Predicting content proficiency through disciplinary-literacy variables in English-medium writing

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ARTICLE INFO

ABSTRACT

The debate on the roles of language and literacy in the increasingly internationalised university contexts where disciplinary content is taught through the medium of English has been a matter of recent research concerns. Despite the limited focus on language and literacy in English-medium instruction (EMI) programmes, there is currently increasing recognition of the need for explicit awareness of subject-specific language and literacies to favour content learning. However, there is a paucity of empirical research that measures the impact of students' disciplinary language and literacy skills on content achievement in EMI contexts. To address this issue, this paper analyses the relationship between the use of disciplinary-literacy variables related to the genre and specialized-language features of the laboratory report at the levels of text structure, cohesion, grammar, and vocabulary, and students' content proficiency in English-medium writing in a Spanish undergraduate setting. Results show a positive relationship between the frequency of occurrence of certain disciplinary-literacy variables and students' content proficiency. In particular, moves, cohesive devices, technical words, and passive voice appear as significant indicators of content proficiency in English-medium laboratory report writing. These findings strengthen the need to provide students with subject-specific language and literacy support for successful academic development in EMI courses.

1. Introduction

The global higher education system has undergone an increasing internationalisation process since the advent of the 21st century. The number of student and staff mobilities and the international collaboration among universities have skyrocketed in the last two decades, becoming mainstream in the strategy agendas of higher education institutions (HEI) worldwide. As a response to this internationalisation process, a myriad of non-languagerelated university courses taught through an additional language has burgeoned in the last decade across higher education syllabi. Most of these have been developed in the form of Integrating Content and Language in Higher Education (ICLHE) programmes (Valcke & Wilkinson, 2017) and, especially, through English-medium instruction (EMI) courses, due to the prevalence of English as the main common language of communication in most internationalised university settings of non-Anglophone countries (Macaro, 2018; Wächter & Maiworm, 2014). While both ICLHE and EMI refer to the teaching and learning of disciplinary content through the medium of a foreign (FL) or a second language (L2), there are significant conceptual differences between these two approaches. The former refers explicitly in its acronym to the integration of both content and language, which implies that this model

considers somehow the learning of disciplinary content and the acquisition of the language of instruction concurrently. However, EMI programmes are primarily concerned with content learning and they rarely include English language learning goals (Dafouz & Smit, 2016, 2020; Mancho-Barés & Aguilar, 2016; Schmidt-Unterberger, 2018). The rapid implementation of such programmes across universities has brought many challenges both for lecturers and students, notably pertaining to the development of the English language (Doiz & Lasagabaster, 2020; Macaro, 2020), literacy skills (Airey, 2011, 2012; Breeze & Dafouz, 2017; Dafouz, 2020; Lyster, 2017, pp. 7−14), and content achievement (Dafouz & Camacho-Miñano, 2016; Graham, Choi, Davoodi, Razmeh, & Dixon, 2018; Rose, Curle, Aizawa, & Thompson, 2019), among others.

The debate on the role of language in EMI programmes, where the principal objective is to learn disciplinary content, has continued for the last decade and is still the topic of current research concerns (Airey, 2020; Block & Moncada, 2019; Lasagabaster, 2018; Lyster, 2017; Macaro, 2020). Despite the broad consensus about the benefits of providing students with English language and literacy support for successful academic development (Airey, 2011, 2012; Bazerman et al., 2005; Rose & Martin, 2012), this provision is rather infrequent in EMI higher education settings (Airey, 2012; Breeze & Dafouz, 2017; Costa, 2012; Dafouz, 2020). Some of the reasons reported by the literature for this lack of provision include, among others, the generalized supposition that students already have the necessary English language skills (Dafouz & Smit, 2016, 2020; Wilkinson, 2018); the reluctance to take responsibility for language-related issues on the part of EMI lecturers due to an assumed lack of expertise, pedagogical training, or time (Costa, 2012; Pavón & Gaustad, 2013); or the widespread assumption that these issues fall somewhat beyond content lecturers' teaching competence (Airey, 2012; Fortanet-Gómez, 2013; Lyster, 2017).

In contrast to northern European contexts, where writing development has been addressed extensively in higher education research (Rienecker & Jørgensen, 2013), this language productive skill has generally received little attention in EMI research in southern Europe, particularly in Spain (but see Dafouz, 2020, and Breeze & Dafouz, 2017 for a recent account of writing in a Spanish EMI higher education context).

Report writing is a common task of knowledge and skill development, being the laboratory report, the written text analysed in this study, the most common academic text genre within the fields of science and engineering (Parkinson, 2017a). Generally, very few students are acquainted with the specialized-language and discourse features of academic genres before entering university, which entails serious difficulties when it comes to the writing of these texts, especially in an L2 (Wingate, 2015). Consequently, EMI students need to develop disciplinary literacy in English in parallel with disciplinary content learning (Airey, 2011), which involves learning to use the specialized genres, discourses, and registers of their discipline appropriately (Bhatia, 2004).

