The interrelationship of behavioural, emotional, and cognitive classroom engagement in higher education: understanding the mechanisms of student success

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Abstract: This study delves into the correlation between undergraduate student engagement and their academic achievements within the context of Chinese culture. It systematically explores the interrelationship of various aspects of student engagement, including teacher-student relationships, student-student relationships, as well as cognitive and behavioural dimensions. Additionally, it investigates the moderating role of gender in the relationship between student engagement and student academic achievement. The results provide the following insights: 1) overall student engagement, teacher-student relationship, cognitive engagement, and behavioural engagement exhibit significant direct effects on student academic achievement, while student-student relationships do not significantly impact student academic achievement; 2) among the various components of student engagement, behavioural engagement has the most substantial influence on student academic achievement, followed by the teacher-student relationship. Cognitive engagement has the least pronounced effect on student academic achievement; 3) the four main components of student engagement affect student academic achievement in a serial pattern: teacher-student/student-student relationship → behavioural engagement → cognitive engagement → student academic achievement; 4) the influence of teacher-student relationship/behavioural engagement on student academic achievement is more prominent in male students than in female students.

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1 Introduction

Student engagement (followed by SE for short) is defined as the degree of participation and the emotional intensity with which a student initiates and carries out a learning activity (Fredricks et al., 2004). Within the realm of instructional technology research, a critical focus lies in supporting students to actively engage in the learning process. In higher education, educators, theorists, and policymakers alike view SE as the cornerstone for improving student outcomes and enhancing retention rates (Fredricks, 2011; Fredricks et al., 2004). SE serves as a vital lens through which we can understand the impact of educational programs on student academic achievement (followed by SAA for short), thereby fostering academic success (Crossan et al., 2003). Conversely, achieving academic success fosters further SE, creating a 'virtuous cycle of learning' (Lei et al., 2015).

According to Fredricks et al. (2004), SE is a multidimensional concept shaped by the intricate interplay of various influences (Hagel et al., 2012; Kahu, 2013). SE consists of three distinct yet interconnected dimensions: behavioural, cognitive, and emotional, each with its unique characteristics. Cognitive engagement (followed by CE for short) is closely associated with students' learning goals, motivation, self-regulation, self-monitoring, self-efficacy, critical thinking, and reflective practices. It signifies students' willingness to invest effort in comprehending course content and mastering skills. Emotional engagement (followed by EE for short) revolves around the emotional bonds that students form with their instructors and peers (Jimerson et al., 2003), and it

can be further divided into student-student relationships (followed by SSR for short) and teacher-student relationships (followed by TSR for short) (Gunuc and Kuzu, 2015). Behavioural engagement (followed by BE for short) is the most frequently reported dimension as it materialises in evident (Bond, 2020), observable actions (Appleton et al., 2006). It encompasses active participation, diligent effort, collaborative spirit, perseverance, and students' engagement in learning activities tied to their coursework. Previous research has established clear connections between BE, CE, and EE and vital educational outcomes, including SAA (Fredricks et al., 2004).

However, previous studies have either analysed changes in one dimension of SE, encompassing behavioural, cognitive, and emotional aspects (Berrett, 2012), and explored the impact of this dimension on student learning (Jamaludin and Osman, 2014), or treated the three components of SE as 'parallel' predictor variables, merely comparing their respective strengths and weaknesses in predicting learning outcomes, without delving into the inherent connections among these components (Li and Lerner, 2013).

Understanding how these three dimensions of SE operate in conjunction remains largely unexplored (Li and Lerner, 2013). There exists a dearth of information regarding the interplay between BE, EE, and CE, their mutual influence, and their collective effects on the SAA of university students (Ladd and Dinella, 2009).

Furthermore, there is a limited number of studies (Lam et al., 2012; Altermatt, 2019; Wentzel et al., 2016; Leung et al., 2021; Vargas-Madriz and Konishi, 2021) that compare the correlation between different types of personal relationships and SAA. Moreover, the connections between TSR, SSR, and SAA seem unclear and inconsistent based on the findings of existing studies (Yu et al., 2023). Therefore, pinpointing the specific types of personal relationships that exhibit the strongest links to academic performance will offer invaluable insights for future educational planning, encompassing both theoretical and practical applications.

