Supporting Mathematical Communication for STEM Students through Open-Access Resources: A Case Study at SWJTU-Leeds Joint School

Introduction

Across countries and academic fields, many institutions of secondary and tertiary education are using English as the medium of instruction. This applies to contexts where English is the native language of teachers and students, but also where English is a second, third or subsequent language to those learning at the institution. Considering non-native English-speaking students of STEM degrees, various points of concern emerge. While mathematics is often considered a universal language universally understood to those in the field, the same cannot be assumed for the process of learning mathematics (Nijku, 2025). Comprehensive communication is needed to acquire mathematical knowledge and for students to be able to communicate mathematics themselves. Important mathematical skills like reasoning, explaining, analysing and outlining arguments are rarely represented purely in mathematical notation and for students learning mathematics it is crucial to understand the concepts behind the notation as well as to possess the English academic vocabulary used to describe and explain them (Lombardi, 2021). This research will explore the linguistic challenges students from linguistically diverse communities experience when studying STEM degrees with English as the medium of instruction. The specific focus of the research is students studying at the Southwest Jiaotong-Leeds joint school in Chengdu, China and their specific challenges. Furthermore, the research will consider whether *The Academic Language of Mathematics* open access book address those challenges and how it can attempt to solve or lessen the challenges that the students experience.

Context

The Southwest Jiaotong-Leeds joint school is a transnational education (TNE) partnership between the University of Leeds and Southwest Jiaotong University, delivering Leeds engineering programmes to students at the SWJTU campus in Chengdu, China, with English as the medium of instruction (EMI).

Students from Joint School who were attending the Leeds International Summer school were invited to participate in the research and to share which linguistic challenges they meet as SWJTU-Leeds Joint school students as well as their experiences using *The Academic Language of Mathematics* open access book to overcome these challenges. The students were already familiar with the book as it had been used in some of their classes at the Joint School, therefore their first-hand experiences with the book were valuable to evaluating its effectiveness. All

participants were first- or second-year students studying a Bachelor of Engineering at the Joint School with English as the language of instruction. Prior to university, the participants have completed the Chinese national high school degree Gaokao, where the language of instruction is Mandarin Chinese.

Aims and research questions

The aim of this project is to evaluate the linguistic challenges faced by students in STEM degrees in The Southwest Jiaotong University-Leeds Joint School and how *The Academic Language of Mathematics* open access book address those challenges.

Research Questions:

- What linguistic challenges do SWJTU-Leeds Joint School students face when learning mathematics in English?
- How can our open-access book address these challenges?

Ethics approval has been obtained for this project. Ethical review reference number: FREC1947 (University of Leeds)

Methodology

The research was conducted in two main parts, a focus group followed by an intervention. The purpose of the focus group was to get accurate first-hand information from the students on the linguistic challenges they meet as Joint School students and how they experienced that the book addressed those challenges. The contents of the focus group were then used to facilitate the intervention which consisted of a mock class with activities intended to address the challenges expressed in the focus group, a questionnaire and a homework task completed by the students before and after the mock class.

To get accurate results it was crucial to the project that the participants would share their thoughts and opinions openly and honestly. Therefore, the project had to be conducted by someone that did not inflict any power dynamics and had no conflict of interest with the book or the students' home university. Considering this, the project was carried out by a Laidlaw scholar from The University of Hong Kong who had no connection or contact with the participants prior to commencing the project. This attempted to alleviate power-imbalances that might have occurred if the project was conducted by a teacher or any author of the book, resulting in open conversations where the students shared both positive and negative opinions and thoughts on their experiences with linguistic challenges at the Joint school and with the book.

Focus group

The first part of the project was the focus group. The aim was to gather qualitative information on what challenges the students at the Joint school face and to what extent *The Academic Language of Mathematics* open access book enables them to solve those problems. The focus group lasted 60 minutes and it consisted of 6 students from the Joint School, five of which had studied one year, and one participant who had studied two years at the university at the time of the focus group.

The participants were randomly seated in a semi-circle facing the camera with the moderator placed in the middle between them. All participants had received guiding questions beforehand along with the participant information sheet and the consent form. The moderator asked the guiding questions as well as eventual follow-up questions. Participants were encouraged to discuss freely to share any thoughts or experiences related to the questions.

