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The influence of university library environment on student interactions and college students' learning engagement

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Over the past decade, learning engagement has received increasing attention from researchers. As a critical factor in college students' academic achievement, learning engagement is significant in students' long-term future development and social creativity. Present studies show that the overall level of college students' learning engagement is low, which is highly unfavourable to educational quality and long-term development. There is no doubt about the position of the university library in academic circles. However, the influence of the university library environment on college students' learning engagement has not been fully explored. The data in this study came from a survey of 45 Chinese universities. This paper investigates the relationship between the university library environment, students' interaction, and students' learning engagement. The results showed differences in Chinese college students' learning engagement in liberal arts and sciences majors. The learning engagement of liberal arts majors is much lower than that of science students. We found that the library environment has an important influence on college students' learning engagement. And the library environment can affect college students' learning engagement through the intermediary role of interactive participation among students. In addition, for liberal arts students, the direct effect of the library environment on their learning engagement is more significant. However, for science students, the influence of the library environment on their learning engagement is more strongly intermediated by the students' interaction. Therefore, future construction and renovation of library environments should cater not only to the diverse needs of different academic disciplines, especially liberal arts students who need special attention but also guide more students to interact friendly through the spatial characteristics of the library so as to improve the overall learning engagement of college students.

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Background

The university age is the golden period for people to accumulate knowledge and a critical stage of development in life. As an essential indicator of students' learning quality (Xie et al., 2020), learning engagement is highly correlated with students' learning persistence, academic satisfaction, academic performance, and academic completion (Salanova et al., 2003; Kuh, 2009; Salanova et al., 2003; Tatiana et al., 2022; Mizani et al., 2022). And it has a positive influence on college students' academic achievement and long-term future development (Carini, et al., 2006; Pintrich et al., (1990)), such as pursuing higher education, the stability of learning models, improving job prospects, positive self-awareness and welfare, and fewer depressive symptoms. (Li & Lerner, 2011; Salmela-Aro, Upadyaya (2012); Salmela-Aro, Upadyaya (2014); Tuominen-Soini, Salmela-Aro (2014); Wang & Peck, 2013). Learning engagement refers to the positive, focused, and fully absorbed state students demonstrate during the learning process (Trowler, 2010). Learning engagement encompasses the cognitive strategies students employ during learning activities, the quantity of learning behaviors exhibited, and the emotional experiences during learning (Axelson & Flick, 2010; Mader & Bry, 2019; Puritat, 2019). Students with a high level of learning engagement will have a strong enthusiasm for learning and can concentrate on the learning process (Carmona-Halty et al., (2021)). However, the current results show that the overall learning engagement of Chinese college students is not ideal (Ma & Fu, 2021). Therefore, in the context of the rapidly changing information society, how to maintain and improve college students' learning engagement has become an essential factor that requires urgent attention in current research (Lei, 2022).

The existing literature has analysed the factors affecting college students' learning engagement from different perspectives and found the effectiveness of individual physiological factors, learning persistence, and environmental factors in promoting learning engagement (Fredricks et al., 2004; Lu et al., 2022). In social learning, personal and environmental impacts are interdependent, and the environment can automatically activate normative behavior and psychological representation of behavior itself (Aarts & Dijksterhuis, 2003). Research has demonstrated that the campus environment and architectural surroundings impact college students' engagement in learning (Shernoff, 2013; Karol & Mackintosh, 2011; Bandura et al., 1977). Some scholars have pointed out that as a significant department of higher education institutions and an informal learning space, the library is closely related to students' learning behavior (Chan, 2012; Massengale et al., 2016; Bennett et al., 2015). Library also provides students with a space to cultivate autonomous learning and create new knowledge (Nitecki, 2011). The United Kingdom Library Impact Data Project implemented by the University of Huddersfield shows a statistically significant relationship between library use and degree levels (Massengale et al., 2016). However, there are few studies on the influence of library environmental factors on the learning engagement of college students. In the library, students determine their learning needs and goals and consciously or autonomously participate in learning (Bennett, 2009; Bennett et al., 2015). Scott Bennett calls the current phase of library design "learner-centered". The first focus of learning-centered design practice is to create space to promote intentional learning (Bennett, 2009; Bond, 2020; Bennett et al., 2015). Students' use of Intentional Learning refers to the "cognitive process of learning as an intrinsic goal rather than an accidental outcome" (Bennett et al., 2015). The most critical educational function of physical library space is to foster a culture of intentional learning (Bennett et al., 2015). Learning engagement is the process of consciously completing learning tasks (Abu-aisheh et al., 2016). Some scholars

also find that learning spaces can encourage or constrain behavior (Blumenfeld et al., 2006). In the process of intentional learning, the ability for independent learning and self-discipline will increase (Hagaman & Reid, 2008; Sze-yeng & Hussain, 2010), and the cultivation of this ability has a positive effect on learning engagement (behavior, cognition, and emotion) (Lekissa & Hsiu-Ling, 2021). Students can be more actively involved in learning in spaces encouraging learning (Matthews et al., 2011).

At the same time, libraries provide students with the opportunity to "hang out outside the classroom, meet and have informal conversations" (Acker & Miller, 2005). These spaces in libraries aim to enhance user learning and encourage social learning. In this environment, open dialogue and collaborative learning among students can be encouraged (Oblinger, 2004), and communication between students outside the classroom can be promoted (Hunley & Schaller, 2009). Furthermore, libraries also provide many group learning spaces, as well as learning-sharing spaces, which are the main features of library planning (Bennett et al., 2015; Abu-aisheh et al., 2016). Malcolm Brown also proposes the theory of constructivism (Brown, 2005; Montgomery, 2014), that is, the library can be "a place to coexist with others in the learning/cultural environment" (Demas, 2005). Firstly, Libraries provide a space to enrich students' social learning needs. Researches have proved that students can participate in learning more actively in a space that encourages social learning (Matthews et al., 2011; Montgomery, 2014). Humans are social animals whose behavior will be strongly influenced by the behavior of other humans. Therefore, for students, "being seen to learn" or "seeing others learn" seems to be a valuable stimulus and inspiration for their learning behavior (Montgomery, 2014). This effect is usually straightforward, and also known as the "peer effect" (Poldin et al., (2016)). Secondly, when students communicate and interact with each other, their ideas and behaviors will be exchanged and input (Aarts & Dijksterhuis, 2003). Ubon and Kimble (2003) emphasize that students' interaction can help to stimulate motivation (Rubin, 1975). Previous studies have also proved the positive influence of motivation on learning engagement (Wu et al., 2020). Thirdly, increasing students' interaction is conducive to improving the psychological security of students. Students can maintain a good growth mentality in a complex social environment to ensure better learning engagement (Lei, 2022; Zhao et al., (2021)). In summary, the influence of the university library environment on students' learning engagement does not exist in isolation. The factors affecting college students' learning engagement are influenced by multidimensional factors. Students' interaction may be the intermediary variable between the library environment and college students' learning engagement. The university's priorities include creating an attractive and vibrant library environment that provides a place for students to learn, encourages socialization, and helps increase learning engagement. However, previous studies have paid more attention to the library environment and the academic achievements of college students (Montgomery, 2014; Chih-Ming, 2013; Catherine, 2021); the relationship between teacher-student interaction or online interaction and classroom learning participation (Bailey, 2022; Harbaugh & Cavanagh, 2012). Currently, there is no research on the direct relationship between autonomous learning spaces such as the library and college students' learning engagement and students' interaction as a mediating variable.