Despite the limited focus on English language and literacy in EMI contexts, there is currently increasing recognition of the need for explicit awareness of academic language and of the importance of including subject-specific literacies into subject-learning curricula to support content learning in EMI programmes (Airey, 2020; Breeze & Dafouz, 2017; Lyster, 2017; Rose & Martin, 2012). While there are numerous studies addressing the relationship between English language proficiency and academic performance, mainly in L1 academic contexts (Cho & Bridgeman, 2012; Graham, 1987; Huong, 2001; Light, Xu, & Mossop, 1987; Woodrow, 2006), there is a dearth of empirical research that measures the impact of students' disciplinary language and literacy skills on content achievement in EMI settings (but see Van Dyk, 2015, for an account of the use of academic literacy tests as predictors of academic success in a South African multilingual context). Indeed, the relationship between students' English language and literacy skills and content outcomes appears as a major research lacuna in EMI studies (Graham et al., 2018; Lyster, 2017; Macaro, Curle, Pun, An, & Dearden, 2018; Rose et al., 2019). To fill this gap, this paper analyses the relationship between the use of disciplinary-literacy variables and content proficiency in English-medium writing. In particular, it examines whether Spanish undergraduate students whose written texts show a higher frequency rate of certain linguistic variables suggested by the literature related to the genre, discourse, and register features of the text under analysis (i.e., the laboratory report) get higher marks when they are assessed by virtue of content proficiency. This study may influence EMI content specialists, curricular planners, and university administrators' awareness of the significant roles of disciplinary literacy and subject-specific language for students' successful academic development in English-medium courses, an issue that has often been overlooked in these contexts (Airey 2011, 2012; Fortanet-Gómez, 2013; Lyster, 2017; Sert, 2008).

2. Background

2.1. Disciplinary literacy in EMI

Learning at tertiary level is a complex endeavour that has frequently been related to the arduous task of decrypting an encrypting an intricate disciplinary code (Middendorf & Pace, 2004). Indeed, many of the challenges encountered by university students have been attributed to the use and interpretation of the specialized communicative practices of their discipline (Säljö, 2010). Airey (2011) refers to the ability to participate in such communicative practices appropriately as disciplinary literacy. This concept is defined as the "knowledge and abilities possessed to by those who create, communicate, and use knowledge within the disciplines" (Shanahan & Shanahan, 2012, p. 8), which implies the ability to recognize and use the academic genres, discourses, and registers of a particular discipline (Bhatia, 2004).

While the concern about the development of disciplinary literacy is certainly important in L1-medium teaching contexts, it acquires extra relevance in EMI programmes, where students learn disciplinary content through a non-native language

(Airey, 2012). In EMI contexts, students are developing disciplinary competence and English language competence concurrently (Breeze & Dafouz, 2017), which renders the process of disciplinary literacy development even more challenging.

The question on how, where, and when disciplinary literacy should be addressed in EMI contexts remains particularly controversial, especially when discussed with content specialists (Airey, 2020; Lyster, 2017; Mancho-Barés, Arnó-Macià, Moncada, & Sabaté-Dalmau, 2019). The well-renowned assertion "I don't teach language, I teach physics" by a content lecturer in a Swedish EMI university context (Airey, 2012, p. 74) fairly illustrates content lecturers' widespread reluctance to take responsibility for language and literacy-related issues in their EMI lessons, either because they do not have sufficient time nor expertise to focus explicitly on discipline-specific language use (Costa, 2012; Dafouz, 2020; Hyland, 2006; Lasagabaster, 2018; Pavón & Gaustad, 2013; Schmidt-Unterberger, 2018), or because they consider that language and literacy-related issues fall somewhat beyond their teaching competence (Airey, 2012; Block & Moncada, 2019; Fortanet-Gómez, 2013; Lyster, 2017; Macaro, 2020). However, separating disciplinary language from disciplinary content is rather "difficult, if not impossible" (Lyster, 2017, p. 12). Both EMI content lecturers and students use academic and subject-specific language to teach and learn, and they need such language "to assess and demonstrate learning", respectively (p. 12). Therefore, in order for students to be able to access and demonstrate content learning in EMI courses, they need to acquire and develop specific English language and disciplinary-literacy skills (Airey, 2011, 2012, 2020; Lyster, 2017; Schmidt-Unterberger, 2018).

