Enhancing Academic English Literacy for STEM Graduate Students: A Mixed-Methods Study

Qian Wang*

School of Foreign Studies, Northwestern Polytechincal University, Xi'an 710129, China

Abstract: In recent years, the significant expansion of postgraduate education in China has highlighted the imperative for an in-depth examination of the academic English proficiency of graduate students in STEM disciplines. This study employs a mixed-methods design to explore the structural elements and influencing factors contributing to the advancement of academic English proficiency among STEM graduate students in three "Double First Class" universities in the western region of China. Through interviews and surveys involving graduate students, their supervisors and English language instructors, the research aims to unveil the key dimensions of academic English proficiency and pinpoint factors that influence its development. The study identifies three fundamental dimensions: academic English integrity, academic English critical thinking ability, and academic English communicative competence. The influencing factors encompass the academic English environment, academic English practice, and academic English beliefs. The findings of this research provide valuable insights for enhancing academic English proficiency among STEM graduate students and elevating the overall quality of graduate education.

Keywords: Academic English Literacy; Science and Engineering Graduate Students; Element Structure; Influencing Factors

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1 Introduction

Academic language, acting as the cornerstone for knowledge construction and meaningful exchange within specific disciplines and professional fields, is pivotal in fostering individual disciplinary and professional competence. Representing an advanced stage of language development, academic language mirrors an individual's higher-order thinking abilities and the adept use of language in professional domains. Proficiency in academic language serves as a crucial tool for individuals to access social resources, participate in disciplinary discourse communities, and elevate the academic literacy of graduate students [1-3].

Undoubtedly, graduate education is a primary pathway for cultivating high-level innovative talents, forming the foundation for addressing global talent competition, and serving as a cornerstone for implementing innovation-driven development strategies and constructing an innovative nation. The ongoing construction of "Double First-Class" implies that future scientists and engineers in China must possess international discourse power in their respective fields. English, as a globally recognized language, maintains an indispensable position as a language medium in international academic publications and scholarly exchanges. Against this backdrop, cultivating the for-

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*Corresponding author: Qian Wang, wangq@nwpu.edu.cn

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eign language academic language proficiency of graduate students becomes crucial in aiding their integration into disciplinary discourse communities, engaging in scholarly dialogues with international peers, acquiring professional knowledge and skills, and participating in communication, exchange, and collaboration within their academic domains.

Academic English literacy is a compound of academic English and academic literacy. Its development is not an isolated activity of learning abstract knowledge and skills but a process where individuals, through peripheral participation, enter the academic practice community, seek meaning, and construct their academic identity [2]. Academic English literacy is multi-layered. Specifically, at the technical level, it primarily refers to the structure of academic texts and the language, rhetoric, and cognitive structures mastered by students. It focuses on academic writing, conventions of academic texts, and rhetorical practices, discourses, and genres associated with specific disciplines. At the epistemological level, it refers to the socialization process of students entering the academic community within a certain social structure. At the ideological level, it emphasizes the interaction between knowledge construction traditions and the development of academic English literacy, as well as the role of individual resources in enhancing academic English literacy [4].

Against the backdrop of the "Double First-Class" initiative, enhancing the academic English literacy of graduate students is not only a fundamental requirement for English learning in STEM postgraduate education but also a pathway for China's scientific and technological personnel to elevate their research level and gain discourse power through international academic exchanges. Given the close correlation between the world ranking of higher education institutions and their research output and international exchange level [5], academic English literacy holds significant value in advancing the overall standard of higher education in China, establishing world-class universities, and developing first-class disciplines.

Existing research on academic English literacy primarily focuses on its functional components [6-8], individual development factors [9, 10], and elements related to maintaining fairness and rights [11]. Previous studies, such as Mu (2015), have emphasized the necessity of training students in learning academic writing conventions and language through literature reviews, improving language proficiency, and cultivating their logical thinking abilities [12]. Fentonsmith & Humphreys (2016) proposed that graduate students using English as an additional language should possess competencies in academic motivation, academic maturity, and academic confidence [7]. Drawing on empirical research on project-based learning models in university English writing, Yang and Han (2012) argued that students' academic English literacy should include research skills, innovative awareness and capabilities, as well as proficiency in both general English and academic English writing skills [13]. Tribble (2017) suggested that, within the context of English as a global language, the developmental process of academic English literacy should involve self-reflection, liberating teachers and students from the dichotomy of standard and non-standard languages [11].