Over an extended period, many countries, including China, have implemented differentiated education in high schools and universities, focusing on science and liberal arts disciplines. Science education emphasizes logical thinking and the scientific method, while liberal arts education emphasizes social and

humanistic issues. Students majoring in the liberal arts and sciences exhibit significant differences in various aspects, such as the nature of their disciplines, specialized directions, cognitive patterns, learning environments, and employment prospects (Heojeong et al., 2014). Consequently, the behavior of liberal arts and science students within the university's public learning space, the library, and the potential influence of the library environment on student interactions and learning engagement may vary (Heojeong et al., 2014). Specific liberal arts courses may necessitate a greater emphasis on reading and writing, making them more amenable to independent study modes. Conversely, students in science majors may require more laboratory work and mathematical computations and may collaborate within small groups (Entwistle, 2009). The variations in learning and thinking patterns stemming from differences in academic disciplines may potentially result in divergences in the pathways through which the learning environment influences student interaction and learning states, particularly within the library—an essential space in the university that serves both public and educational purposes. However, it is worth noting that systematic research on this issue has yet to be identified in existing literature, necessitating further investigation. Therefore, our study aims to fill this gap by considering the professional field as a moderating variable and exploring how the library environment influences the learning engagement of liberal arts and science students. This research holds practical significance in shedding light on these interactions.

The impact of the environment on behavior has become a consensus (Gifford, 2007; Schultz & Kaiser, 2012; Thaler & Sunstein, 2008), and the significance of exploring the influence of the campus learning environment on the behavior and learning status of college students in the education system is substantial. This exploration aids in enhancing the learning status of college students through improvements in the physical environment and campus architectural spaces. Such research aims to analyze environmental behavior as a foundation and subsequently explore the directions for future research in environmental education. Accordingly, our research focuses on the relationship between the library environment and learning engagement. It discusses whether there is a correlation between the university library environment and students' interaction and college students' learning engagement. Furthermore, we introduce the professional field as a moderating variable and analyze variations among different disciplinary attributes, providing valuable information and strategic recommendations for the refinement of library environment optimization design and construction.

Research hypothesis and theoretical model

Many factors influence learning engagement, such as school culture, students' social and physiological characteristics, learning methods, and environment. Some scholars have pointed out that in addition to individual factors, environmental factors significantly influence learning engagement (Fredricks et al., 2004). Based on the theoretical framework of environmental behavior, research indicates that different environments can elicit distinct psychological states and behavioral characteristics (Hernoff et al., 2014). College students, as a specific demographic group, are often more susceptible to the influence of the campus environment on their learning states (Edinger, 2019; Wu et al., 2020; Mannerström et al., 2019). For example, evidence demonstrates that biophilic architectural elements in the university campus environment can enhance cognitive functionality and improve students' learning attentiveness (Blumenfeld et al., 2006). The physical learning environment significantly impacts students' learning, increasing the likelihood of student engagement (Baafi,

2020; Asiyai, 2014). The university library, as a physical, open, and flexible learning space, has evolved into a central space closely associated with student self-directed learning (Scott-Webber et al., 2018). Students in an aesthetically pleasing, low-noise, and secure architectural environment tend to have enhanced learning satisfaction (Flutter, 2006), increasing interest in learning, and a willingness to engage in the educational process. Such an architectural environment can positively influence learning motivation and attention (Asiyai, 2014; Bachman & Bachman, 2011) and promote students' learning engagement (Oliveras-Ortiz et al., 2019). Simultaneously, the library offers individual, independent learning spaces for immersive reflection and exploration, facilitating the transition to abstract thinking. Research has confirmed that the learning environment on campus influences students' pursuit of knowledge and their level of learning engagement (Shernoff, 2013; Karol & Mackintosh, 2011; Bachman & Bachman, 2011). Based on the above analysis, we propose Hypothesis 1.

Hypothesis 1: The university library environment significantly positively influences college students' learning engagement during self-directed learning.

The university library serves not only as a primary learning space closely associated with students' self-directed learning (Widemalm, 2016) but has also evolved into a nexus for interactive communication and collaboration among students (Bodnar, 2009). The university library provides a conducive environment for open dialogue and collaborative learning among students, fostering the development of positive interpersonal relationships, enhancing interpersonal communication skills, and increasing emotional engagement. Thus, it strengthens students' autonomy in learning and facilitates improvements in their learning states (Acker & Miller, 2005; Oblinger, 2004). Baker et al. (2007) have considered academic libraries as an extension of the classroom. This space fosters collaborative and interactive learning. They recognize the need for an environment supporting a new learning culture that combines "serious" learning with collaborative social learning, facilitating interactions among students outside the traditional classroom (Hunley & Schaller, 2009). The library creates various flexible and shared learning environments to accommodate a range of learning or collaborative activities, such as learning commons, group study rooms, open study areas, and cozy cafés (Thomas et al., 2015). These emerging collaborative spaces in the library allow students to engage with a greater number of peers than in traditional classrooms, enhancing opportunities for interactive communication and knowledge sharing in various ways (Kim & Son, 2021; Lu et al., 2020). Consequently, an increasing number of scholars advocate not only positioning the library as a crucial learning space but also emphasizing its role as a public space supporting academic exchange and student interaction. It can foster a positive overall learning environment and a friendly atmosphere (Birdsall, 2010; Thomas et al., 2015). Environmental factors are closely related to students' learning and interactive behaviors. Based on the above analysis, we propose Hypothesis 2.

Hypothesis 2: The university library environment significantly positively influences student interactions during self-directed learning.

Student interactions contribute to emotional expression, open communication, and team cohesion (Miao et al., 2022). Macpherson (2015) suggests that students engage with students during interactions to acquire knowledge, share information, exchange ideas, foster in-depth ideation, enhance academic performance, and increase their learning engagement (Cole et al., 2021; Quadir et al., 2022). Additionally, scholars have pointed out that the emotional motivation stemming from student interactions can lead to steadfast academic efforts. Furthermore,

thought-sharing and collaborative thinking among students enhance social cohesion, sustain learning motivation, and engage in cognitive learning tasks (Spector & Kim, 2014). Based on the above analysis, we propose Hypothesis 3.

Hypothesis 3: Student interaction behaviors positively influence students' learning engagement during self-directed learning.