In most EMI contexts, lessons are taught by content specialists who often have difficulties in ascertaining the disciplinary-literacy needs of their courses due to their non-linguistic expertise (Airey, 2012; Dafouz, 2020; Sánchez-García, 2020). To overcome these obstacles, many scholars have argued extensively on the need for collaboration between content lecturers and language specialists (Airey, 2012; Costa, 2012; Lasagabaster, 2018; Lyster, 2017; Pavón & Gaustad, 2013; Schmidt-Unterberger, 2018) due to the "tools available to these professionals to analyse discourse" and to identify language and literacy needs (Airey, 2011, p. 2). On this basis, and on account of the applied-linguistic nature of this study, this paper aims to provide insights into those disciplinary-literacy variables that can be considered as indicators of content proficiency in English-medium writing through the analysis of laboratory reports written by EMI students.

The current study operates under the premise that disciplinary literacy is intrinsically related to content lecturers' judgements of perceived content proficiency in English-medium writing. As explained above, language and literacy development are rarely included within the learning goals in most EMI courses (Mancho-Barés & Aguilar, 2016; Dafouz, 2020; Dafouz & Smit, 2016, 2020), and assessment is often purely based on students' content proficiency (Nesi & Gardner, 2012; Schmidt-Unterberger, 2018), understood as the demonstrated knowledge of the subject matter (García, 2009). However, testing content proficiency independently of language and disciplinary literacy in English-medium writing seems rather unrealistic (Hyland, 2006). If disciplinary literacy reflects the ability to understand, use, and convey disciplinary content knowledge (Airey, 2011), and thus to recognize and use the genres, discourses, and registers of a particular disciplinary area appropriately (Bhatia, 2004), then content proficiency and disciplinary literacy are inextricably intertwined (Lyster, 2017), and the latter may be a reliable indicator of content proficiency in English-medium writing.

2.2. Linguistic variables as predictors of academic proficiency in L2 writing

In general, appropriate writing has been related to successful academic performance, whereas deficiencies in literacy skills have been recognized as a major indicator of academic failure (Wingate, 2015). Regarding the linguistic variables attributed to academic proficiency in L2 writing at tertiary level, most of the research available to date has focused on the analysis of L2 writing in ESL and EAP contexts, with EMI settings still underexplored. With regards to the former contexts, there are numerous studies about the language and literacy variables attributed to L2 academic writing proficiency at the level of lexicon, syntax, and cohesion, among others (Crossley & McNamara, 2012; Crossley, Roscoe, & McNamara, 2014). Some of the variables predicting L2 academic writing proficiency include lexical diversity and word sophistication (Crossley & McNamara, 2012), syntactic complexity and subordination (Grant & Ginther, 2000; Jarvis, 2002; McNamara, Crossley, & McCarthy, 2010), the use of passive voice (Ferris, 1994; Grant & Ginther, 2000), nominalisations (Connor, 1984; Liardét, 2015), modal verbs (Grant and Ginther; 2000), or cohesive devices such as connectives, conjunctions, demonstratives, hedges, or emphatics (Jin, 2001; Longo, 1994), among others.

While these studies have provided valuable insights into the associations between L2 writing and academic success in higher education contexts where texts are judged by language experts in terms of L2 and writing proficiency, there is a dearth of research into this relationship in contexts where academic performance is primarily assessed by content specialists by virtue of disciplinary content proficiency, such as EMI settings (Breeze & Dafouz, 2017; Rose et al., 2019). Additionally, most of the previous studies on L2 writing have focused on general academic genres, such as essays or question answering, with the laboratory report being rather underexplored in EMI contexts. Consequently, this study uses this text genre to explore the relationship between the use of L2 disciplinary-literacy variables and content proficiency in an EMI context.

3. Research questions

This paper aims to fill an existing research gap by analysing the relationship between the use of disciplinary-literacy variables and content proficiency in English-medium writing, an association which remains underexamined yet amply demanded in EMI research (Lyster, 2017; Macaro et al., 2018; Rose et al., 2019). In particular, it explores whether those students whose written texts contain a higher frequency rate of certain linguistic variables suggested by the literature related

to the genre, discourse, and register features of the text under analysis (i.e., the laboratory report) are judged by content lecturers as more proficient than those whose written texts contain a lower rate of these variables. Concurrently, it seeks to identify those disciplinary-literacy variables that can be considered as significant predictors of content proficiency in English-medium laboratory report writing. To accomplish these goals, the following research questions are addressed:

1. Does the frequency of use of disciplinary-literacy variables related to the genre, discourse, and register features of the laboratory report have a positive impact on students' academic mark in English-medium writing when they are assessed by virtue of content proficiency?
2. Which of the disciplinary-literacy variables analysed at the level of text structure, cohesion, grammar, and vocabulary can be considered as significant predictors of content proficiency in English-medium laboratory report writing?