Upon reviewing the literature, it is evident that although academic English literacy is a current hot topic in academia, research on comprehensive literacy or specific aspects of graduate students' academic English in China is still in its infancy. Particularly, there is limited empirical research on the academic English literacy of STEM graduate students in China. In-depth exploration of the structure and influencing factors of academic English literacy for graduate students in STEM disciplines not only clarifies the issues of "what to teach" and "how to teach" in the cultivation of foreign language academic literacy for graduate students but also provides important implications for guiding reforms in foreign language education programs, curriculum and teaching transformations, and ultimately, improving the quality of graduate education.

2 Method

2.1 Sampling

This study employed a mixed-methods research design that incorporates both qualitative and quantitative approaches. Qualitative research primarily involved semi-structured interviews with master and doctoral students, academic advisors, and academic English instructors to collect qualitative data. Grounded theory was employed to extract key events and their characteristics through open coding, axial coding, and selective coding. This process aimed to identify the structural elements of graduate students' academic English literacy and key indicators influencing it. Based on the core indicators, we developed a survey on "Factors Influencing Academic

English Literacy for STEM Graduate Students" and distributed the survey, consisting of 18 items, with an overall validity Cronbach's alpha value of 0.839, to collect large-scale data. Quantitative methods were used to elucidate the relationship between the structural elements of academic English literacy for STEM graduate students and influencing factors.

Interview participants were selected from five outstanding master and doctoral supervisors, three instructors engaged in teaching academic English to graduate students (with more than 5 years of teaching experience), and ten STEM graduate students (five Ph.D. students, two students for a Professional Master Degree, and three students for an Academic Master Degree) from three "Double First-Class" universities in the western region of China. Interviewees, both graduate supervisors and English instructors, hold a doctoral degree and the title of associate professor or above. They possess firm educational beliefs, high moral standards, rich experience in graduate teaching, and significant achievements in academic research and student supervision. The graduate students participating in the interviews have experience in project participation and the publication of SCI-indexed papers. Each interviewee received a small gift as a token of appreciation for their participation.

2.2 Research Process and Data Analysis

1) Qualitative Data Collection and Coding

In the initial phase, qualitative data is gathered through semi-structured interviews. Grounded theory is applied through successive coding stages to comprehend interviewees' perspectives on graduate students' academic English literacy. The interview questions cover the value and significance of enhancing graduate students' academic English literacy, the dimensions constituting graduate students' academic English literacy, the hierarchical structure of academic English literacy, the developmental process, and the pathways for fostering academic English literacy. With the participants' consent, the entire interview process is recorded and transcribed. Ten random samples from the original analyzed text are coded using qualitative analysis software NVivo 11, and an additional two samples are used to test theoretical saturation. The qualitative data undergoes three levels of coding, following open coding (level one), axial coding (level two), and selective coding (level three), resulting in themes or patterned codes that reveal the essence of the data. The three-level coding process and results are illustrated in Tables 1 and 2. Two reserved interview texts are used to assess data saturation regarding the structural elements of graduate students' academic literacy, ensuring that the extracted indicators do not generate new categories and sub-concepts. The interview excerpts are translated into English and included in this paper.

2) Quantitative Data Collection and Analysis:

For the quantitative phase, surveys are distributed to STEM graduate students at different educational levels (as indicated earlier) from the three aforementioned universities. A total of 255 questionnaires are distributed, with 245 valid responses (185 male and 60 female respondents received after excluding 10 incomplete responses). Academic master students constitute 112 (46%), professional master students 55 (22%), and doctoral students 78 (32%), respectively. We use a Likert five-point scale, ranging from "completely disagree" to "completely agree," scored from 1 to 5. The questionnaire data are input into SPSS 23.0, and descriptive statistics and variance analysis are utilized to observe differences between different samples.

Table 1 Coding Process and Results of Structural Elements of Academic English Literacy

Open Coding	Axial Coding	Selective Coding
A01 Actively Introducing Oneself in International Academic English Communication		
A02 Reading English Literature to Obtain Relevant Information		
A03 Reading English Literature to Identify Research Gaps		
A04 Understanding Academic Norms in International Journals	B01 Establishing Academic Connections (A01, A07, A10)	C01 Academic English Critical Thinking Skills (B02)
A05 Respecting Customs of Others in International Academic Exchanges	B02 Keeping Abreast of Research Developments (A02, A03, A08, A11)	C02 Academic English Communication Skills (B01, B03, B04)
A06 Clearly Indicating Source of Literature and Material	B03 Enhancing International Influence (A09)	C03 Academic English Integrity (B05)
A07 Maintaining Contact with Foreign Peers Encountered	B04 Respecting Academic Customs (A04, A05, A12)	
A08 Reading English Literature to Familiarize with	B05 Cultivating Integrity (A06, A13)	