The focus group was recorded and transcribed to facilitate analysis. The video was used to differentiate between individual students to ensure that data from all participants was included in the analysis. All participants were anonymised, and any identifiable information was not included in the analysis or the report.

Analysis

The data was analysed using thematic analysis. The following themes were identified to be reoccurring and distinct linguistic categories expressed by participants as challenging or problematic.

- **Vocabulary:** including struggles with recognizing, learning and remembering English mathematics vocabulary and using the vocabulary in a mathematics context.
- **Notation**: including struggles with recognizing, learning and using mathematics notation and the ability to connect it to the proper definitions.
- **Speaking:** including struggles with producing English speech, comprehending English speech, confidence and willingness to communicate in spoken English.
- **Writing**: including struggles with producing English writing, comprehending English writing and recognizing and producing different forms of text in English.

Quotes from the focus group transcript pertaining to these four themes were arranged into columns to better visualize the weight of each theme. Some representative quotes are shown below.

Vocabulary	Notation	Speaking	Writing
"Some vocabulary, like *proportional,* if you don't know its meaning you cannot finish the task" "Some things I have learned in Chinese, but I'm not clear about it in English" "Academic words are very easy to forget."	"It is easy to forget our understanding of the formula," "To remember the formula (...) you will remember right now, but after several weeks [I] forget what it is in detail"	"If we ask them questions, we still cannot understand the answer " "I can't express clearly, especially in English" "You might feel embarrassed and afraid to speak out" "Group discussion will turn into silence or Chinese."	"I'm having some troubles to write linking words" "Teachers are writing on the blackboard and after, we just take a photo and then pretend we know it."

Findings of the focus group

In the analysis, all four themes were apparent and expressed by all or most participants in the focus group. Especially apparent was the struggles with speaking. All six participants expressed that they have met struggles comprehending or producing spoken English often when communicating with a teacher or lecturer. They suggested that these problems were likely due to lack of confidence, low English proficiency, unwillingness to communicate in front of their peers as well as teachers' accents or speed of talking. This theme was the most evident source of struggles, and was repeatably expressed by all participants. Some participant expressed that they regularly meet challenges relating to spoken communication and that they sometimes avoid asking teachers for help or contributing to class discussions in English.

> *" I mean, the students talk and talk, but suddenly they speak Chinese."*
> Student 1 on group work and communicating with peers.

> *"Even if we know what he's talking about, in this fast speed, no one knows what he is saying."* Student 4 on understanding teachers.

Less prominent, but still evident as a source of struggle was the theme of vocabulary. Most of the participants expressed that they either currently or in the past have met struggles with

learning or retaining mathematics vocabulary in English, yet they also expressed that struggles with vocabulary are easier to solve since they usually have access to a digital dictionary except during exams. Most students showed strong non-verbal signs of agreement when others were expressing difficulties with vocabulary.

"Some things I have learned in Chinese, but I'm not clear about it in English." Student 3 on linguistic struggles in class.

Struggles surrounding notation and writing were expressed by some participants, but not as prominently as struggles surrounding speaking and vocabulary.

"I'm like having some troubles to write some linking words, to show my logic, but sometimes it's difficult to explain it accurately." Student 6 on explaining ideas.

The students mentioned that when they meet language-related challenges regardless of the theme, they will likely try to solve it with artificial intelligence or by self-studying the material due to these methods being more reliable, convenient and not having to communicate with others.

Other than the language-related themes, another theme appeared when analysing the focus group, although this theme is outside the scope of this report since it is not a direct linguistic challenge. All participants mentioned to varying extents, struggles with learning strategies, and study environment. This included difficulties focusing and retaining knowledge due to various environmental factors, like noise or crowded rooms, and dissatisfaction with learning styles of the university courses. This is worth noting since experiencing language-related challenges might make the students more sensitive to environmental and teaching related challenges since they already struggle with communicating or understanding content, making them more prone to avoid communication-heavy learning settings or environments.

In summary, the linguistic challenges that the students expressed can be sorted into four themes; *vocabulary, notation, speaking and writing*. Most prominent was the theme *speaking* with all students expressing difficulties to varying degrees. Second most prominent was the theme *vocabulary*, which mentioned less by the students, but widespread agreement sustained when challenges of this nature were mentioned. Lastly, challenges surrounding *notation* and *writing* were similarly evident in the focus group and were mentioned by some students.