4. Material and methods

4.1. Setting and sample

This study was conducted at a state-run university from a southern Spanish monolingual region implementing a Multi-lingualism Promotion Plan within its internationalisation strategy. A total of 136 laboratory reports written in English by undergraduate students (49 females and 87 males) following an EMI course between the academic years 2015−16 and 2017−2018 were analysed. Sample selection was made on the basis of the completion of a writing assignment in English as a form of assessment. The course under analysis was Chemistry II, a 6-ECTS course taught completely in English in two non-language-related academic disciplines, i.e., Chemical Engineering ($N = 69$) and Agricultural Engineering ($N = 67$). All students were non-native English speakers in their 2nd and 3rd year with an average age of 20. They had an English language level of an independent user (B1−B2) according to the Common European Framework of Reference for Languages (CEFR) upon entrance. The course was taught jointly by the same lecturers during the whole period of analysis. They were two Spanish-native content lecturers with 5- and 10-years' experience in EMI, respectively.

The written text analysed was a specific academic text genre of the students' area of knowledge (i.e., engineering). Students were asked to write a laboratory report in English including all the steps, procedures, and results obtained after conducting an experiment in the laboratory. The writing task was part of the assessment procedure to pass the course and it was completed in class during 2 h with no language support materials.

Through a personal interview, the content lecturers informed the author of the language and writing instruction provided to the students to perform the writing task, and of the criteria to assess the written laboratory reports. According to the lecturers, students had had access to a series of lab report examples in English similar to that of their writing assignment throughout the course, although no explicit instruction on the writing of such text genre was given. Only some lists of specialized vocabulary related to laboratory materials and techniques had been provided. Regarding the assessment criteria, these included: a) correct primary data and calculations, b) correct final results, c) appropriate use of the laboratory methods and materials, and d) clear writing. Each criterion was scored from 1 (lowest mark) to 10 (highest mark), the final academic mark being the average of the four scores. When the lecturers were asked to provide further details about the last criterion (clear writing), they responded that students' writing should be sufficiently intelligible and clear in terms of demonstrated content knowledge, but that English language competence would not be assessed as it was not included within the course teaching objectives. Students' writing was therefore assessed by virtue of content proficiency, and language and literacy issues remained of secondary importance, as in most EMI contexts (Airey, 2012; Dafouz, 2020; Dafouz & Smit, 2016, 2020; Schmidt-Unterberger, 2018).

The researcher contacted the content lecturers in 2018 and the latter were not aware of any research being carried out during this period. Therefore, there were no differences in the way the lecturers taught the course or in the assessment of the written texts that might have affected the students' outcomes over these years. The lecturers provided the researcher with all the students' written texts at one time, although they all belonged to different students who completed the course during the aforementioned academic years. Therefore, the whole sample was considered as a unique corpus and there was no control for differences in the year cohorts.

In order to guarantee the confidentiality and anonymity of the participating students, the EMI course lecturers were asked to provide the author with the students' written texts with no reference to their name or contact details. Instead, students' details were replaced by the following data: student number, gender, age, nationality, and certified English language level. Only the texts written by students with a B1−B2 certified English language level were selected for analysis to eliminate possible confounding variables related to English language proficiency affecting results (Rose et al., 2019).

4.2. Variable selection

This paper explores the relationship between the use of disciplinary-literacy variables and content proficiency in English-medium writing. In this study, disciplinary-literacy variables are referred to as the linguistic elements related to the genre, discourse, and register features of the text under analysis (Bhatia, 2004), i.e., the laboratory report. The analysis of the

variables follows a double-pronged approach combining the methods framed within the spectrum of the English for Specific Purposes (ESP) tradition, namely genre analysis (Bhatia, 1993; Swales, 1990) and specialized-language analysis (Alcaraz, 2000). Based on the theoretical suggestions and research findings regarding the genre and specialized-language features of the laboratory report, a series of variables at the level of text structure, cohesion, grammar, and vocabulary were pre-defined for their subsequent analysis. The following sections provide a detailed description the variables at the different levels of analysis and the rationale for their inclusion.

4.2.1. Text structure

Text structure refers to the organisational format of a text. In can be classified into primary and secondary structure (Alcaraz, 2000). The former (also known as macrostructure) includes a series of protocolized sections which comprise the main text organisation, whereas the secondary structure is formed by moves, the constituent parts of each section defined as functional units with specific communicative purposes (Biber, Connor, & Upton, 2007). Macrostructure and move analysis are the most common models used to analyse academic and specialized text genres (Swales, 1990). The structure of the laboratory report has recently been explored in relation to that of the profoundly investigated research article due to their similarity (Nesi & Gardner, 2012; Parkinson, 2017a). In her analysis of 60 laboratory reports written by highly-graded students from the British Academic Written English (BAWE) corpus, Parkinson (2017a) found that all the laboratory reports had the four Introduction-Methods-Results-Discussion (IMRD) sections considered as standard in research articles, except those specifically related to the field of engineering, which also had an abstract and a conclusion section. Additionally, she labelled the moves that appeared in 80% or more of the reports analysed as obligatory, those found in more than 50% of the sample as usual, and those found in less than 50% of the sample as optional. This study considered the sections and moves identified by Parkinson as obligatory and usual as the variables at the level of text structure for the analysis of the laboratory reports written by the EMI students (Table 1), as they are deemed the standard required in proper laboratory report writing (Parkinson, 2017a).