Open Coding	Axial Coding	Selective Coding
Knowledge		
A09 Participating in International Academic Dialogues to Enhance Impact		
A10 Discussing Issues with Foreign Peers Encountered		
A11 Tracking Cutting-Edge Developments in English Literature		
A12 Noting Differences in Academic Writing Between Chinese and Western Scholars		
A13 Mastering Proper Citation to Prevent Academic Plagiarism		

Table 2 Coding Process and Results of Factors Influencing Academic English Literacy

Open Coding	Axial Coding	Selective Coding
A01 Supervisor's Thesis Proofreading		
A02 Communication Requirements for International Academic Conferences		
A03 Challenges in English Paper Writing		
A04 Existing English Language Proficiency	B01 Research Team Collaboration (A01)	C01 Academic English Environment (B01, B03, B07)
A05 Self-Achievement of Academic Values	B02 Participation in Academic Conferences (A02)	C02 Academic English Beliefs (B05, B08)
A06 Overseas Exchange Program Experience	B03 Opportunities Provided by Supervisor (A10)	C03 Academic English Practice (B02, B04, B06)
A07 Frequent Team Academic Communication	B04 Academic Reading and Writing (A03, A09, A11)	
A08 Academic English Course Design	B05 Self-Value Realization (A05)	
A09 Communication with Journal Editor's Requirements for Language		
A10 International Exchange Opportunities Provided by the Supervisor		
A11 Application of Academic English Reading Strategies		
A12 International Collaborative Paper Writing Practice		

3 Findings

3.1 Structural Elements of Academic English Literacy for STEM Graduate Students

Through iterative coding of interview data, this study identified three core dimensions of academic English literacy for STEM graduate students: academic integrity, academic critical thinking skills, and academic communication skills.

1) Academic Integrity

Academic integrity refers to the principles and norms of academic ethics followed in research, with integrity at its core. It serves as the guiding principle for researchers engaging in scholarly activities. It is the most crucial and fundamental quality in the academic literacy of graduate students. As the future leaders in academia and the driving force in scientific research, graduate students need a strong moral consciousness, understanding, and adherence to academic norms. As a core element, besides incorporating content related to academic norms and ethics into the graduate curriculum, supervisors should lead by example in their collaboration with graduate students, shaping their academic conduct through subtle influence.

2) Academic Critical Thinking Skills:

Academic critical thinking skills encompass advanced thinking abilities such as analysis, reasoning, evaluation, and integration in judging the authenticity of information. In academic English literacy, critical thinking is the ability to analyze and evaluate the reliability of other scholars' viewpoints, pose one's own questions and reflections, and, based on evidence or argumentation, develop innovative perspectives [14]. For example, in critical aspects of academic English literacy, such as literature review and journal paper writing, students engage in literature retrieval, analyze and evaluate the main points of previous literature, compare and categorize logical relationships between claims, question assumptions and research goals through research methods such as experimental design, and criti-

cally examine and interpret research findings. Throughout the process of academic English reading and writing, critical thinking skills pervade, guiding graduate students to rationally understand, analyze, and solve problems, adhere to academic paradigms, eliminate academic misconduct, and shape academic character.

3) Academic Communication Skills:

Academic communication skills refer to the necessary ability to engage in international academic communication, deepen understanding and identification with diverse academic cultures, and include the ability to communicate in an international context. As elite-level education in higher education, cultivating students' cross-cultural communication skills in international academic exchanges is significant for promoting academic achievements, facilitating international academic exchanges and cooperation, and enhancing China's academic discourse in the international academic community. Academic integrity refers to academic ethics, the principles, and norms followed in academic research, with integrity at its core. Integrity is the guiding principle for researchers conducting scholarly activities. It is the most important and fundamental essential quality in the academic literacy of graduate students. Graduate students, as the future rising stars in academia and the initial force in scientific research, need strong moral consciousness, understanding, and adherence to academic norms. As one of the core elements, in addition to incorporating content related to academic norms and ethics into the graduate curriculum, supervisors need to lead by example in their collaboration with graduate students, molding their academic conduct through subtle influence.