As previously proposed in hypotheses 1–3, the library environment can influence college student interaction and learning engagement (Acker & Miller, 2005; Oblinger, 2004). Simultaneously, interactive behaviors have been shown to effectively enhance the states of learning engagement among college students (Manwaring, 2017; Cole et al., 2021; Quadir et al., 2022). The implicit relationship among these three factors suggests the presence of an intermediary pathway, where the library may facilitate student interaction and communication, subsequently enhancing the learning engagement of college students. This is achieved by creating a supportive environment that encourages interaction and collaboration. Student interaction serves as the mediating bridge through which the library environment influences college students' learning engagement.

The library provides diverse learning spaces to support the learning process and functions as a medium for student interaction, communication, and collaboration (Bodnar, 2009). Simultaneously, the behavioral characteristics of student interaction can reflect the extent of students' learning engagement (Wang, 2009). Research indicates that student interaction facilitates academic collaboration and subject understanding and contributes to establishing a supportive academic community, enhancing students' learning engagement. It promotes student learning and fosters a sense of belonging and community, particularly crucial for university students (Matthews et al., 2011; Montgomery, 2014). Scholars like Yi et al. (2022) suggest that individual learning behaviors, interactive behaviors, and social network attributes form the framework of the learning engagement model. Increased student interaction significantly motivates and guides learners, enhancing their learning engagement to a greater extent (Montgomery, 2014; Luan et al., 2020). The more learning peers a learner connects with, the higher their level of learning engagement tends to be (Yi et al., 2022).

Through the above analysis, existing literature and relevant theories have supported the indirect pathway through which the library environment influences the learning engagement of college students via student interaction. Therefore, we propose Hypothesis 4.

Hypothesis 4: The influence of the university library environment on college students' learning engagement during self-directed learning is mediated by student interactions and communication.

Differences between students in science and liberal arts majors in terms of disciplinary characteristics, professional orientations, cognitive frameworks, and learning patterns (Heojeong et al., 2014) lead to significant variations in their needs for learning environments, student interactions, and learning engagement (Kuh, Gonyea (2003); Thomas et al., 2015; Hu & Zhang, 2015; Stewart, 2021; Ko & Song, 2022). These differences may also result in distinct pathways through which the architectural space environment affects student interactions and learning engagement among science and liberal arts students. Despite the complexity of these relationships and the absence of systematic research on the differences among science and liberal arts students, some scholars have conducted relevant studies. For example, research by Shwu-yong, Fisher (2011) indicates that student interactions significantly influence the learning states of science majors. Carrell et al. (2009) found that student interactions have nearly no effect on learning states in humanities disciplines such as physical education and foreign languages. Based on this analysis, we propose Hypothesis 5.

Hypothesis 5: The influence of the library environment on college students' student interactions and learning engagement during self-directed learning varies significantly across different academic majors in the humanities and sciences.

Methods and Measures

Study population. The survey was conducted from October 1, 2021, to January 30, 2022, under the supervision of the Academic Committee of the University, and each university student voluntarily participated in completing the questionnaire to obtain generally relevant data from Chinese universities. There were no focal or concentrated breakouts at the time of the survey, and most of the nation was in the regular management phase of the epidemic. Therefore, all students in the sample were in an area where epidemic prevention and control had been normalized, and teaching on the university campus resumed as usual. Participating students were asked to respond to detailed questions regarding their assessment of the library environment, their learning engagement, and the status of their peer interaction to fully understand the relationship between the library environment, student interaction, and college students' engagement in education.

In order to achieve a better sample representativeness, a multifaceted approach was employed during the school-level sampling process. Various criteria were considered, including the geographical location of universities, campus size, university type, and architectural diversity. The aim was to encompass a wide range of campus types. Simultaneously, while maintaining the feasibility of data collection, a total of 45 universities were ultimately selected for the survey. These universities span across 14 provinces, three municipalities, and four autonomous regions (Fig. 1).

In order to achieve a better representation of student samples, we made extensive efforts during the student-level sampling process. Initially, we aimed to align our selection of university students with the population structure of Chinese university students as closely as possible, using data from the Chinese Ministry of Education and other relevant sources to inform our decisions. For instance, we observed a trend of expanding undergraduate enrollment in Chinese higher education institutions, with an annual increase of approximately 600,000 registered students from 2018 to 2021 (2018 Education Statistics from the Ministry of Education of the People's Republic of China). As a result, our sample included more junior college students and fewer senior college students. Furthermore, based on data from the Ministry of Education for 2021, there are slightly more female students than male students in the national student population. Regarding academic fields, although the ratio of science to liberal arts students admitted varies by province, nationwide, the number of science students is significantly higher than that of liberal arts students, at a ratio of approximately 3:1 (2021 Education Statistics from the Ministry of Education of the People's Republic of China). From the demographic distribution of the final survey sample (Table 1), it is evident that our survey sample exhibits a random characteristic, encompassing various student groups. The demographic characteristics of our sample closely align with the overall population structure of Chinese university students. Therefore, despite the final effective sample of only 1060 individuals, we consider it relatively representative.