As a result, there is a compelling need to elucidate the specific processes and mechanisms by which SE operates and how these four components impact SAA. In light of this objective, the study presents the following research questions:

Research question 1   How do the dimensions of SE influence SAA?

Research question 2   Among the dimensions of SE, which one exerts the most significant influence on SAA?

Research question 3   What is the interrelationship between CE, SSR, TSR, and BE?

Research question 4   Does SE exhibit varying effects on SAA based on gender differences?

2   Literature review and research hypotheses

SAA is widely acknowledged as a significant outcome of SE. Despite extensive empirical research on their relationship, the findings have been inconsistent, leading to two primary perspectives.

On one hand, scholars like Zhu (2010) have identified a significant and relatively strong correlation between SE and SAA. Similarly, research by Lei et al. (2018) demonstrated moderate positive correlations between all dimensions of SE (overall, BE, EE, and CE) and SAA, consistent with the findings of Mo and Singh (2008).

On the other hand, in certain studies, researchers have failed to identify any significant correlation between SE and SAA. For example, Shernoff and Schmidt (2008) conducted research that found no predictive relationship between SE and African American GPAs. Similarly, Chen et al. (2013) found no significant correlation. Consequently, the connection between SE and SAA remains ambiguous (Lei et al., 2018), as the literature continues to yield diverse and often inconclusive results. Therefore, the following hypotheses were formulated for this study:

H1 SE has a significant positive influence on SAA.

2.1 Cognitive engagement and student academic achievement

Previous research has demonstrated the significance of CE in predicting classroom learning outcomes (Pietarinen et al., 2014). The quality of learning heavily relies on the learning strategies that students employ (Jovanovic et al., 2017). Notably, CE plays a direct role in forecasting one's performance (Greene et al., 2004). Moreover, a positive correlation exists between CE and SAA (Pietarinen et al., 2014). However, research by Appleton et al. (2006) revealed a weak correlation between CE and SAA. Therefore, the following hypotheses were formulated for this study:

H1a   CE has a significant positive influence on SAA.

2.2 Emotional engagement and student academic achievement

The current research findings on the relationship between TSR and SAA are varied and at times inconsistent. For instance, the quality of TSR is correlated with a variety of school outcomes (Roorda et al., 2011; Wentzel, 2012). Lei et al. (2023) conducted a three-level meta-analysis in China and discovered an overall positive correlation between TSR and SAA ($r = 0.259$). Quin (2017) further demonstrated that stronger TSR was significantly and positively associated with academic performance reported by students and officially recorded by schools, and these associations exhibited generally moderate to high effect sizes. Additionally, Bear et al. (2011) conducted correlation analyses that revealed a positive association between enhanced TSR and better performance in both English ($r = 0.40^*$) and mathematics ($r = 0.64^{**}$). Research by Haapasalo et al. (2010) supported the notion that the quality of the TSR directly impacted academic performance. Similarly, Davis and Lease (2007) through MANOVA analyses, found that groups of students who expressed more positive feelings towards their teachers achieved better grades. Furthermore, the findings by Molinari et al. (2013) indicated a direct and positive relationship, showing that stronger TSR were associated with higher SAA ($\beta = 0.44^{***}$). On the other hand, teacher role strain was negatively associated with SAA ($r = -0.19^{***}$) (de Bruyn, 2005).

Nevertheless, there are research findings that challenge this notion. For example, a study conducted by Barile et al. (2012) revealed that students, despite having a positive relationship with their teachers, may not experience significant improvements in their math performance, especially during high school.

Likewise, the findings regarding the relationship between SSR and SAA exhibit inconsistency. For instance, research has shown that SSR are significantly correlated with students' academic performance (Espelage et al., 2013; Li et al., 2020; Vignery and Laurier, 2020). Wentzel's study demonstrated that connecting with peers had a lasting

positive influence on various academic outcomes (Wentzel et al., 2010). On the other hand, peer rejection results in disengagement from school and lower levels of achievement (King and Ganotice, 2014).

Nonetheless, certain studies have demonstrated the absence of a significant correlation. For instance, the findings of Haapasalo et al. (2010) suggested that there was no significant correlation between parental support, student autonomy, and peer relationships, and school performance. Furthermore, the Chen (2008) found no significant direct or indirect relationship between perceived peer support and SAA across all grade levels. Therefore, the following hypotheses are proposed:

H1b   SSR has a significant positive influence on SAA.