3.2 Current Status of Academic English Literacy for STEM Graduate Students

Through data analysis of the survey results, the study found that the average values of academic English literacy for STEM graduate students in the three dimensions, from high to low, were academic critical thinking skills (mean M=4.467), academic integrity (mean M=3.155), and academic communication skills (mean M=2.245). This indicates that STEM graduate students possess the strongest academic critical thinking skills, followed by a moderate awareness of academic integrity, and the weakest academic communication skills.

ANOVA results (as shown in Table 3) indicate that in the dimension of academic integrity, doctoral students outperform academic master students, and academic master students outperform professional master students. In the dimension of academic critical thinking skills, doctoral students outperform professional master students, and professional master students outperform academic master students. In the dimension of academic communication skills, doctoral students outperform academic master students, and academic master students outperform professional master students. However, the p-values for the statistical significance of these three dimensions are all greater than 0.05, indicating no statistically significant differences. This suggests that overall, the academic English literacy of STEM graduate students has gradually developed with increasing academic training but has not been effectively enhanced with in-depth scientific research work.

Table 3 Descriptive statistics of the academic English literacy components of STEM graduate students

Structural components		Case No.	Mean	Standard Deviation	Standard Error	95% Confidence Interval		Minimum	Maximum
						Lower bound	Upper bound		
Academic Integrity	Professional Mater Graduate Students	55	3.146	0.445	0.345	3.11	3.75	1.33	5.56
	Academic Master Graduate Students	78	3.224	0.345	0.656	3.21	3.85	1.23	4.44
	Ph.D Students	112	3.517	0.453	0.435	3.24	3.67	1.45	5.88
	Total	245	3.282	0.564	0.254	3.23	3.73	1.21	5.67
Academic Critical Thinking Skills	Professional Mater Graduate Students	55	3.359	0.598	0.495	3.26	3.45	1.11	4.57
	Academic Master Graduate Students	78	3.349	0.611	0.345	3.27	3.42	1.17	5.06
	Ph.D Students	112	3.481	0.522	0.334	3.38	3.57	2.52	5.67
	Total	245	3.383	0.456	0.245	3.11	3.77	1.12	4.55
Academic	Professional Mater Graduate	55	3.111	0.345	0.634	3.31	3.78	1.17	4.55

Structural components		Case No.	Mean	Standard Deviation	Standard Error	95% Confidence Interval		Minimum	Maximum
						Lower bound	Upper bound		
Communication Skills	Students								
	Academic Master Graduate Students	78	3.231	0.534	0.451	3.56	3.75	1.56	5.71
	Ph.D Students	112	3.356	0.642	0.324	3.42	3.75	1.85	5.23
	Total	245	3.153	0.512	0.434	3.21	3.62	1.45	4.86

3.3 Influencing Factors on Academic English Literacy for STEM Graduate Students

Based on the qualitative analysis results of interview data, the influencing factors on academic English literacy for STEM graduate students mainly include academic English environment, academic English practice, and academic English beliefs.

(1) Academic English Environment

Academic English environment refers to the academic English communication environment created for graduate students, including the macro national-level planning environment, the international atmosphere at the mid-level of universities, and the micro-level interpersonal support environment. National-level plans such as "Double First-Class" and "New Engineering" provide possible conditions for constructing an international environment at the university level, creating opportunities for individual international development. In the three universities surveyed, STEM graduate students can apply for exchange programs (such as the exchange program provided by the China Scholarship Council). This allows them to gain internationalized training. Furthermore, each university creates an internationalized training environment based on the strengths of its disciplines. The followings are some interview excerpts.

For example, in my school, we organize simulated international academic conferences for graduate students every year. There is a main venue and many parallel sessions focusing on presenting papers and reports. Those with good English skills are more active and have advantages during the conference. (Master student S-2)

Our supervisor recruits international students, but when communicating with them, I feel that their pronunciation is not as good as mine because they are all Pakistani, and their pronunciation is a bit strange. I don't feel much pressure in oral communication; I can understand them. When writing papers, in terms of wording, they are more precise than me. Sometimes I consult them. (Ph.D. student S-3)

As excerpted from the interviews, the university where Master student 2 is pursuing a degree conducts simulated international academic conferences to enhance graduate students' academic English abilities. The supervisor of a Ph.D. student (S3), guided by the macro policies of the country's international development, recruits international students, which helps create an international academic team.