Furthermore, we implemented several effective measures to enhance the reliability of survey sample data. For example, we secured the survey website with passwords and login credentials, preventing access without the necessary password. We also eliminated invalid questionnaires submitted with random or dishonest answers with the intent of obtaining rewards. These specific measures included enforcing questionnaire access
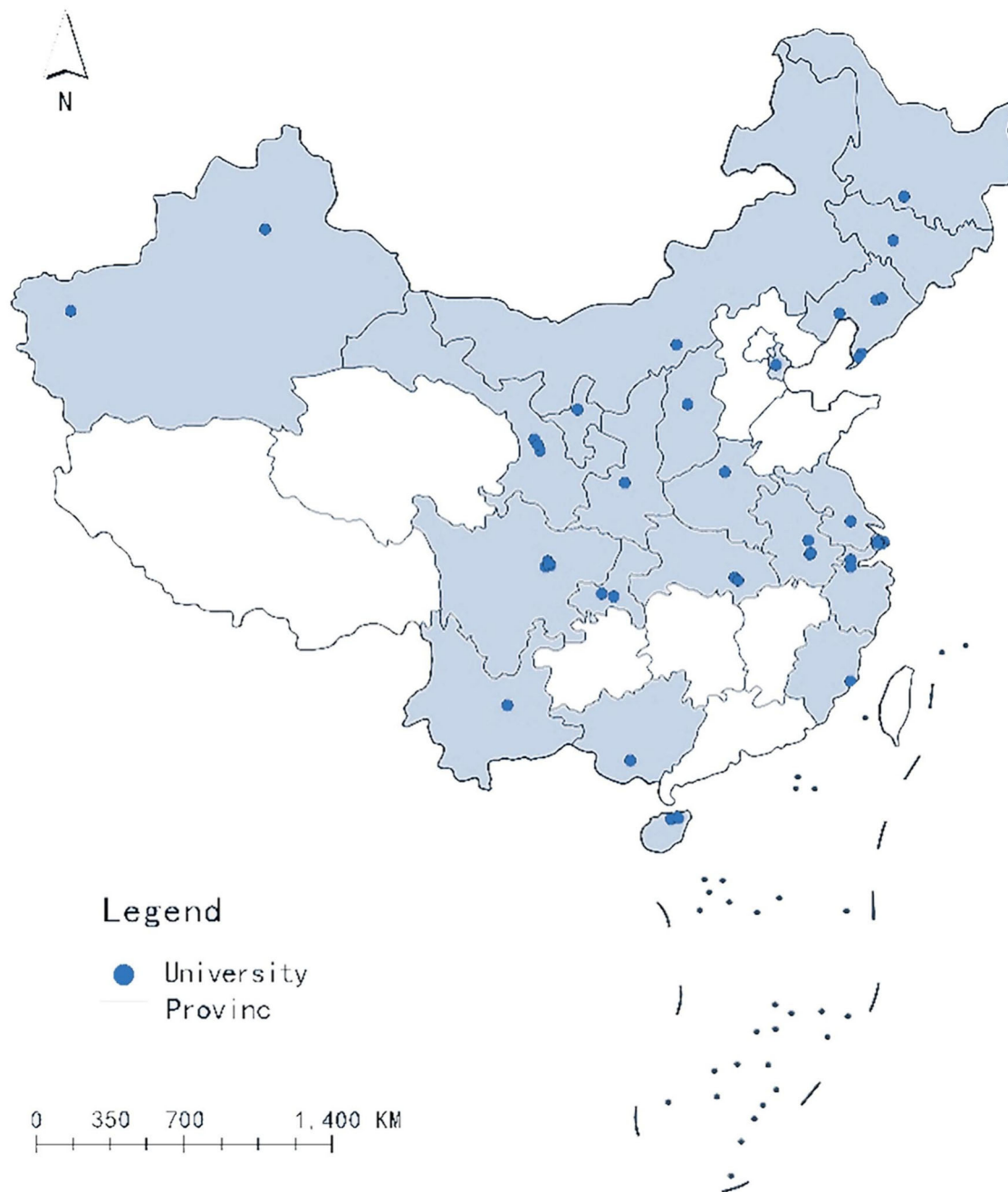
Fig. 1 Sample distribution diagram. Figure 1 describes the provinces where the 34 colleges and universities are located.

restrictions, carefully crafting questionnaire items, implementing a real-name drawing system, screening for duplicate IP addresses, and setting a minimum required completion time for the questionnaire. The application of these multiple restrictions and filtering measures ensured the integrity and quality of the collected data.

Measurement

Dependent variable: learning engagement of college students. Learning engagement refers to an individual's positive and focused attitude during the learning process. It is a crucial indicator and a critical factor in assessing the effectiveness and quality of learning (Kop et al., 2011; Parsons & Taylor, 2011; Tatiana et al., 2022; Mizani et al., 2022). Learning engagement reflects the depth of an individual's thinking, analysis, and understanding of

learning materials during the learning process. It also encompasses emotional responses, experiences, and emotional states toward learning tasks during the learning process (Jiang, 2014; Ferrer et al., 2022; Fredricks et al., 2004). Additionally, it includes behavioral performance and motivation during learning, representing the initiative, self-discipline, persistence, active participation, and effort exerted towards learning tasks (Liu et al., 2020; Ravindran et al., (2005); Axelson & Flick, 2010). Scholars have primarily employed content analysis and questionnaire surveys to evaluate learning engagement (Li et al., 2019; Zhu et al., 2005; Li & Huang, 2010). Our study on learning engagement was assessed by referencing a scale developed by Fang et al. (2008) known as UWES-S. This scale evaluates the frequency of four positive states that university students may experience during learning: (1) feeling energetic during learning, (2) being passionate about learning, (3) perceiving time passing quickly while studying, and

Table 1 The sample demographics.

Demographics	N	%
Subject		
Liberal arts	270	25.48
Sciences	790	74.52
Grade		
Junior college students	620	58.49
Senior college students	440	41.91
Gender		
Male	490	46.23
Female	570	53.77
Monthly living expenses		
Less than 1000 yuan	96	9.05
1000-2000	668	63.02
2000-3000	237	22.36
More than 3000	59	5.57

(4) experiencing joy and concentration when fully engaged in learning. Participants measured their learning engagement based on their actual experiences and selected the frequency of these positive emotions. Each question corresponds to a score range from 1 to 5: "1 = never; 2 = rarely; 3 = sometimes; 4 = often; 5 = always". The overall learning engagement score ranges from 5 to 25, with higher scores indicating higher levels of engagement in learning.

Independent variable: library environment. In this study, the university library environment refers to the subjective assessment of the physical aspects of the library by college students. It measures the library environment characteristics based on the subjective perceptions and personal experiences of college students (Zhang, 2019; Li et al., 2018; Peng et al., 2022). In the existing literature, discussions on the library environment in some studies tend to focus on the evaluation of physical spatial aspects such as temperature, lighting, and sound (Castilla et al., 2017; Li et al., 2018; Gómez-Cruz et al., 2020). Others emphasize assessing functional aspects, layout, facilities, air quality, artistic aesthetics, and visual perception in the learning environment (Hin et al., 2018; da Graça et al., 2007; Fantuzzi et al., 1996). Based on references to past evaluation frameworks, the subjective assessment of the library environment in this study encompasses six aspects: appropriateness of location, completeness of functionality, adequacy of equipment, appropriateness of lighting, the presence of a conducive artistic atmosphere, and the effectiveness of post-maintenance management. We provide a more detailed illustration of the evaluation of the library environment in this study; all questions are rated on a scale from 1 to 5, where "1 = very dissatisfied, 2 = somewhat dissatisfied, 3 = neutral, 4 = somewhat satisfied, and 5 = very satisfied". The overall score for the library environment ranges from 5 to 25 points. A higher score indicates a higher level of approval from the respondents regarding various aspects of the library environment, reflecting a better quality.

Intermediary variables: students' interaction. Student interaction refers to the process of communication, collaboration, and mutual engagement among students (Mahbuba, 2022). Through student interaction, individuals can learn from each other, provide support, and motivate one another, fostering knowledge-sharing and collaboration. This interaction holds significant importance in cultivating teamwork, communication skills, and social abilities among students (Mahbuba, 2022; Webb, 1985; Zhu & Zhu, 2013). Student interaction is a broad concept characterized by diversity in both content and form (Borokhovski et al.,

2012). Some scholars consider the content of student interaction to involve social, psychological, or emotional interactions and communications among students occurring in various learning or living spaces (Isohätälä et al., 2020; Kaya et al., 2015; Borokhovski et al., 2012). Other scholars argue that student interaction encompasses content related to academic and disciplinary interactions (Miao et al., 2022; Webb, 1983; Sher, 2009; Webb, 1985).