The intervention

The intervention was arranged to address the struggles that became apparent in the focus group analysis and to test possible applications of the book in a real-life context. This consisted of a 90-minute mock class along with a pre-class homework task, a post-class homework task, and a questionnaire for the students to complete. The purpose of the questionnaire was to gather information from the students on how the mock class addressed the problems they meet as students and whether they found the activities beneficial to their learning. The pre- and post-class work focused on speaking and was arranged to see if there was any evidence of improvement of the students' speaking skills when comparing the tasks from before and after the class.

Mock class

The participants of the mock class were 4 students who were also present in the focus group. The mock class was an opportunity to implement activities that responded to linguistic challenges the students had expressed in the focus group. Each activity was carefully chosen to address one or multiple themes from the focus group analysis (vocabulary, notation, speaking, or writing.) The mock class content was taken from Chapter 6: Vectors and Coordinate Systems in *The Academic Language of Mathematics* open access book and either used directly as proposed in the book or with minor changes. The mathematical content was not the focus of the class but rather improving the students' linguistic skills and addressing the challenges brought up in the focus group. All activities were chosen, so they best addressed the challenges that arose from the focus group bearing in mind the relative prominence of each theme. Therefore, spoken communication was the most prioritized theme in the mock class to accurately affect the needs of the students. The whole mock class was conducted without the use of the students' personal computers or other individual electronic advice to ensure AI or other electronic tools were not used to get the most accurate judgement of their learning process and current level.

Description and purpose of each activity:

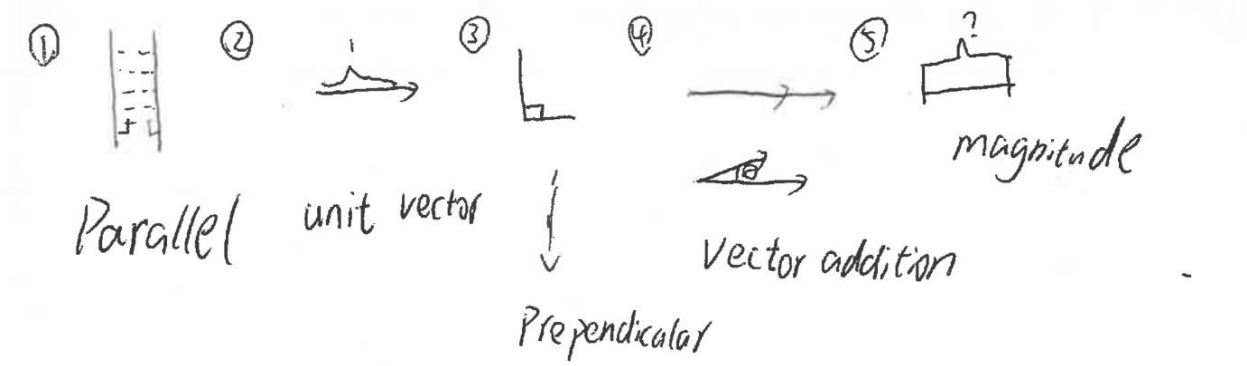
Activity 1) Matching paper cut-outs with technical terms and their respective definitions. Relevant theme(s) of linguistic challenges: vocabulary.

In the first activity, the students were split into pairs and given nine sets of technical terms {vector, dot product, modulus, coordinate system, unit vector, cross product, perpendicular, parallel} and corresponding definitions all relating to the content of section 6.1 in *The Academic Language of Mathematics* open access book, and they were instructed to match the correct

terms and definitions. The sets of terms and definitions were printed on paper to enable the students to work in pairs as well as to limit distractions and to prevent students from using digital tools or dictionaries. The students were encouraged to communicate in English within the pairs, yet they tended to speak in Chinese which is why this activity is not considered to address the linguistic theme of speaking. This activity made the students more familiar with common terms from mathematics and exposed them to the proper spelling and pronunciation of all the terms.

Activity 2) Visualizing mathematical concepts.
Relevant theme(s) of linguistic challenges: vocabulary.