Different majors in our school have different requirements for students publications. Each department has its own requirements. For example, our Materials Science department has relatively high requirements, and students publish more SCI papers. (Academic English teacher T-2)

Yes, I ask my Ph.D. students to read in English. Of course, they also read in Chinese, but English is the default language for publication. I try to give my Ph.D. students the opportunity to go abroad for conferences. Aside from the funding provided by the school, I will at least use my own project funds to support each Ph.D. student in attending an international conference. There are also some external funds that my Ph.D. students can apply for to go abroad. On the one hand, it is about providing support and assistance, and on the other hand, it is about forcing them to communicate. As long as they go abroad for exchanges, they have to prepare English conference papers, materials, PPTs, and what they want to say. This whole process is a form of practice! I also plan to recruit some international students, creating a small multinational environment in my team. (Ph.D. supervisor T-5)

It is evident that each university has established international training requirements for STEM graduate students, considering them essential for degree attainment. In response to these requirements, supervisors at the respective institutions provide relevant resources. The results reveal that they mandate graduate students to include a specific percentage of English literature in the references of their graduation projects and theses. Additionally, Ph.D super-

visors impose reading requirements on English literature and offer financial support from project funds to facilitate students' international development.

Micro-level academic English environment is reflected in the interpersonal environment provided by graduate supervisor and academic English teachers. The interviews in this study found that some academic English teachers, due to work needs, cooperate with STEM graduate advisors through joint project applications, auditing courses, providing language services, and editing and proofreading papers. However, such cooperation is often an individual behavior and encounters many resource constraints during implementation.

(2) Academic English Practice

Academic English practice involves STEM graduate students applying academic English in diverse academic activities, primarily encompassing the acquisition of specialized knowledge in English and engaging in English communication. Numerous STEM graduate students encounter shortcomings in their practical academic English skills. However, through academic English practice, individuals are prompted to enhance their strategies for using academic English and refine their overall learning approaches.

I find it difficult to read English literature. I use translation software. For a document about 15 pages long, it takes me 15-16 hours to read. Apart from terminology, there are also differences in the logic and thinking patterns in English expressions, which are different from what I was exposed to before and the Chinese literature. However, in the later stages, when you read articles in your field, the vocabularies are consistent. If you become familiar with it, reading things in your own field will be relatively quick. Even if it's slow at the beginning, it will get faster later. (Master student S-2)

When participating in academic conferences, communication is a big problem. I am not so confident in my oral English. When I am giving a speech, others don't react until I talk about important content. In the English presentation I just made, the sentences are relatively long. I shouldn't use so many long sentences; I should break them into several short sentences, which are more suitable for oral presentation. Also, because I haven't been trained, I worry about the question-and-answer session, not knowing how to start and how to answer questions. When others throw questions at me, I don't know how to respond. I prepare my own questions, but when they come over, I'm not prepared and don't know the answers. I write a lot and speak less. (Ph.D. student S-1)

As illustrated, the Master student (S-2) initially encountered challenges in reading specialized books, grappling with insufficient knowledge, limited vocabulary, and a lack of logical thinking leading to comprehension difficulties. Nevertheless, as his learning deepened, he continuously adjusted his reading strategies and discovered that gaining familiarity with the subject matter significantly improved his academic English reading skills. The academic English challenges faced by the Ph.D. student (S-1) are more intricate and specific. He identifies difficulties in delivering presentations at academic conferences, emphasizing the need for more practice using concise sentences suitable for oral communication. This, he believes, is essential to enhance academic English skills and build confidence in communication.

In practice, the academic English environment and academic English practice for STEM graduate students are interconnected influencing factors. The macro-level planning environment provides policy support, creating opportunities for international development. The university-level international environment serves as the practical setting for academic English. The micro-level interpersonal environment further contributes resource support.

(3) Academic English Beliefs

Beliefs encompass emotions grounded in a particular understanding, fostering unwavering attitudes toward the acceptance of theories, propositions, ideologies, ideals, etc., yet to be diligently realized. Being inherently subjective, beliefs epitomize the unity of cognition, emotion, and will [15]. Within the academic community, beliefs denote a shared understanding, converging toward consensus. In the context of academic English, beliefs pertain to an individual's subjective understanding and emotions cultivated during the process of constructing professional academic cognition through practical experience.

Academic English beliefs take shape as STEM graduate students develop their understanding of professional academia, chart their career paths, and explore the potentials that academic English brings to research practice.