Control variables. In this study, education, expenditure, and gender are included in the conceptual model as control variables, where the value of education is: 1 = freshman; 2 = sophomore; 3 = junior; 4 = senior. The item scores of monthly expenses are from 1 to 7: 1 = below 1000 yuan; 2 = 1000–2000 yuan; 3 = 2000–3000 yuan; 4 = 3000–5000 yuan; 5 = 5000–8000 yuan; 6 = 8000–12,000 yuan; 7 = more than 12,000 yuan. Gender is 2 categorical variables, with 1 for males and 2 for females.

Statistical analysis. This study explores the relationship between the library environment, students' interaction, and college students' learning engagement through the Multifactor Validation Analysis of All Measurement Models in the Conceptual Model. The results revealed that all measurement models exhibited good reliability and validity, meeting the criteria with compositional reliability greater than 0.6, average variance extraction greater than 0.5, factor load of the observed variables greater than 0.6, and a reliability coefficient greater than 0.36 (Fornell & Larcker, 1981). The model fit the data well, as indicated by the model fitting results with indices (CFI > 0.90, TLI > 0.90, RMSER < 0.08).

Results

Descriptive statistics. The descriptive statistics of variables are shown in Table 2. When evaluating the individual learning engagement of college students majoring in liberal arts and science, the average total score for learning engagement was 14.794. Specifically, students majoring in liberal arts had an average total score of 14.649, while students majoring in science had an average total score of 14.833. All observed variables indicate that science majors had higher scores and generally exhibited higher learning engagement compared to students majoring in liberal arts. However, in terms of library environment, the average overall score for library environment perception was 18.136. Liberal arts students had an average overall score of 18.812, whereas science students had an average overall score of 17.961. All observed variables indicate that liberal arts students had higher scores than science students in this regard. In terms of student interaction, the average value of student interaction was higher than 3. The average total score for student interaction was 12.742, and liberal arts students have slightly higher scores than science students. Among the control variables, junior students majoring in liberal arts and sophomore students majoring in science account for the majority. The monthly expenditure of students ranges from 1000–2000 yuan and above, and female students account for a large proportion.

Table 3 and Fig. 2 show the simulation integration results based on the sample. From the perspective of the total effect, after controlling the grade stage, major, monthly expenditure, and gender, we found that students' learning engagement was significantly and positively affected by both the library environment and students' interaction, with a total effect value of 0.320 and 0.316, respectively, supporting Hypotheses 1 and 3. The library environment also significantly impacts interactions among students, with an effect value of 0.227, supporting Hypothesis 2.

The direct and indirect effects of the library environment on college students' learning engagement were significant, indicating some mediating variables in the path. The mediating effect value

Table 2 Variable descriptive statistics.

Observed Variables		Variable Items	Mean Scores		
			Mean (All)	Mean (Liberal arts)	Mean (science)
College Students' learning engagement	Study_h1	I feel energetic when I study	3.631	3.592	3.642
	Study_h2	I am full of enthusiasm for learning	3.625	3.572	3.639
	Study_h3	When I study, I feel that time passes quickly	3.791	3.752	3.801
	Study_h4	I feel happy when I devote myself to my study	3.747	3.733	3.751
	Total score	Study_h1+Study_h2+Study_h3+Study_h4	14.794	14.649	14.833
Library environment	B_L_1	The location of the library is very reasonable	2.987	3.003	2.983
	B_L_2	The functional layout of the library is very good	3.059	3.176	3.029
	B_L_3	All functional classrooms of the library are fully equipped	3.032	3.156	3.000
	B_L_4	The maintenance and management of all functional classrooms in the library are very good	3.045	3.149	3.018
	B_L_5	The lighting design of each functional classroom in the library is reasonable	3.062	3.207	3.024
	B_L_6	The design of the library is very artistic	2.951	3.121	2.907
	Total score	B_L_1+B_L_2+B_L_3+B_L_4+B_L_5	18.136	18.812	17.961
Students' interaction	Com_ma1	Interaction and communication among students - Communication and discussion with roommates on study, life, etc	3.298	3.341	3.287
	Com_ma2	Communication and discussion with roommates on psychological thoughts and emotions	3.188	3.203	3.184
	Com_ma3	Communication and discussion with students other than roommates on study and life	3.172	3.188	3.168
	Com_ma4	Communicate and discuss with students other than roommates about their psychological thoughts and emotions	3.084	3.070	3.088
	Total score	Com ma1+Com ma2+Com ma3+Com ma4	12.742	12.802	12.727
Control variable	Class	What education stage are you in now	2.710	3.184	2.587
	Cost	How much do you spend every month	2.299	2.274	2.305
	Gender	Are you a boy or a girl?	1.552	1.670	1.52

Table 3 Total, direct and indirect effects of the full sample model.

Independent variable	Intermediate variable	Dependent variable		
	Students' Interaction (Com)	College Students' learning engagement (study)		
		Total effect	Direct effect	Indirect effect
Library environment(B-L)	0.227***	0.320***	0.249***	0.072***
Students' Interaction (Com)	–	0.316***	0.316***	–

Note: *** means significant at the 1% confidence level, ** means significant at the 5% confidence level.

of students' interaction was 0.072, which suggested that the positive effect of the library environment on college students' learning engagement needed to be achieved by increasing the frequency of students' interaction, supporting Hypothesis 4.

Comparison of model differences among different major groups. We employed the professional field as a moderating variable and compared their model pathways. The output result coefficient was set with the same P value < 0.05, indicating significant differences in the model paths of college students in liberal arts and science. Table 4, Figs. 3 and 4 compare the model-fitting results based on the sample of college students majoring in liberal arts and science. Hypothesis 5 was also accepted based on the model results analysis.

The learning engagement of liberal arts students was significantly positively affected by the library environment and the students' interaction, with total effect values, were 0.329 and 0.215, respectively. The direct effect of the library environment on the learning engagement of liberal arts students is significant, and the effect value was 0.306. In contrast, the indirect influence was insignificant, indicating no mediating effect in the path. At the

same time, the library environment had no significant effect on the students' interaction with liberal arts students, which meant that the library environment had a direct and independent influence on the learning engagement of liberal arts students. The positive effect of liberal arts students' learning engagement needs to be achieved by improving the library environment, which will not be interfered with by the students' interaction and other factors.