H1c   TSR has a significant positive influence on SAA.

2.3   Behavioural engagement and student academic achievement

The link between BE and SAA has been robust in educational research (Marks, 2000). According to King (2015), SAA demonstrates a positive correlation with both BE and EE. BE plays a direct role in an individual's successful learning performance, leading to increased recognition and satisfaction with their learning (Lei et al., 2018). Thus, the following hypotheses are formulated based on the existing studies:

H1d   BE have a significant positive influence on SAA.

2.4   Importance of dimensions of student engagement for student academic achievement

Conclusions regarding the significance of different dimensions of SE for SAA vary across studies. For instance, research by Chen et al. (2016) found that flipped classrooms had the most significant impact on students' EE. Alternatively, a study by Jamaludin and Osman (2014) suggested that in a flipped classroom setting, EE was the primary focus, followed by BE and CE.

Nonetheless, many researchers (Furrer and Skinner, 2003; Klem and Connell, 2004; National Centre for School Engagement, 2006) indicated that BE exhibited a more substantial correlation with SAA than EE and CE. A meta-analysis conducted by Lei et al. (2018), using data from 69 independent samples, further supported this idea. It revealed that BE had the highest average effect size, followed by CE and EE. Additionally, Furrer and Skinner (2003) observed that the positive correlation between BE and SAA was more prominent than EE and CE, with CE following, and EE demonstrating the lowest effect size.

2.5   Emotional engagement and behavioural engagement

Several empirical studies have demonstrated that TSR exert a positive influence on BE. For instance, higher levels of teacher support have been consistently associated with elevated levels of BE (Conner and Pope, 2013; Perry et al., 2010; You et al., 2011). The research conducted by Lee (2012) substantiates this concept by emphasising that a more robust TSR results in elevated levels of BE. Numerous positive psychology theorists (Cacioppo et al., 1999; Fredrickson, 2001) have argued that positive emotions play a vital

role in shaping 'future behaviour' and 'sustained action' (Clore, 1994). Positive emotions are considered an inherent signal prompting individuals to approach or continue their actions (Fredrickson, 2001). The study by Skinner et al. (2008) emphasised the significant contribution of the emotional dimension of school engagement on shifts in BE. Similarly, another study established a link between EE and subsequent BE (Li et al., 2010). The directionality of the relationship between BE and EE was partially demonstrated in a longitudinal study conducted by Skinner et al. (2008). As a result, the following hypotheses are proposed:

H2   EE has a significant positive influence on BE.

H2a   SSR has a significant positive influence on BE.

H2b   TSR has a significant positive influence on BE.

2.6   Emotional engagement and cognitive engagement

Research in the field of emotions has consistently shown that emotions exert a significant influence on various cognitive processes that are essential for learning. These processes include perception, attention, social evaluation, cognitive problem-solving, decision-making, and memory functions (Clore and Huntsinger, 2007). Fredrickson and Joiner (2002) have underscored the significance of positive emotions in enhancing overall well-being by expanding cognitive abilities, which frequently result in effective actions. It is also worth noting that high-quality TSR contribute to the advancement of students' cognitive skills (Yu et al., 2023). Consequently, the following hypotheses are proposed:

H3   EE has a significant positive influence on CE.

H3a   SSR has a significant positive influence on CE.

H3b   TSR has a significant positive influence on CE.

2.7   Behavioural engagement and cognitive engagement

Li and Lerner (2013) demonstrated that BE influences CE by exploring the interplay between the BE, EE, and CE of school engagement in adolescents' grades 9–11. Martin (2007) contends that a deep CE is initiated as students' BE rises. Thus, the following hypotheses are formulated:

H4 BE has a significant positive influence on CE.

2.8   Moderating effect of gender

At present, there is a limited body of research suggesting that gender plays a pivotal role in influencing the correlation between SE and SAA. Possible reasons for the ambiguous relationship between SE and SAA are the effects of moderating factors such as gender (Lei et al., 2018). For instance, in a study conducted by Lei et al. (2018), it was revealed that gender had a discernible effect on the relationship between overall, BE, and CE, and SAA, although the moderating effect of gender on the relationship between EE and SAA was not significant. Therefore, the following hypotheses are proposed:

H5   Gender moderates the relationship between SE and SAA.