My major is biomedical engineering... This field has developed in China for only about ten or twenty years. It is not very popular in many schools, and it is quite disconnected from developments abroad. The cutting-edge research is still at abroad. If I plan to continue with a Ph.D., considering going abroad, academic English is certainly very important. (Master student S-4)

I used to prefer oral English, that is, communication

with people. I also hope to have more opportunities to communicate with foreigners... Our major involves high-end technologies and materials, most of which are from abroad. You can only understand the latest developments through English. I plan to go abroad for six months. My supervisor is helping to arrange it, and I need to strengthen my academic English. I think establishing connections with the academic community should be part of academic life... (Ph.D. student S-1)

Extracted from the aforementioned interviews, STEM graduate students, in their journey of learning and utilizing academic English, strategically position themselves and shape their career trajectories. Unlike Master students, Ph.D. students have, to a certain extent, solidified their academic identity, integrating the use of academic English into their professional careers. They firmly believe that forging connections with the academic community through academic English communication is an integral aspect of academic life. Consequently, they proactively exchange resources within the academic community, thereby securing opportunities for academic development.

Regular English learning focuses more on communication, while academic English learning requires more understanding and needs to be more rigorous. Especially when you are writing, you need to pay attention to its English expression and wording. In our lab, when senior students submit papers, they have to repeatedly revise them, especially the expression of experimental processes. Some people may do experiments well, but if the English is not very good, the paper may be rejected. (Master student S-3)

I think the logic is the most important. For example, when writing a literature review, it's not just listing literature. The narrative of the literature has internal logic. If you do it well, the entire paper shines. As my work progresses, I increasingly know what I need English for and strengthen my practice accordingly. (Ph.D. student S-2)

Analyzing the data from the aforementioned interviews reveals that STEM graduate students' understanding of academic English is rooted in the acknowledgment of their individual shortcomings. However, disparities emerge when comparing Master and Ph.D. students. Master students emphasize academic English knowledge, particularly focusing on vocabulary and language style. Conversely, while Ph.D. students concentrate on honing academic English skills, especially their critical thinking abilities within an academic context, specifically delving into logical reasoning during academic communication. Simultaneously, Ph.D. students exhibit rational thinking skills, demonstrating an awareness of the logic inherent in academic English and the correlation between their own reasoning and that of authors of the publications they read.

3.4 Characteristics of Influencing Factors on STEM Graduate Students' Academic English

Upon scrutinizing the questionnaire results, it becomes apparent that the influencing factors on academic English literacy for STEM graduate students exhibit varying average values across three dimensions, with academic English beliefs ranking the highest (mean M=3.526), followed by academic English environment (mean M=3.278), and academic English practice (mean M=3.106). This suggests that academic English beliefs play the most significant role in enhancing academic English literacy, followed by academic English environment and academic English practice. ANOVA results reveal (as indicated in Table 4) statistically significant differences among academic Master students, professional Master students, and Ph.D. students for all three influencing factors (*P* values all less than 0.05). Across all dimensions, Ph.D. students exhibit superior performance compared to academic Master students, while academic Master students surpass professional Master students.

Table 4 Descriptive Statistics of Academic English Influencing Factors for STEM Graduate Students

Influencing Factors		Case No.	Mean	Standard Deviation	Standard Error	95% Confidence Interval		Minimum	Maximum
						Lower bound	Upper bound		
Academic English Beliefs	Professional Mater Graduate Students	55	3.711	0.513	3.28	3.92	1.25	5.14	55
	Academic Master Graduate Students	78	3.754	0.618	3.17	3.79	1.19	5.67	78
	Ph.D Students	112	3.882	0.527	3.19	3.82	1.27	5.37	112
	Total	245	3.525	0.433	3.39	3.76	1.19	5.58	245
Academic	Professional Mater Graduate Stu-	55	3.313	0.572	3.26	3.16	1.22	5.52	55

Influencing Factors		Case No.	Mean	Standard Deviation	Standard Error	95% Confidence Interval		Minimum	Maximum
						Lower bound	Upper bound		
English Practices	dents								
	Academic Master Graduate Students	78	3.356	0.536	3.27	3.23	1.19	4.35	78
	Ph.D Students	112	3.453	0.467	3.38	3.29	1.72	5.33	112
	Total	245	3.428	0.388	3.11	3.56	1.45	5.25	245
Academic English Environment	Professional Mater Graduate Students	55	3.245	0.525	3.31	3.34	1.25	5.85	55
	Academic Master Graduate Students	78	3.275	0.623	3.56	3.52	1.43	4.89	78
	Ph.D Students	112	3.331	0.527	3.42	3.43	1.58	5.62	112
	Total	245	3.242	0.526	3.21	3.56	1.33	5.16	245