The learning engagement of science majors was positively affected by the library environment and the students' interaction, with total effect values of 0.315 and 0.339, respectively. The direct and indirect effects of the library environment on college students' learning engagement were both significant, indicating a partial mediating effect in the path, and the mediating effect value of students' interaction was 0.087. At the same time, the library environment also significantly influenced the college students' interaction, and the effect benefit value was 0.255, which indicated that science majors should realize the positive effect of the library environment on learning engagement by improving the interaction frequency among students.
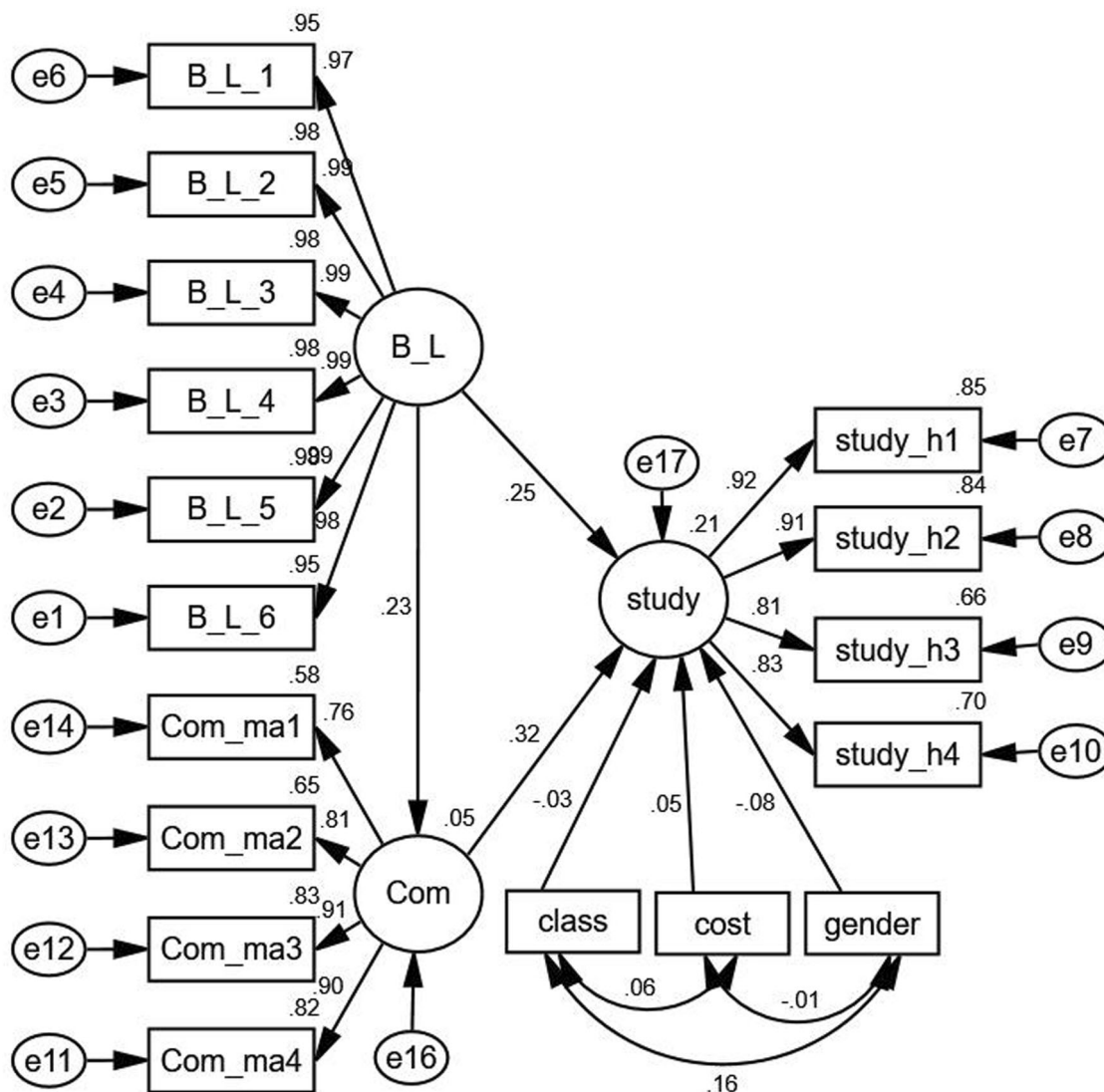
Fig. 2 Standardized path diagram for the whole sample model. Describes the normalization path for the entire model.

Table 4 Comparison of the model paths in different groups.					
Independent variable			**Intermediate variable**	**Dependent variable**	
			Students' Interaction	**College Students' learning engagement**	
				Total effect	**Direct effect**	**Indirect effect**
Liberal arts	Library environment		0.110	0.329***	0.306***	0.024
	Students' Interaction		–	0.215**	0.215**	–
science	Library environment		0.255***	0.315***	0.229***	0.087***
	Students' Interaction		–	0.339***	0.339***	–
Note: *** means significant at the 1% confidence level, ** means significant at the 5% confidence level.						

Discussion

Our study explored the complex relationship between the library environment, students' interaction, college students' learning engagement, and the differences between liberal arts and science majors. Our survey confirmed differences in college students learning engagement, and science students were higher than liberal arts students in learning engagement. However, the interaction frequency between science students and their classmates is mostly lower than that of liberal arts students.