The students were provided with a list of five mathematical concepts {parallel, unit vector, perpendicular, vector addition, magnitude} chosen from section 6.3 of the book, and they were instructed to visualize each of the five concepts on paper. This allowed the students to conceptualize the words and to consider how to communicate the essence or effect of the terms. Afterwards, they attempted to match their neighbours' drawings to the correct terms and discussed first among themselves, then in the class, whether they managed to correctly match the concepts and which considerations they had while completing the task. The purpose of this activity was for the students to not only understand the terminology in isolation but to connect it to concepts they already know. Below is an example of how a student executed the activity.



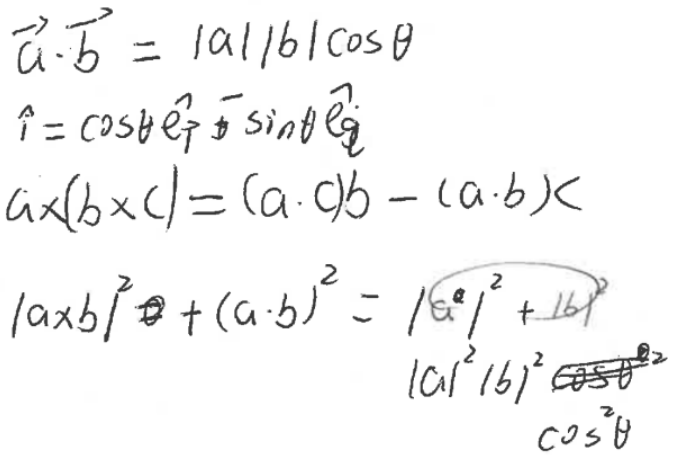
Activity 3) Reading equations aloud.
Relevant theme(s) of linguistic challenges: speaking, notation.

The first activity from section 6.4 of the book was shown on the classroom screen and the students practiced in pairs reading the equations aloud in English. After a few minutes, the students took turns reading the equations aloud in the class, whereafter the correct answers were shown, and any mistakes or questions were addressed. The purpose of this activity was to

familiarize the student with how equations and notation is represented verbally, so they become better equipped to discuss mathematics with peers or ask questions in class. Additionally, the students spoke in front of the whole class in a low-pressure environment, allowing them to build their confidence.

Activity 4) Recognizing notation in speech and writing it down.
Relevant theme(s) of linguistic challenges: speaking, notation.

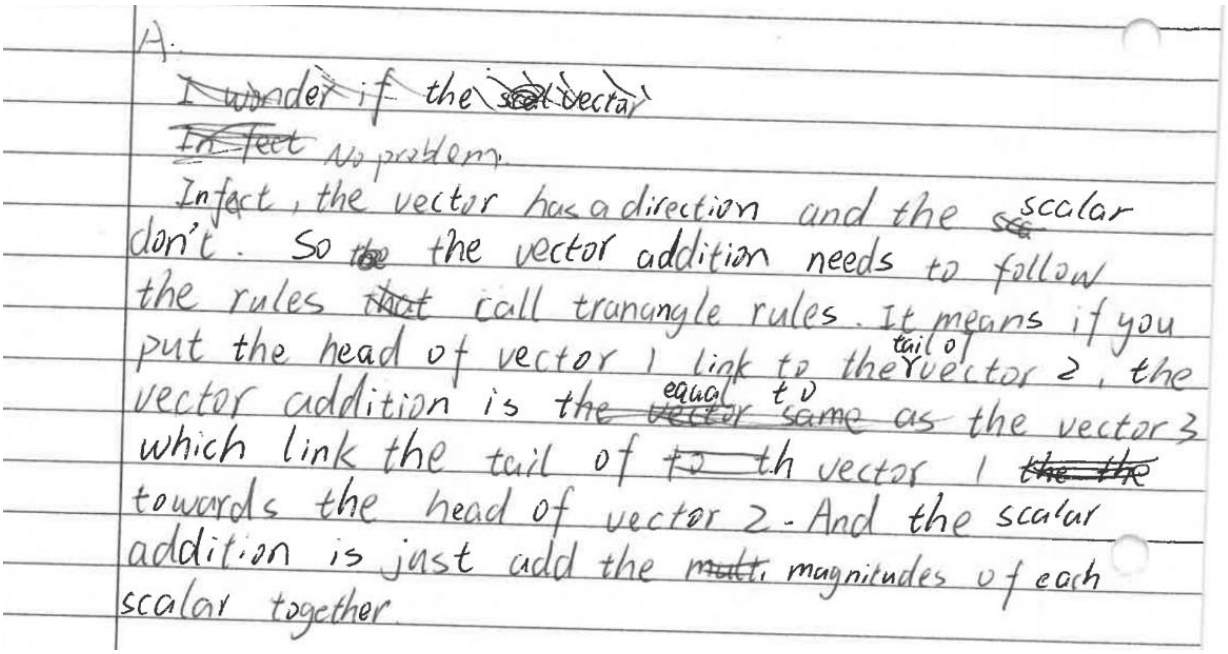
Activity 4 is the opposite of activity 3, where the teacher reads four equations aloud and the student attempts to write it down in the correct notation. All four equations are from the second activity in section 6.4 of the book but adapted, so the students had to identify the equation from speech as opposed to writing. After all four equations were read aloud the answers were shown on the classroom screen and the students were encouraged to ask any questions they had. With this activity, the students learn to identify mathematics equations from speech and to formalize them in writing. Below is an example of how a student executed the activity.