The analysis of the questionnaire items related to academic English beliefs reveals that academic English beliefs function as a system: by establishing beliefs, graduate students can enhance the breadth and depth of their professional cognition and gain a sense of value. Regarding the differences in items related to enhancing the professional cognition and gaining a sense of value, the order from high to low is consistently doctoral students, academic master students, and professional master students. This result indicates that doctoral students and academic master students, who are positioned for academic research, pay more attention to the transformative role of academic English beliefs. This involves transforming functional goals, such as expanding international perspectives and elevating professional levels, into professional cognition and a sense of value. In contrast, professional master students prioritize achieving functional goals. If the realization of functional goals is reflected in the instrumental value realization of academic English literacy, and the acquisition of professional cognition and a sense of value is reflected in the humanistic literacy of academic English literacy, then the academic beliefs of doctoral students and academic master students, who are positioned for academic research work, can better help them achieve this transformation through practice.

The statistical outcomes of academic English practice reveal variations in the influence of such practice on graduate students of different training levels, attributed to distinctions in their positioning and objectives. The differences in items related to work communication follow the order from high to low: doctoral students, professional master students, and academic master students. Similarly, the differences in items related to academic matters are in the order from high to low: doctoral students, academic master students, and professional master students. In terms of items related to work receptions, the order is from high to low: doctoral students, professional master students, and academic master students. This outcome indicates that different academic English practice activities exert varying effects on graduate students of different training levels. Comprehensive participation in academic, work, and transactional communication practice activities has a more significant impact on doctoral students. In contrast, academic work-related practice activities have a greater influence on academic master students compared to professional master students, while work-related and transactional communication practice activities have a more pronounced effect on professional master's students.

The study also revealed variations in the impact of the academic English environment on graduate students at different training levels. Doctoral students are most significantly affected, while factors related to internationalization have a greater influence on academic master students, and environmental factors associated with degree requirements have a more pronounced impact on professional master students.

Based on these findings, the study constructs a model of academic English literacy for graduate students in STEM disciplines (Figure 1), outlining its structural elements and influencing factors. Each influencing factor does not act independently but collectively produces systematic effects on the structural elements of academic English literacy. Among these factors, academic English beliefs play the most significant role, encompassing the cognition developed by graduate students through their experiences with academic English and the formation of a sense of value linked to their career goals. Due to differences in career positioning and future plans, academic English environment and academic English practice have diverse effects on graduate students. Doctoral students consistently score the highest in each item across the three dimensions of influencing factors. At the master level, factors related to

the academic English environment, such as training requirements, and factors associated with academic English practice, such as work communication and reception, have a more substantial impact on professional master students with a career orientation. This not only indicates the training characteristics of professional master students but also suggests that professional master students in research-oriented science and engineering universities prioritize the utilization of relevant environmental factors to achieve functional goals with a tool-oriented value orientation. The promoting effect of academic beliefs is insufficient. Future research should explore ways to create conditions that help students at different levels, especially professional master students, improve effective strategies for professional cognition and value perception, promoting the transformation between the instrumental and humanistic aspects of academic English literacy.