H5a   Gender moderates the relationship between CE and SAA.

H5b   Gender moderates the relationship between SSR and SAA.

H5c   Gender moderates the relationship between TSR and SAA.

H5d   Gender moderates the relationship between BE and SAA.

The conceptual model for this study is shown in Figure 1.

Figure 1   Schematic of the hypothesised model of the relationship between SE and SAA
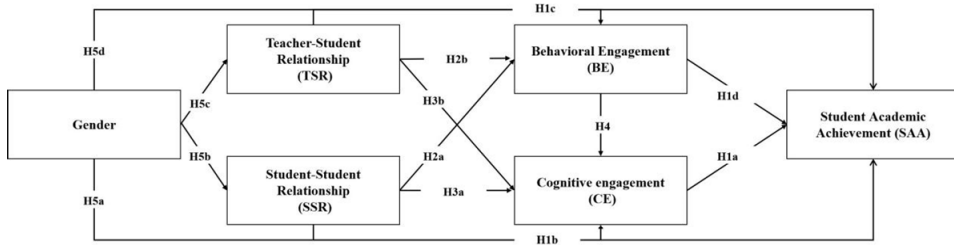
3   Methods

3.1   Participants

The data for this study were collected from a university in Gansu, China. A total of 569 electronic questionnaires were distributed via questionnaire star, and after excluding outliers, 507 valid questionnaires were obtained. Among the respondents, 280 were female, accounting for 55.2% of the total, while 227 were male, comprising 44.8% of the total.

3.2   Instrument

3.2.1   Student engagement scale

The student engagement scale comprises 21 items, assessing CE (10 items), SSR (3 items), TSR (4 items), and BE (4 items). These items are primarily adapted from the FLSES research instrument (Yan and Lv, 2023) and have been employed in prior studies (Yan et al., 2023). The scale employs a five-point rating system, ranging from 'totally disagree' to 'totally agree' on a scale from 1 to 5, with higher scores signifying greater engagement among university students in their learning.

3.2.2   Student academic achievement

In this study, student achievement scores pertained to their overall academic performance in the C language programming course. The course evaluation encompasses a total score, which is a combination of the online score (60%) and the offline score (40%). The online course grade is determined by the final online exam (60%), while the offline course grade is based on the final project (40%). It's important to note that the evaluation and grading

criteria for this course have been established by the C language programming course's teaching and research group.

3.3   *Data processing*

The research data were subjected to statistical and analytical analysis using SPSS 26.0 and AMOS 24.0. This analysis encompassed reliability and validity, goodness of fit testing, path analysis, and bootstrap mediation effect testing, and moderating effects testing.

4   **Results**

4.1   *Reliability and validity testing*

The reliability and validity of the scale were assessed using SPSS 26.0 and AMOS 24.0. The cumulative explained variance of the four common factors, determined through the eigenvalue method, reached 79.115%, surpassing the standard threshold of 60%. All factor loadings fell between 0.664 and 0.856, exceeding the standard value of 0.6, indicating that each measurement item effectively reflects the four dimensions. Furthermore, the Cronbach's alpha values for each dimension exceeded the standard value of 0.7, indicating strong internal consistency within each dimension (Nunnally, 1975). The values of composite reliability (CR) and average variance extracted (AVE) also exceeded the standard values of 0.7 and 0.5, respectively, confirming the model's robust convergent validity (Table 1).

Table 1   Reliability and convergence validity examination

Dimension	Item	Factor loading	Cronbach α	CR	AVE
CE	Q1	0.764	0.961	0.962	0.715
	Q2	0.768			
	Q3	0.737			
	Q4	0.768			
	Q5	0.814			
	Q6	0.856			
	Q7	0.805			
	Q8	0.841			
	Q9	0.816			
	Q10	0.762			
SSR	Q11	0.715	0.901	0.937	0.848
	Q12	0.793			
	Q13	0.742			
TSR	Q14	0.676	0.926	0.928	0.763
	Q15	0.816			
	Q16	0.846			
	Q17	0.722			

Table 1 Reliability and convergence validity examination (continued)

Dimension	Item	Factor loading	Cronbach α	CR	AVE
BE	Q18	0.717	0.926	0.927	0.761
	Q19	0.713			
	Q20	0.754			
	Q21	0.664			

As suggested by Fornell and Larcker (1981), inter-dimension discriminant validity is established when the open square of the dimension's AVE is greater than the Pearson's correlation coefficient with other dimensions. In this study, the open squared of AVE values for each dimension exceeded the correlation coefficients with other dimensions, indicating strong discriminant validity among the dimensions (Table 2).