Activity 5) Writing in different text forms.
Relevant theme(s) of linguistic challenges: writing.

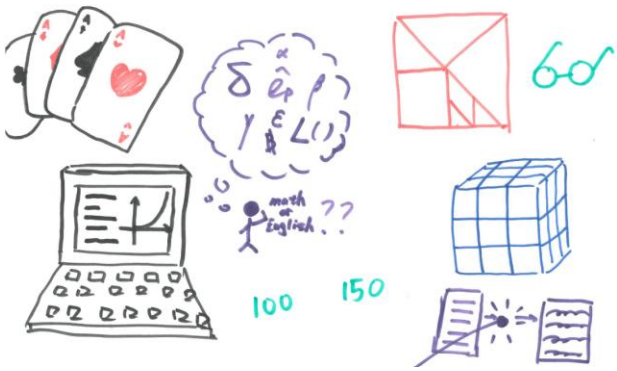
In each pair, the students were divided into student A and student B. Student A from each pair were instructed to write a WeChat response to a friend asking them to explain the difference between vector addition and regular addition. Student B was instructed to answer a simulated exam question where they need to outline the effect of vector addition and its difference to real number addition. The students were also prompted to consider how these texts differ in format, as well as appropriate formality and level of technicality. After writing, student A and

student B of each pair read each other's writing and gave feedback. Lastly, the students had to mention one thing to the class that they had done to fit the appropriate format. This familiarized the students with common ways of communicating mathematical knowledge and compelled them to consider how to communicate the content in a clear and accurate way. Below is an example of how a student executed the activity


A.
I ~~wonder~~ if the ~~scal~~ vector
~~In fact~~ No problem.
In fact, the vector has a direction and the scalar don't. So ~~the~~ the vector addition needs to follow the rules ~~that~~ call tranangle rules. It means if you put the head of vector 1 link to the tail of vector 2, the vector addition is the ~~vector~~ same as the vector 3 which link the tail of ~~to~~ th vector 1 ~~the the~~ towards the head of vector 2. And the scalar addition is just add the ~~multi~~ magnitudes of each scalar together.

Activity 6) Creating and presenting posters on mathematics
Relevant theme(s) of linguistic challenges: speaking.

In pairs, the students were instructed to create a poster on a A3 piece of paper to the prompt: that do you think of when you think of math. Afterwards each pair presented the posters they had made in around 2 minutes. The purpose of this activity was to get the students to talk English for a longer period of time without worrying about difficult mathematics content. It also let the students reflect on their perspective of mathematics and share their personal opinions in English instead of only mathematics content. Below is an example of how a pair of students made their poster.



Evaluation of the mock class

A questionnaire and a comparative analysis of the pre-class homework and the post-class homework were used to evaluate the relevance of the intervention. Immediately after the mock class, students were encouraged to answer a questionnaire with questions regarding their own perception of the class. Additionally, the pre-class homework and post-class homework were compared and analysed to see whether any changes in the students' English communicative skills appeared.