4.2.2. Cohesion

The term cohesion in this study is used to refer to the link between information and ideas that allows for coherent discourse development (Halliday & Hasan, 1976; Louwerse, 2004). The variables at this level of analysis were selected from the metadiscourse model for L2 academic writing proposed by Hyland (2010), formed by interactive and interactional resources. The former include the resources used by writers to manage the flow of the information and to deliver a clear structure to the writing, whereas the latter focus on the relationship between writers and their text, and between writers and readers. This model was premised on the fact that most of the discourse devices included therein have been found to contribute to the cohesion of L2 academic writing (McKay, 2006). Nevertheless, some metadiscourse features are more commonly found within particular disciplines. For example, in their study of the discourse analysis of laboratory reports written by experts and EAP students using Hyland's model, Ranawake, Gunawardena, and Wilson (2017) found that interactive resources such as transitions, frame and endophoric markers, evidentials, and code glosses, were commonly present in all the laboratory reports analysed; whereas interactional resources (with the exception of hedges) such as boosters, attitude and engagement markers, and self-mentions were rarely found. Accordingly, in this study, we only considered the interactive resources and one interactional resource (hedges) of Hyland's model as the variables for analysis at the level of cohesion (Table 2).

4.2.3. Grammar

At the level of grammar, the selection of variables was based on the distinctive syntactic features of laboratory reports. As in other scientific and technical texts, the register of laboratory reports is governed by three main writing principles, namely expressive accuracy, objectivity, and approximate exposition (Alcaraz, 2000). Indeed, the passive voice is one of the main grammar hallmarks of scientific and technical writing. In these types of texts, there is a tendency to describe reality in an objective way, avoiding any subjective influence and reference to agents (Lewin, 1998). Another syntactic feature that contributes to the expressive accuracy of scientific-technical texts is nominalization (Alcaraz, 2000), a common resource whose

Table 1
Variables of analysis at the level of text structure (adapted from Parkinson, 2017a).

Sections	Moves
1. Abstract	
2. Introduction	1. Establishing topic
	2. Introducing experiment
3. Method	3. Describing experimental procedures
4. Results	4. Announcing results
	5. Commenting on results
5. Discussion	6. Contextualising discussion
	7. Interpreting results
	8. Stating limitations
6. Conclusion	

Table 2

Variables of analysis at the level of cohesion (adapted from Hyland, 2010).

Cohesive devices	Function	Examples
Transitions	Express relationship between clauses	*In addition, but, thus, and,* etc.
Frame markers	Refer to the discourse acts, sequences, or text stages	*First, then, finally, to conclude,* etc.
Endophoric markers	Refer to information in other parts of the text	*Noted above, see figure, in* section X, etc.
Evidentials	Refer to the source information from other texts	*According to X, (Y, 1990),* etc.
Code glosses	Help readers grasp meanings	*Namely,* e.g., *such as,* etc.
Hedges	Show the writer's reluctance or hesitation to present propositional information	*Might, perhaps, possible,* etc.

purpose is to present what could be described through a long verbal predicate in a summarized form by means of a noun (Bloor & Bloor, 1995). Finally, the use of verb tenses in scientific and technical texts is similar to general language, with some exceptions, such as the low use of progressive forms (Malcolm, 1987). Generally, laboratory reports use a limited range of tenses, chiefly the simple present and past (University of Southampton, n.d.). The simple present prevails in definitions, expression of scientific rules, general truths, repeated processes and actions, and specification of properties, whereas the simple past is used to refer to earlier findings or experimental procedures which occurred in the past and are finished (Alcaraz, 2000). Further grammar features, such as modal verbs, are also usually found in scientific and technical writing. They commonly occur in discussion sections to avoid making unquestionable assertions and to search for approximate exposition (Flowerdew & Wang, 2017). However, as modal verbs were are included in this study within the hedging elements at the level of cohesion (see section 4.2.2), they are not considered within this category. Table 3 shows a description of the variables selected for analysis at the level of grammar.