Table 2 Discriminate validity examination

Dimension	BE	SSR	TSR	CE
BE	*0.872*			
SSR	0.718	*0.921*		
TSR	0.782	0.798	*0.873*	
CE	0.757	0.63	0.578	*0.846*

Note: The square root of the AVE for each construct is denoted in italic, while the inter-construct correlations are shown off-diagonally.

4.2 Goodness of fit testing

The model's goodness of fit was assessed using AMOS 24.0 software. A χ^2/df ratio between 0 and 3 signifies a good fit for the model. However, because chi-square testing is sensitive to sample size (Hair et al., 2006), Kline (2023) suggested that for large samples, a χ^2/df ratio less than 5 corresponds to an intermediate level of fit. Moreover, the chi-square test seems to be less suitable as the sole indicator for model evaluation. It is also necessary to refer to other important fit indices as a basis for evaluation. When the goodness of fit indices (GFI, NFI, TLI, CFI) exceed 0.9 and approach 1, they indicate a strong data-to-model fit. Additionally, if the discrepancy indices (RMSEA, SRMR) fall below 0.08, the model is considered to fit well. In this analysis, the results were as follows: $\chi^2/df = 3.733$, GFI = 0.877, NFI = 0.937, TLI = 0.946, CFI = 0.953, RMSEA = 0.073, and SRMR = 0.037. These results collectively signify a good fit for the model, as shown in Table 3.

Table 3 Goodness of fit index of structural equation model

Fit indicator	χ^2/df	SRMR	RMSEA	GFI	NFI	TLI	CFI
Reference point	<3	<0.080	<0.080	>0.900	>0.900	>0.900	>0.900
Testing value	3.733	0.037	0.073	0.877	0.937	0.946	0.953

4.3 Path analysis

Table 4 reveals the standardised path coefficients for hypotheses H1a, H1c, H1d, H2a, H2b, H3a, H3b, and H4, which are 0.137, 0.148, 0.201, 0.341, 0.403, 0.231, 0.106, and

0.367, respectively, all with p-values below 0.05. These results provide support for all of these hypotheses. However, the relationship between SSR and SAA (β = –0.107, p > 0.05) did not reach the level of significance, leading to the lack of support for hypothesis H1b.

Table 4   The test results of path relationship

Hypotheses	Path	Unstd.	Std.	S.E	Z value	p value	Results
H1a	CE → SAA	1.609	0.137	0.62	2.594	0.009	Supported
H1b	SSR → SAA	–1.199	–0.107	0.637	–1.883	0.06	Not supported
H1c	TSR → SAA	1.662	0.148	0.638	2.604	0.009	Supported
H1d	BE → SAA	2.306	0.201	0.677	3.406	***	Supported
H2a	SSR → BE	0.335	0.341	0.041	8.257	***	Supported
H2b	TSR → BE	0.395	0.403	0.041	9.763	***	Supported
H3a	SSR → CE	0.221	0.231	0.045	4.957	***	Supported
H3b	TSR → CE	0.101	0.106	0.046	2.21	0.027	Supported
H4	BE → CE	0.357	0.367	0.046	7.8	***	Supported

Notes: ***: $P < 0.001$, **: $P < 0.01$, *: $P < 0.05$.

4.4   Mediation effect testing

As highlighted by Fredrickson and Joiner (2002), positive emotions play a pivotal role as the foundational trigger for the three components of SE. Consequently, in this study, SSR and TSR were employed as independent variables, respectively. To evaluate the significance of the mediating effects of BE and CE, a Bootstrapping approach with 1000 extractions from the sample and a 95% confidence interval was utilised. The results of the mediation effect test (Table 5) for 'SSR/TSR → BE → SAA' showed two indirect paths with 95% confidence intervals of (0.201, 1.521) and (0.178, 1.648), respectively. The indirect path 'SSR → CE → SAA' had a 95% confidence interval of (0.071, 0.77). Additionally, for the path 'SSR/TSR → BE → CE → SAA', the 95% confidence intervals for these two chain paths were (0.034, 0.459) and (0.04, 0.55). Notably, none of these five indirect paths contained zero at the 95% confidence interval, signifying the significance of all mediating paths.