Our study confirmed the influence of environment on learning engagement (Lei, 2022; Fredricks et al., 2004), but previous studies focused more on the influence of e-learning environment or classroom learning environment on learning engagement (El-Sayad et al., 2021; Yang et al., 2021; Kwon & Chung, 2018; Shernoff, 2013; Ayçiçek, Yanpar Yelken (2018)). Our research has found that a sizeable autonomous learning environment like the library influences college students' learning engagement. The library environment referred to in this paper was evaluated from
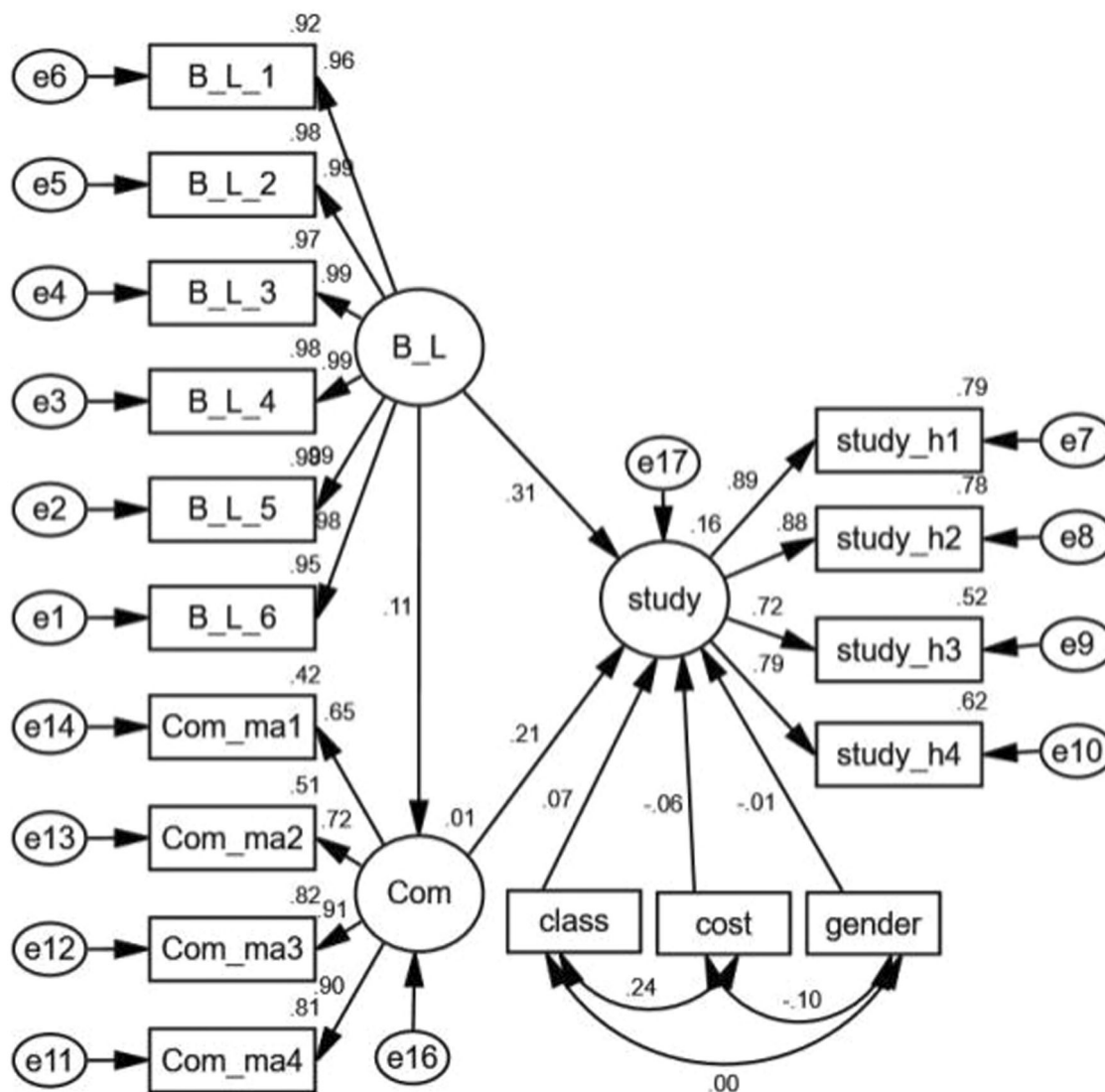
Fig. 3 Comparison of Standardized path diagram for different major groups. Introduced the influence paths of the model for the student groups of liberal arts and science majors respectively.

six aspects: suitable location, pleasing function, complete equipment, proper lighting, artistic atmosphere, and later guarantee. Optimizing and improving the library environment in these six aspects may benefit learning engagement. At the same time, our research confirmed that the students' interaction also significantly promotes college students' learning engagement (Yang et al., 2021; Jie & Daniel, 2014; Lei, 2022). Moreover, the study found that the library environment influences the learning engagement of college students through the intermediary role of students' interaction. That is to say, improving the quality of the library environment will effectively improve the frequency of interaction and communication between college students and thus improve the state of college students' learning engagement. Therefore, it is necessary to improve the learning engagement of college students by improving the library environment and guiding friendly interaction among students.

More importantly, our study also found significant differences in the path of the library environment affecting the learning engagement of college students of different majors. For liberal arts students, the state of their learning engagement depended on the superiority of the library environment. On the contrary, for science students, the influence of the university library environment on their learning

engagement was strongly mediated by the students' interaction. The influence of the library environment on liberal arts students' learning engagement was strong and direct and will not be interfered with by students' interaction. However, for science students, the influence of the library environment on their learning engagement needs to be achieved through the mediating role of students' interaction.

Due to the difference in the influence path of the library environment on the learning engagement of college students majoring in liberal arts and science, the needs of various professional students must be considered to improve college students' overall learning engagement, and targeted opinions and strategies must be presented per the group characteristics of various professional students to achieve differentiated responses and precise library environmental governance. First of all, improving the library environment is significant for both liberal arts students and science students. A well-designed and adequately maintained library environment is crucial in promoting college students' learning engagement. It can provide a comfortable and conducive environment for studying, thereby enhancing students' learning experiences and alleviating stress among students, enabling better focus on studying, and enhancing learning engagement.
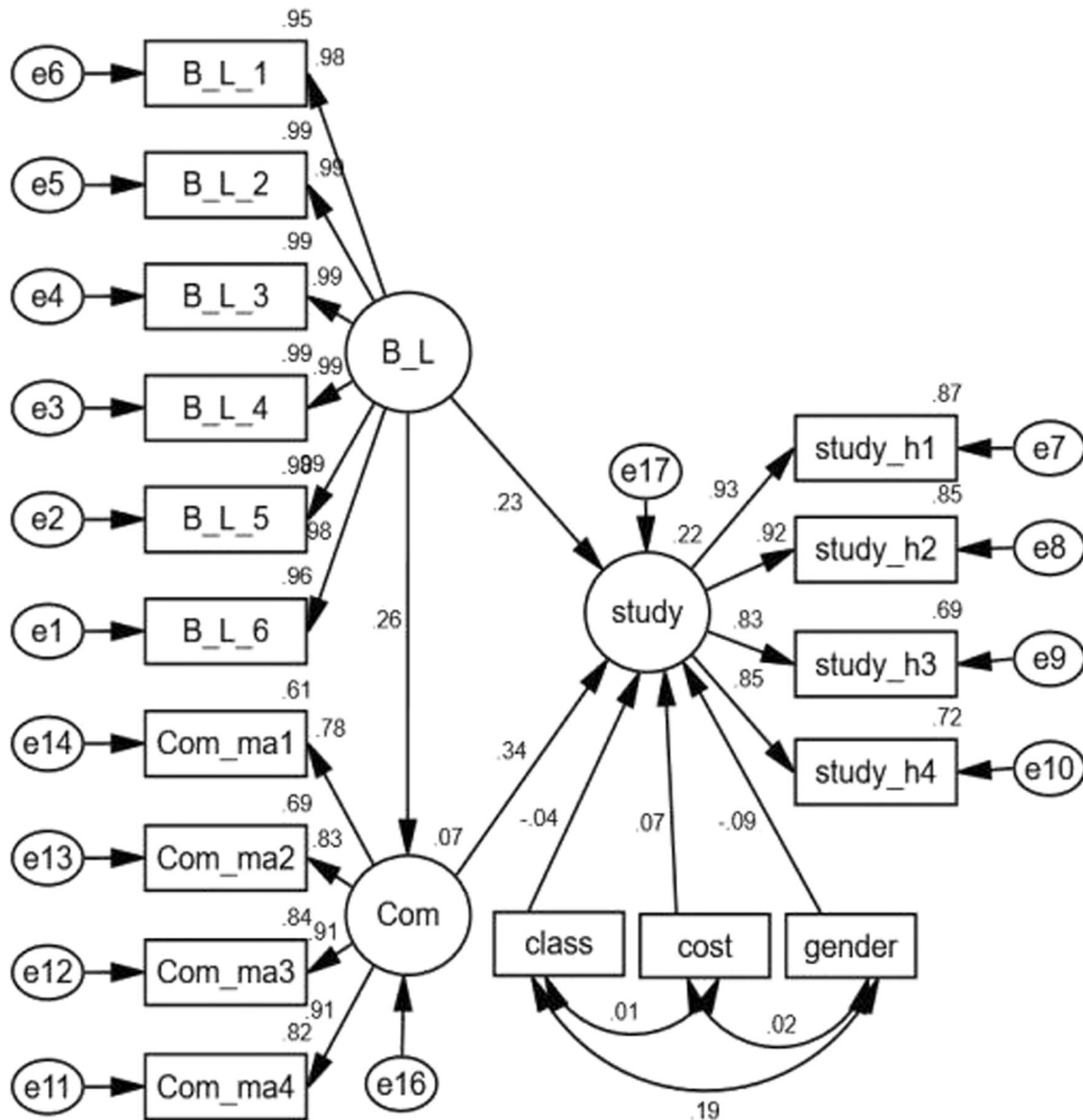
Fig. 4 Comparison of Standardized path diagram for different major groups. Introduced the influence paths of the model for the student groups of liberal arts and science majors respectively.