4.2.4. Vocabulary

The words of specialized genres can be classified into technical, semi-technical, and general vocabulary (Alcaraz, 2000). Technical terms are monosemic subject-related words that are primarily found within a specialized domain (Chung & Nation, 2014). Conversely, semi-technical words have a polysemic character which include lexical units of common language that have acquired new meanings within a particular discipline (Alcaraz, 2000; Farrel, 1990; Swales, 1990), whereas general vocabulary refers to words of common use that can be found in specialized texts (e.g., function words). A discipline-specific text can consist of up to 30% of technical vocabulary (Chung and Nation, 2004). The fact that nearly a third of a discipline-specific text is made up by technical vocabulary, and the remainder by semi-technical and general vocabulary, is a powerful reason in itself for including them in this analysis.

Identifying technical and non-technical terms is a highly complex endeavour due to the functional aspect of such "technicalness" (Chung & Nation, 2014, p. 251). In recent decades, there have been many attempts to categorize discipline-specific vocabulary in the field of science and technology, either through technical dictionaries (Oh, Lee, Lee, & Choi, 2000), or by means of specialized corpus analyses through computer-based approaches (Coxhead, 2000). However, these have not been without their critics due to the difficulty in finding sources with complete lexical coverage in a particular field of knowledge and for the appropriate contexts. For this reason, and inspired by Chung and Nation's (2004) work, this study used its own rating scale to identify technical, semi-technical, and general vocabulary. In their study on the comparison of different approaches to identifying technical and non-technical vocabulary in the field of anatomy, Chung and Nation found that the rating scale was the most reliable and accurate approach, compared to other approaches such as the use of technical dictionaries, clues provided in texts, and computer-based analyses. Their model included a four-point scale designed to determine those words that more strongly related to the field, ranging from words not particularly related to the field (step 1) to words specifically related to the field (step 4). They considered items classified as steps 3 and 4 as technical words and those at steps 1 and 2 as non-technical words. In our study, a slight variation to this scale was made as our purpose was to identify not only technical and non-technical words, but also semi-technical vocabulary. Consequently, we designed a three-point rating scale (Table 4). Words classified at step 3 were considered as technical vocabulary and included words directly related to the specific field of chemistry. Words classified at step 2 were considered as semi-technical vocabulary and comprised words related to the field that were likely to appear outside the field either with the same or with a different meaning. Finally, words classified at step 1 were considered as general vocabulary and included words with no particular relationship with the field (e.g., function words).

Following Chung and Nation's recommendation regarding the need for a good knowledge of the subject matter to appropriately use such a scale, the word classification for this study at the level of vocabulary was made jointly between the author and one of the content lecturers on the whole sample of lab reports, reaching a high level of inter-rater agreement (96.4%).

Table 3

Variables of analysis at the level of grammar.

Grammatical element	Description	Examples
Passive voice	Passive structures	*This machine was designed by …; A set of data was collected,* etc.
Nominalization	Noun phrases	*Percentage growth rate; DNA binding region,* etc.
Verb tense	Simple present and past	*Steels of permanent magnets contain about 30% cobalt; Smith found that a large percentage of …,* etc.

Table 4
Rating scale to identify the different types of vocabulary (adapted from Chung and Nation, 2004).

Steps	Classification	Description	Examples
Step 1	General vocabulary	Words with no particular relationship with the field (e.g., function words)	*An, a, the, common, especially, try, check, among, between,* etc.
Step 2	Semi-technical vocabulary	Words related to the field that are likely to appear outside the field either with the same or with a different meaning	*Solid, solution, power, strength, agent, abstract, energy, consist,* etc.
Step 3	Technical vocabulary	Words directly related to the specific field	*Cobalt, bond enthalpy, potassium permanganate, Ph, oxalate, chloride, Kps, H_2O,* etc.

4.3. Analysis procedure

A total of nine disciplinary-literacy variables were pre-defined at the level of text structure, cohesion, grammar, and vocabulary (Table 5). The analysis of this study follows a quantitative approach in order to measure the relationship between the frequency of occurrence of such disciplinary-literacy variables and students' content proficiency. All the laboratory reports were transcribed using NVIVO software yielding a total of 68,952 words, and each variable was identified and coded in each written text. Subsequently, the frequency rate of each element was calculated according to the number of instances found in each text. As laboratory reports were of different lengths (ranging from 233 words of the shorter text to 698 words of the longer text), the rates of occurrence of cohesion, grammar, and vocabulary variables where normalized to 100 (i.e., number of instances per hundred word) following standard practice in linguistic variable counting (Gray, 2019). However, the variables at the level of text structure (sections and moves) were calculated in absolute terms, since the number of instances of each of these variables in a text is not influenced by text length.

All the variables were identified and coded independently by the author and an additional language expert (except the variables at the level of vocabulary, which were identified by the author and one of the content lecturers. See section 4.2.4), reaching an inter-rater agreement of 93.2%. The few inter-rater disagreements where solved by consensus.