To be specific, the mediating effects of SSR transmitted through BE and CE were 0.772 and 0.355, respectively, constituting 29.5% and 13.6% of the total mediating effects. The mediating effect of TSR transmission through BE was 0.912, accounting for 34.8% of the total mediating effect. In the case of multiple mediation effects, SSR transmitted through BE and CE had a mediating effect of 0.193, contributing to 7.3% of the total effect, and TSR transmitted through BE and CE had a mediating effect of 0.227, accounting for 8.7% of the total effect. The total mediated effect is 85%. Notably, these results highlight that 96% of the overall effect on SAA is attributed to TSR, while SSR contribute only 4%. The results presented in Table 5 reveal that the 95% confidence intervals for the contrasts in the effects of the six mediating paths encompass zero. This observation implies that there are no statistically significant differences in the effect sizes among these paths.

Table 5 The mediating effect of bootstrapping

Path relationship	Point estimates	Product of coefficient		Bootstrapping			
				Bias-corrected 95% CI		Percentile 95% CI	
		SE	Z value	Lower	Upper	Lower	Upper
Indirect effects, direct effects, total effects							
Path1:SSR → BE → SAA	0.772	0.34	2.271	0.201	1.521	0.157	1.471
Path2:SSR → CE → SAA	0.355	0.181	1.961	0.071	0.77	0.06	0.76
Path3:SSR → BE → CE → SAA	0.193	0.109	1.771	0.034	0.459	0.026	0.452
Path4:TSR → BE → SAA	0.912	0.367	2.485	0.178	1.648	0.178	1.65
Path5:TSR → CE → SAA	0.162	0.115	1.409	−0.008	0.465	−0.043	0.417
Path6:TSR → BE → CE → SAA	0.227	0.126	1.802	0.04	0.55	0.035	0.545
TSR → SAA	1.662	0.734	2.264	0.281	3.069	0.277	3.054
SSR → SAA	−1.199	0.706	−1.698	−2.66	0.159	−2.669	0.153
TIE	2.621	0.562	4.664	1.487	3.675	1.491	3.699
DE	0.464	0.76	0.611	−1.014	1.933	−1.011	1.947
TE	3.085	0.549	5.619	1.98	4.122	2.001	4.134
Proportion							
TIE/TE	0.85	0.251	3.386	0.467	1.459	0.464	1.449
DE/TE	0.15	0.251	0.598	−0.459	0.533	−0.449	0.536

Notes: TIE is the sum of the mediated effects; DE is direct effect; TE is total effect; SE is the standard error.

4.5   *Moderating effects testing*

For this study, the PROCESS program module was selected, and a sample of 1,000 iterations was drawn. Gender was introduced as a moderating variable to examine whether it had a moderating effect on the relationships between CE, SSR, TSR, BE, and SAA. Under the specified conditions with 95% confidence intervals, CE, SSR, TSR, and BE were sequentially treated as independent variables, and gender was included as the moderating variable. This led to the creation of moderating effect variables (i.e., CE*gender, SSR*gender, TSR*gender, BE*gender), along with the dependent variable (SAA). The results of these analyses are presented in Table 6. Notably, none of the confidence intervals for the interaction terms between TSR/BE and gender contained 0, signifying that the relationship between TSR/BE and SAA is influenced by the moderating variable (gender). This validation supports hypotheses H5c and H5d.