Especially for liberal arts students with relatively poor learning engagement who need special attention, the library environment strongly influenced their learning engagement. This influence was straightforward and will not be affected by students' interaction or other factors. Because some liberal arts students may be involved in independent research projects that typically require extensive reading and writing, these tasks demand them to work independently and engage in deep thinking (Entwistle, 2009). Perhaps a relatively quiet and focused environment is more suitable for liberal arts students. The library may be ideal for this type of academic work, making it easier for liberal arts students to concentrate on reading and profound reflection without being disturbed by their peers. Therefore, student interactions may not be as crucial for liberal arts students as for natural science students. This observation also confirms a previous study that library use appears unrelated to the frequency of substantive conversations with peers among liberal arts students (Kuh, Gonyea (2003)). It means that improving the library environment is the most effective way to increase the learning engagement of liberal arts students. Therefore, in the process of library environment

construction and transformation in the future, the relevant decision-makers and environmental designers should pay special attention to the needs of college students for the library environment or related behavior characteristics, pay attention to the aesthetic and functional needs of the environment, and create a more immersive learning atmosphere.

Secondly, improving the library environment must start from many aspects. For science students, their learning engagement will be affected not only by the physical environment of the library but also by the social environment created through students' interaction. Because most science students typically require more laboratory work, mathematical computations, and collaborative teamwork, they tend to favour group-based learning (Heojeong et al., 2014). Student interactions and collaborations may be more critical in such cases as they need to communicate and discuss experimental results and problem-solving. Science students may rely more on student interactions to enhance their learning engagement, which can influence their learning behaviours in the library environment. Consequently, we must recognize that the role of student interactions will significantly

mediate the influence of the library environment on student learning engagement. This means that the library environment alone may not be sufficient to improve science students' learning engagement. We should pay special and more attention to fostering a positive social environment that encourages friendly and productive interactions among students. To achieve this goal, university decision-makers and educators should focus on providing opportunities for students to engage with each other outside of the classroom setting. This could include organizing social events, study groups, and other extracurricular activities that foster collaboration and communication among science students. Additionally, the design and layout of the library should be optimized by creating communal workspaces or integrating technology that facilitates group work to promote social interaction. For instance, female students greatly appreciate the new lounge area in the library, which includes several chairs and a fire pit. This area can be a gathering place for them to reconnect with friends during breaks (DeLauer et al., 2022). Furthermore, it is essential to recognize the unique needs and characteristics of science students in fostering a positive social environment. For example, science students may be more focused on technical aspects of their coursework and may benefit from structured group projects that encourage collaboration on specific problems or experiments. By considering the specific needs of science students, university decision-makers and educators can better support their learning engagement and overall success.

However, the study still has certain limitations. First, the survey scope and sample size are both constrained. Since only a few universities were chosen for in-depth investigation, the sample of science students was significantly larger than that of liberal arts students. The research conclusions cannot delegate all library environments in Chinese universities, and more empirical study is needed in the future. Secondly, the representativeness of the sample of college students needs to be further improved, and the sample of science students is significantly more than that of liberal arts students. Finally, since the library environment in this study is based on subjective evaluation, subsequent studies should combine subjective and objective environmental evaluation systems to better explore the relationship between the library environment and college students' learning engagement.

Conclusion

Our research results suggested that there were variations in the learning engagement of Chinese college students. The learning engagement of students majoring in liberal arts is relatively lower compared to science students. Therefore, it is necessary to pay special attention to the learning engagement of liberal arts college students.

Our study demonstrated that the library environment significantly influenced college students' learning engagement, and students' interaction served as a mediator variable of the library environment affecting college students' learning engagement. More significantly, we discovered variations in how the library environment influenced the learning engagement of college students from different specializations. The direct effect of the library environment on the learning engagement of liberal arts majors was more potent, while the influence of the library environment on the learning engagement of science students was more strongly mediated by students' interaction.

The paper's conclusion offers fresh suggestions for constructing, improving, and revitalizing the present library environment. The social ecosystem for college students influences each other, including the library environment, students' interaction, and learning engagement. To improve the learning engagement of students with different majors, specific recommendations and

tactics should be offered based on the characteristics of college students majoring in the liberal arts and sciences. University decision-makers should pay attention to the students' interaction that affects science students and improve the library environment, which can increase the opportunities and frequency of students' interaction to increase the learning engagement of science majors. At the same time, universities should pay more attention to the library environment that directly affects the learning engagement of liberal arts majors.

In summary, to improve college students' learning engagement, it is necessary to consider multiple factors, including the library environment, students' interaction, teaching quality and methods, and students' physical and mental health. By providing a comprehensive and supportive learning environment for college students, we can help them achieve better learning outcomes and promote their personal and professional growth. Therefore, the findings of this study hold significant practical implications for teaching practices in Chinese higher education.

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Acknowledgements

Author contributions
Conceptualization: Z.Z. and M.Z.; Data curation: Z.Z.; Formal analysis, Z.Z and N.S.; Methodology: Z.Z. and M.Z.; Validation: Z.Z. and W.H.; Investigation: Z.Z. M.Z. and W.H.; Software: Z.Z and M.Z.; Resources: Z.Z.; Writing—original draft preparation: Z.Z.; writing—review and editing: Z.Z. and N.S.; Visualization: Z.Z. and M.Z.; Supervision: Z.Z.; Project administration: W.H.; Funding acquisition: Z.Z.

Competing interests
The authors declare no competing interests.

Ethical approval
The data used in this study did not involve ethical issues. All survey participants provided written informed consent. All methods employed in the study were performed in accordance with the relevant international guidelines and regulations.

Informed consent

Informed consent was obtained from all survey participants. No identifying information was collected during the survey, and there are no ethical issues with science and technology.

Additional information

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