A correlation analysis was conducted to compare the frequency rate of each pre-defined disciplinary-literacy variable in each laboratory report with the final mark delivered by the lecturers based on content proficiency (see section 4.1). Subsequently, those variables that correlated significantly with students' academic mark were used in a multiple linear regression analysis, through a stepwise method, to examine whether they were statistically significant predictors of higher content proficiency.

To avoid issues of collinearity, a Pearson correlation analysis between all the variables was conducted to ensure that there were no strong correlations between two or more variables ($r < 0.70$), following standard practice in correlation statistical analysis in second language research (Larson-Hall, 2010). For those variables that correlated highly with each other, the one showing the lowest correlation value with the students' academic mark was discarded from the subsequent regression analysis to avoid including variables that measured similar constructs (Crossley et al., 2014; Crossley & McNamara, 2012).

5. Results

5.1. Pearson correlation analysis

In response to the first research question on the impact of the frequency of use of disciplinary-literacy variables related to the genre, discourse, and register features of the laboratory report on students' academic mark in English-medium writing when they are assessed by virtue of content proficiency, the results of the Pearson correlation analysis demonstrate that six of the nine variables analysed correlated significantly with the students' academic mark ($p < 0.05$). Table 6 shows the r values and p values of the correlated variables sorted by the strength of the correlation. These variables belong to the levels of text structure (moves and sections), cohesion (cohesive devices), vocabulary (technical vocabulary), and grammar (passive voice

Table 5
Summary of the disciplinary-literacy variables selected for analysis.

Level of Analysis	Element	Code	Description
Text structure	Sections	SEC	Macrostructure
	Moves	MOV	Constituent parts of each section
Cohesion	Cohesive devices	CD	Transitions, frame markers, endophoric markers, evidentials, code glosses, and hedges
Grammar	Passive voice	PV	Passive structures
	Nominalization	NOM	Noun phrases
	Verb tenses	VT	Simple present and past
Vocabulary	Technical vocabulary	TEC	Words directly related to the field of chemistry
	Semi-technical vocabulary	SEM	Words related to the field that are likely to occur outside the field either with the same or with a different meaning.
	General vocabulary	GEN	Words with no particular relationship with the field

and verb tense). All these correlations were positive, which indicates that those laboratory reports containing a higher frequency rate of these variables were judged by the content lecturers as more proficient. Moves, sections, and cohesive devices, were shown to have, in the indicated order, the highest effect size ($r \geq 0.50$). Technical vocabulary was shown to have a medium effect size ($r < 0.50$); whereas passive voice and verb tense were shown to have a low effect size ($r < 0.30$) (Cohen, 1988).

The Pearson correlation detected an issue of collinearity ($r > 0.70$) between the variables sections and moves at the level of text structure ($r = 0.725$, $p < 0.01$). As the latter showed the highest correlation value with the students' academic mark ($r = 0.623$, $p < 0.01$) it was retained for the subsequent regression analysis, and the variable sections was removed to ensure we were not measuring overlapping features (Crossley et al., 2014; Crossley & McNamara, 2012). Therefore, five elements were finally included in the regression analysis.

5.2. Multiple linear regression analysis

In response to the second research question on the predictive character of the variables resulting from the Pearson correlation analysis regarding the students' content proficiency, a multiple linear regression analysis, using a stepwise method, was conducted. To control for overfitting, (i.e. the use of too many variables that may result in misleading predictive values) the conservative approach that allows a minimum of 20 observations per predictor was followed (Babyak, 2004). With 136 observations we could safely include the five variables in the regression analysis.

To check for residuals independence, we used a Durbin Watson test. A value close to 2 ($DW = 1.636$) was obtained (Table 7). Therefore, the residuals were completely independent (Herrera, Martínez-Arias, & Amengual, 2011). Additionally, coefficients were checked for tolerance and variance inflation values (VIF). All tolerance values were beyond the 0.20 threshold and all VIF values were far below 10; therefore, the model was not affected by multicollinearity (Witten, Frank, & Hall, 2011).

The linear regression analysis yielded a significant model $F(4, 131) = 35.939$, $p < 0.001$, $R^2 = 0.493$, $R^2_{adj} = 0.482$ (Table 7). Four of the five variables included in the regression analysis were statistically significant predictors of the students' academic mark, namely, moves, cohesive devices, technical vocabulary, and passive voice. These results demonstrate that the combination of these variables accounts for 48% of the variance in the students' academic mark of this study, revealing that nearly half of the students' content proficiency is explained by the frequency rate of these disciplinary-literacy variables in their written texts.