Table 6   Moderating effect test

DV	IV	Unstd.	SE	t	p	95% CI LLCI	95% CI ULCI
SAA	constant	62.127	2.528	24.573	0	57.16	67.094
	CE	3.605	0.692	5.209	0	2.245	4.965
	Gender	–0.939	3.589	–0.262	0.794	–7.99	6.112
	CE*Gender	–0.85	0.977	–0.87	0.385	–2.77	1.07
$R^2 = 0.132$ F(3,503) = 25.527 p < 0.001; $\Delta R^2 = 0.001$ F(1,503) = 0.756 p = 0.385							
SAA	constant	70.697	2.753	25.68	0	65.288	76.105
	SSR	1.098	0.679	1.616	0.107	–0.237	2.433
	Gender	–8.367	3.851	–2.172	0.03	–15.933	–0.8
	SSR*Gender	1.179	0.962	1.225	0.221	–0.712	3.07
$R^2 = 0.083$ F(3,503) = 15.161 p<0.001; $\Delta R^2 = 0.003$ F(1,503) = 1.501 p = 0.221							
SAA	constant	68.27	2.795	24.426	0	62.778	73.761
	TSR	1.676	0.679	2.47	0.014	0.343	3.009
	gender	–12.129	3.814	–3.18	0.002	–19.623	–4.635
	TSR*Gender	2.152	0.939	2.292	0.022	0.307	3.997
$R^2 = 0.129$ F(3,503) = 24.758 p<0.001; $\Delta R^2 = 0.009$ F(1,503) = 5.253 p = 0.022							
SAA	constant	67.069	2.707	24.776	0	61.75	72.387
	BE	2.082	0.694	3.002	0.003	0.719	3.445
	gender	–12.257	3.653	–3.355	0.001	–19.434	–5.08
	BE*Gender	2.292	0.946	2.424	0.016	0.434	4.15
$R^2 = 0.151$ F(3,503) = 29.864 p<0.001; $\Delta R^2 = 0.01$ F(1,503) = 5.847 p = 0.016							

As shown in Figure 2, the positive impact of TSR/BE on SAA was less pronounced for female students ($\beta_{TSR} = 1.676$, $p_{TSR} = 0.014$, $\beta_{BE} = 2.082$, $p_{BE} = 0.003$), while it was more significant for male students ($\beta_{TSR} = 3.828$, $p_{TSR} = 0$, $\beta_{BE} = 4.375$, $p_{BE} = 0.000$). In other words, the influence of TSR/BE on SAA was more prominent in male students than in female students. Gender differences in their effect on SAA were weaker when students had higher TSR/BE and stronger when students had lower TSR/BE. However, the

interaction term between CE/SSR and gender, the confidence interval included 0, indicating an insignificant moderating effect. Consequently, hypotheses H5a and H5b were not supported.

Figure 2 Moderating role of TSR and BE between gender and SAA
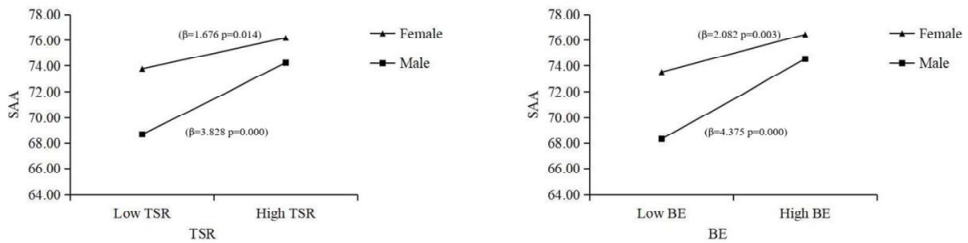
5 Discussion and conclusions

Prior research in the literature suggests the presence of one or two pairs of relationships, such as BE – EE, EE – CE, or BE – CE. However, no model in the SE literature has successfully captured and predicted the intricate interplay between all components of SE and their collective influence on SAA. In this study, we explore the distinct pathways and mechanisms through which SE exerts its impact on SAA in higher education. Our investigation culminates in the following research findings is shown in Figure 3:

1   It was observed that SSR did not exert a direct and significant positive effect on SAA. Nevertheless, SSR could indirectly impact SAA by influencing two mediating variables: BE and CE. In contrast, TSR, BE, and CE all demonstrated direct and significant positive effects on SAA. These findings imply that distinct dimensions of SE exhibit varying associations with SAA. Put differently, elevated levels of SE, BE, EE, and CE were linked to superior SAA.

2   Within the dimensions of SE, BE emerged as the most influential in shaping SAA, followed by TSR, with CE having the least impact. This is partially consistent with the findings of Lei et al. (2018) and Furrer and Skinner (2003).

3   Dimensions of SE have a cascading impact on SAA, following a sequence of 'EE → BE → CE → SAA'. Previous research primarily examined SE as a collective factor influencing SAA, treating EE, CE, and BE as working together in parallel to impact SAA. However, the mediation relationships revealed in this study unveil a more intricate mechanism for influencing SAA. These mediating pathways elaborate on how an individual's EE, BE, and CE ultimately affect SAA. The process initiates with EE, where TSR can indirectly influence SAA through two pathways mediated by BE alone and through a chain of BE and CE. Similarly, SSR can impact SAA via three indirect pathways mediated by BE or CE alone and through a chain of BE and CE.

