influences academic achievement. Drawing on *reciprocal determinism* within *Social Learning Theory* (Bandura, 1977, 2001), formative assessment practices are conceptualised as environmental conditions associated with students' behavioural, emotional, and cognitive engagement, which are further linked to academic achievement. By identifying student engagement as a key mediator, the findings help explain why formative assessment does not always have a direct impact on academic performance. Therefore, the results link formative assessment research with student engagement, emphasising that participation is a crucial pathway for assessment practices to influence learning outcomes. In addition, the findings align with active learning by demonstrating that students' active participation serves as a central mechanism through which formative assessment translates into improved academic performance. In the meantime, these findings show the importance of supporting teachers in their use of formative assessment that actively engages students. Professional development opportunities may help teachers better understand how to translate formative assessment principles into classroom practices that encourage student involvement. Likewise, teacher education programmes could include coursework that shows future teachers how formative assessment supports student engagement.

Limitations and future study

This study has several limitations that suggest possibilities for future research. As this article's current results are primarily based on data drawn from students' self-reports, future researchers may aim to incorporate more objective data, such as observational data, for a more complete and accurate measure. Given the limitations of cross-sectional research designs, future research could employ experimental or longitudinal designs to track and test causal relations linking formative assessments, students' engagement, and ongoing effects on achievement. Future studies could also employ qualitative or mixed methods to provide an in-depth exploration into the complex mechanisms by which formative assessment influences academic achievement. In addition, the use of convenience sampling may limit the generalisability of the findings. Future research could use random or stratified sampling to improve external validity. Furthermore, this study focused on middle-school students in mainland China. Since different cultures and educational levels may have unique characteristics, future research could examine the relationships in different cultures and educational levels to better understand the relationship among the three. Finally, since this study only focused on mathematics achievement, it is not certain whether the same conclusions

can be obtained in other subjects due to the different characteristics between subjects. Future research can try other subjects to test the similarities and differences in the results.

Conclusion

This article examined relations among formative assessment, student engagement, and academic achievement. Findings demonstrated that formative assessment is significant and positively related to student engagement, which in turn is significantly positively associated with academic achievement. However, we did not find a significant direct association between formative assessment and academic achievement. Instead, the results indicated an indirect effect through student engagement. In other words, formative assessment practices lead to better academic performance when they enhance student engagement. This finding implies that simply employing formative assessment techniques does not guarantee a positive impact on students' academic achievement unless the internal psychological mechanisms, such as student engagement, are considered. Students who are actively engaged are more likely to derive benefits from the feedback and opportunities provided by formative assessments, leading to improvements in their academic performance. To optimise the advantages of formative assessment, educators need to identify strategies that actively engage students, transforming the learning process into a more engaging and participatory experience.

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No potential conflict of interest was reported by the author(s).

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Appendix

Teacher-directed Formative Assessment Scale

1 My teacher shares the learning intention before we start working in class.
2 My teacher clarifies what is valued for each assessment task.
3 My teacher uses various assessment activities in the classroom to check our mastery of course content.
4 My teacher ensures homework can check our learning progress.
5 My teacher points out our strengths and weaknesses in my feedback.
**6 My teacher provides suggestions for us to improve our performance.*
Student-directed Formative Assessment
**7 My teacher asks us to evaluate our peers' work.*
8 My teacher asks us to provide feedback to help peers improve.
9 My teacher asks us to identify strengths and weaknesses in our own work.
10 My teacher asks us to identify strategies that will improve our own work.
*Italics indicate the deleted items.