Questionnaire

After the mock class, the students were encouraged to submit a questionnaire with feedback on the class. All four students responded. The questionnaire had a total of eight questions and was a mixed-methods approach consisting of both quantitative questions and qualitative open-ended questions. For quantitative questions the possible answers were designated numerical values from one to five to quantitively analyse the answers.

The students strongly agreed that the mock class addressed the language related challenges they meet in mathematics class as a SWJTU-Leeds student (Average: 4.5, 1= strongly disagree, 5= strongly agree.) Activities 1, 3 and 5 were emphasized by the students as activities that addressed the challenges, they meet studying math at SWJTU-Leeds.

All 6 activities of the mock class were evaluated by the students to be effective in helping them through the language related challenged they meet as a SWJTU-Leeds student (Averages range: 3.5-4, 1= really ineffective, 5= really effective) and the students also reported that they feel much more confident in communicating mathematics after the mock class (Average: 4.5, 1= I feel much less confident, 5= I feel much more confident). Activities focused on spoken communication and English pronunciation were explicitly highlighted to be the most helpful in developing their ability to confidently communicate English.

Lastly, the student reported that they would like to have similar activities to the mock class implemented into their own university education (Average: 4.75. 1= definitely no, 5= definitely yes). When prompted to consider how these activities could be best implemented in their university curriculum they proposed for the lectures to integrate activities into their regular classes, or to provide the students with tools to accommodate the possible linguistic challenges they may face at the beginning or in the middle of the semester.

Overall, the students reported that the activities based on *The Academic Language of Mathematics* open access book efficiently addressed the challenges they meet as SWJTU-Leeds

Joint school students and that the mock class was helpful in developing their confidence to communicate mathematics in English.

Pre-class and post-class homework task

Before the mock class the participants were put into pairs and instructed to record a 1-minute verbal exchange, wherein they take turns explaining and describing something they find challenging in mathematics and afterwards providing feedback and comments. After the mock class the participants got the same task to complete. The purpose was to analyse the speech of the recordings rather than the content to judge whether the mock class caused any visible changes to the participants' confidence, clarity, speed of speaking, sentence structure or other linguistic elements of speech.

2 pairs completed the pre-class task, and 1 pair completed the post-class task. After analysing and comparing the pre-class and post-class tasks no significant and sustained change is apparent. Furthermore, the students were not able to complete the pre-class homework, and the post-class homework in the same pairs due to absences, and since the students vary in confidence level and English proficiency inconsistencies and skewed results might occur. Considering this, the small sample size, the comparison of the pre-class and post-class homework is inconclusive in evaluating an improvement of the participants' English proficiency.

Conclusion

STEM degree students of the Southwest Jiaotong-Leeds Joint school expressed that they experience several linguistical challenges when studying mathematics in English, most notably struggles around producing and comprehending spoken communication in English as well as English academic vocabulary. Various activities found in or inspired by *The Academic Language of Mathematics* open access book were implemented and evaluated as successful tools to address the linguistic challenges that the students face.

Limitations

A limitation of the project is the number of participants. Six participated in the focus group and four in the intervention. A year group at The Joint School is around 500 students so our sample is perhaps not representative of the general experience of a Joint School first year student. This is due to various logistic factors. It was necessary that participants studied a STEM degree at the Joint School in Chengdu and that they were physically present in Leeds at the time of the project. Only students who attended the summer school during the same time were able to participate in the project, therefore it was not possible to increase the number of participants.

Lastly, this project was executed in relation to the Laidlaw scholar's programme which is limited to 6 weeks. Further research, data gathering and analysis would be appropriate if the project had continued on for an extended period of time.

Future work

More research is needed on the linguistic challenges of linguistically diverse communities in EMI education. Research could not only consider STEM contexts, but other academic fields as well as challenges might vary in nature and relevance across different fields. Furthermore, future research could also explore cultural and social challenges that non-native English-speakers experience in EMI institutions, and how this affects their learning process and overall experience. Since English is one of the most widely used languages in educational institutions (Nijku, 2025) it is increasingly relevant to research the challenges, and proposed solutions for non-native speakers. Future work could very well also consider other common languages of means of instructions as French, Spanish or Mandarin Chinese which to varying degrees also are the mediums of instruction in non-native areas and communities. The research might find that similar challenges emerge as compared to English or significantly different challenges emerge, both of which would be relevant to providing more accessible education in linguistically diverse communities.

References

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