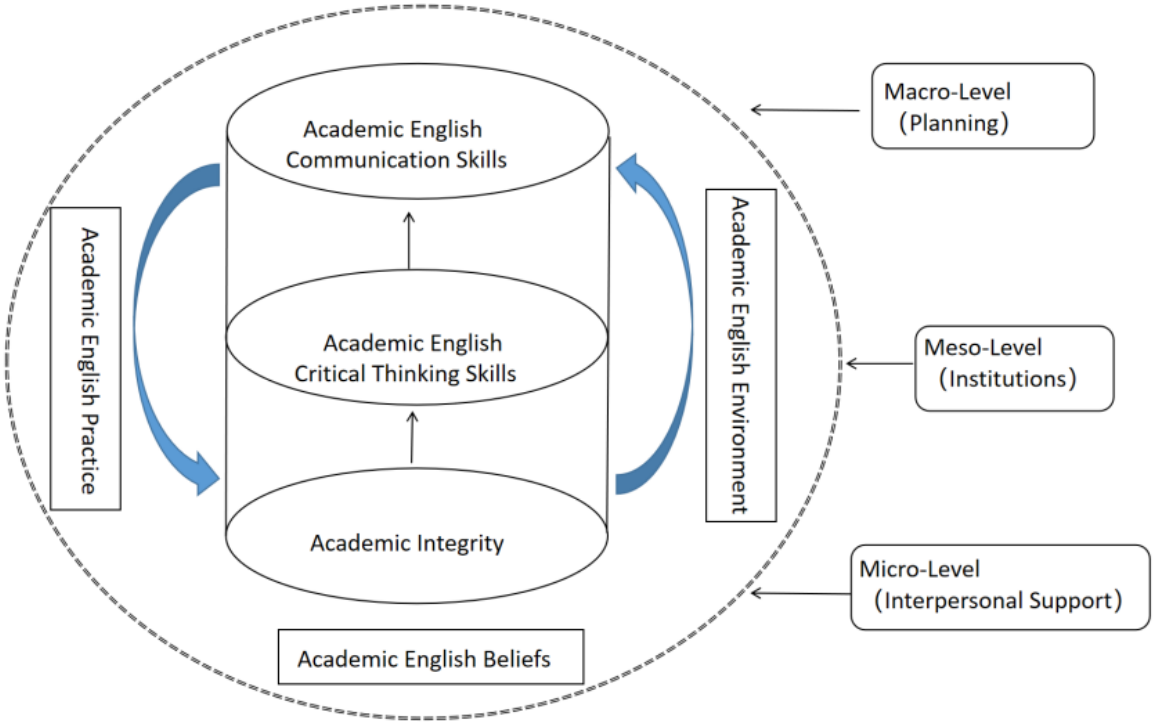

Figure 1 Model of Academic English Literacy for STEM Graduate Students

4 Conclusion

In recent years, the scale of postgraduate education in China has rapidly expanded, entering a crucial phase of development [16]. The imperative of enhancing the academic language literacy of postgraduates and elevating the quality of postgraduate education is a critical challenge in contemporary postgraduate education. This study, grounded in the current landscape of academic English teaching for STEM graduate students and the necessity to augment their academic English literacy, puts forth the following recommendations across the dimensions of values, content, and execution planning.

Firstly, at the macro level, we need to fortify the strategic planning and design of academic English literacy for STEM graduate students, establishing an overarching institutional framework conducive to the cultivation of academic English literacy. To be specific, we should advocate a language resource-centric approach, recognizing academic English as a pivotal strategic asset for the internationalization of science and technology and postgraduate education in China. In the content planning dimension, we should revamp the foreign language education planning system, suggesting a revision of the existing curriculum based on the actual state of English teaching in China and the demands of scientific and technological development and higher education. This entails constructing a science and engineering academic resource library by subject and establishing cross-school science and engineering academic English research platforms, providing macro-level guidance for the public English teaching of postgraduates concerning content, class schedule, teaching objectives, etc. In the execution

planning dimension, we should propose the creation of a conducive institutional environment, offering resources for postgraduate international exchanges, internationalizing academic English teachers for postgraduates, and fostering interdisciplinary development. This opens up avenues for individuals to pursue international development through academic English literacy.

Secondly, at the meso level, we need to amplify the role of universities as implementing institutions. Suggested actions include establishing a science and engineering academic English teaching and research system, creating a conducive academic English practice environment. In the content planning dimension, the study recommends refining the teaching and research system by enhancing the academic English curriculum, establishing teaching resource platforms, emphasizing the transformative role of academic English knowledge and skills, creating teaching and research platforms in collaboration with various departments and training departments, shaping a supportive institutional environment, and providing foreign language services for the international cultivation and academic exchanges of universities. Additionally, we need to actively engage in the process-oriented, resource-oriented, and institutional planning and construction of science and engineering graduate education. Suggested actions include establishing academic English support centers in universities with the required conditions, organizing simulated international academic conferences, facilitating collaborative learning between domestic and foreign postgraduates, reforming the academic English assessment system, and adopting a postgraduate academic evaluation system that fosters international academic development.

Finally, at the micro level, with the goal of enhancing the academic literacy of postgraduates, we need to recognize academic English literacy for STEM graduate students as a foreign language resource. Furthermore, we should build interpersonal resources for the development of academic English literacy for them, reinforce their academic English beliefs, ignite their subjectivity, encourage active practice, and effectively leverage favorable factors in the environment. In addition, we can consider leveraging the collaborative efforts of postgraduates, academic English teachers, and planning implementation individuals. Most importantly, creating a conducive micro-level interpersonal support environment, generating interpersonal resources for the development of academic English literacy for STEM graduate students can contribute to the enhancement of their academic English literacy.

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Biography

Qian Wang

Born in 1981, Associate Professor, Doctor. Her research interests focus on cognitive linguistics, psycholinguistics, and foreign language education.

E-mail: wangq@nwpu.edu.cn