Among the individual mediators, SSR and TSR accounted for the largest proportion of mediating effects through BE. Specifically, the mediating effect of SSR transmitted through BE surpassed that of CE, while the mediating effect of TSR

transmitted through BE exceeded that of SSR. Within the multiple mediated effects, the values for mediator effects were higher for TSR transmitted through both BE and CE compared to SSR. In other words, the overall influence of TSR on SAA significantly exceeded that of SSR. This underscores the critical importance of strengthening TSR in both policy and practice.

These findings clarify an inherent logic and progressive hierarchy among university students in enhancing SAA through SE. SE exerts a positive influence on SAA, with EE serving as the starting point. Higher levels of EE lead to increased BE and deeper CE, indicating a stronger commitment to academics and subsequently resulting in more positive engagement (Li and Lerner, 2013).

4   As the number of female participants in the sample increased, the effect of TSR/BE on SAA was weakened. Conversely, the effect strengthened as the number of male participants increased. Moreover, as students' TSR/BE increased, the influence of gender differences on SAA decreased.

Figure 3   Schematic diagram of the relationship model between SE and SAA
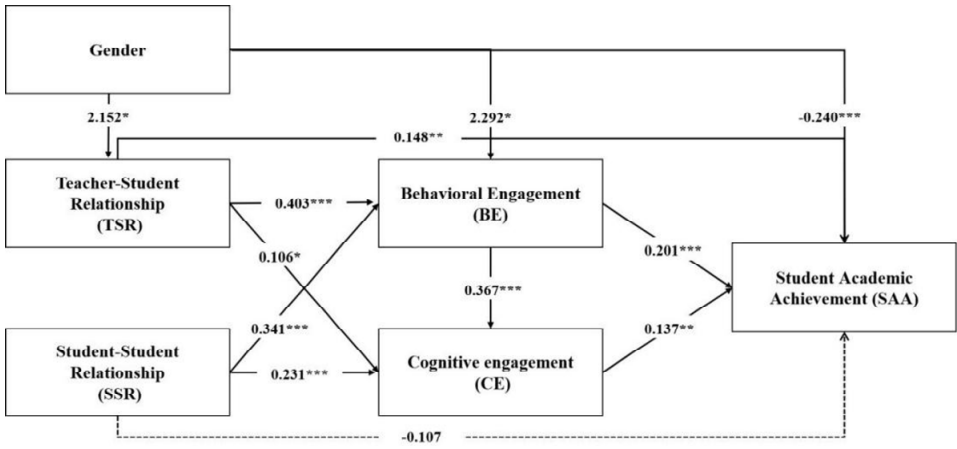
Notes:***P < 0.001,** P < 0.01,* P < 0.05

This study delved into the mechanisms influencing SE and SAA in the flipped classroom and validated them through the SEM method. This approach established a model to predict the complex interactions among all components of SE and their impact on SAA in the flipped classroom, thereby enhancing our comprehension of the influencing factors of university students' SE and its mechanisms.

However, several limitations should be noted. Firstly, this study relied on a questionnaire, a subjective reporting method that may be susceptible to social desirability bias. Future research could incorporate a variety of indicators to measure the psychological attributes of participants, such as facial expressions, head postures, eye movements, Platform logs and video coding, etc. Secondly, this study solely explored the mechanisms underlying the relationship between SE and SAA among university students without conducting any intervention studies. In future research, intervention methods could be employed to enhance university students' SAA by targeting their SE. Thirdly, This study focused on undergraduate students in science and engineering at University A

(mainly freshmen and sophomores), without considering differences in grade level, university tier, ethnicity, place of birth, location of the university, academic discipline (arts, science, engineering, etc.), or nationality. This limits the diversity of the research subjects. Therefore, future studies should expand the sample size and fully consider the diversity of learners' origins and types. In-depth analyses of their participation levels and behavioural patterns should be conducted to enhance the adaptability and transferability of the research findings. Additionally, longitudinal studies should be carried out to clarify the long-term impact of SE on their SAA in the flipped classroom.

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Declarations

All authors declare that they have no conflicts of interest.

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