6. Discussion

This paper set out to analyse the relationship between the use of disciplinary-literacy variables and content proficiency in English-medium writing. It also sought to identify those disciplinary-literacy variables that can be considered significant predictors of content proficiency in English-medium laboratory report writing. Our findings evidence a positive relationship between the frequency of occurrence of certain disciplinary-literacy variables at the level of text structure, cohesion, vocabulary, and grammar, and students' content proficiency, indicating that those texts with higher frequency rates of such variables are judged by content lecturers as more proficient than those which contain a fewer number of these elements. Concurrently, it was found that moves, cohesive devices, technical vocabulary, and passive voice can be considered as statistically significant indicators of students' content proficiency in English-medium laboratory report writing. In particular, the combination of these four variables accounts for nearly half of the variance of the students' academic mark, revealing that students' content proficiency can be explained, at least, partially, by the frequency of occurrence of these disciplinary-literacy variables in their written laboratory reports. These findings reveal a relatively high degree of explained variance if compared with other L1 studies (e.g., Cho & Bridgeman, 2012; Graham, 1987). This result may be attributed to the fact that the final mark assigned to the students in this study belonged exclusively to the writing task and not to the final course grade. The aforementioned L1 studies used students' grade point average (GPA) as an indicator of academic achievement, which might trigger lower levels of explained variance due to the variety of factors affecting GPA, e.g., students' outcomes in other language and academic skills, course attendance, completion of coursework, etc. (Dafouz, Camacho, & Urquia, 2014).

Regarding the predictive variables, the number of moves at the level of text structure was found to be a significant predictor of students' content proficiency. These results are not surprising, as the moves analysed were identified in earlier

Table 6
Pearson correlation values of the disciplinary-literacy variables correlated with students' academic mark.

Variable (code)	Level of Analysis	r value	p value
Moves (MOV)	Text structure	.623**	.000
Sections (SEC)	Text structure	.599**	.000
Cohesive devices (CD)	Cohesion	.587**	.000
Technical vocabulary (TEC)	Vocabulary	.489**	.001
Passive voice (PV)	Grammar	.294**	.000
Verb tenses (VT)	Grammar	.179*	.050
$N = 136$			

Note: **$p < 0.01$; *$p < 0.05$.

Table 7

Coefficients of the multiple linear regression analysis of the disciplinary-literacy variables predictors of content proficiency.

Variable code	R^2	R^2_{adj}	F (sig.)	B	t	p	TOL	VIF	Durbin-Watson
Model 4	.493	.482	35.939 (.000)						1.636
MOV				.365	4.510	.000	.556	1.800	
CD				.361	3.659	.000	.375	2.668	
TEC				.287	3.516	.001	.548	1.826	
PV				.272	2.869	.005	.405	2.470	

Note: R^2 = coefficient of determination; R^2_{adj} = adjusted coefficient of determination; F (sig.) = F-statistic (statistical significance); B = standardised β; t = t-test; p = statistical significance; TOL = tolerance; VIF = variance inflation value.

studies as obligatory or usual in highly-graded student laboratory report writing (Parkinson. 2017a). Additionally, moves constitute the core of the organisation of the necessary information appearing in a text (Biber et al., 2007). Therefore, our findings suggest that the higher number of the analysed moves a written laboratory report has, the more accomplished the written task may be considered by the content lecturers and, thus, the higher scored it is.

The cohesive devices analysed at the level of cohesion also constitute a statistically significant indicator of content proficiency in our study. These findings adhere to previously research-supported expectations. The use of cohesive devices similar to those analysed in this study has been found to be an indicator of L2 academic writing proficiency as a sign of more organised and coherent writing in past research (Biber, Johansson, Leech, Conrad, & Finegan, 1999; Jin, 2001; Longo, 1994), including laboratory report writing (Ranawake et al., 2017). These results may be ascribed to the notion that more proficient students "possess the linguistic ability to produce more and varied cohesive devices" (Crossley & McNamara, 2012, p. 130). In our study, in which the assessment criteria of the students' written texts included the rather unspecified "clear writing" criterion, it can be surmised that content lecturers understand more clearly the content and organisation of the text through more explicit links between ideas when it comes to reading and assessing it. Hence, they judge those texts containing a higher number of the cohesive devices analysed as more proficient.

As for the lexico-grammatical variables, the use of passive voice and technical vocabulary resulted as statistically significant predictors of students' content proficiency. In the case of the former, this finding echoes previous research relating the use of the passive voice to successful L2 academic writing (Ferris, 1994; Grant & Ginther, 2000), especially in scientific and technical writing, (Miller & Richards, 2017; Parkinson, 2017b). Therefore, our results provide additional evidence of the relevance of this grammar structure for successful English-medium laboratory report writing. In the case of the latter, results were also expected, since, in contrast to semi-technical and general vocabulary, technical terms shape the most subject-related type of vocabulary (Chung & Nation, 2014), and they are pondered as the sine *qua non* of content knowledge (Alcaraz, 2000, p. 68). Additionally, subject-specific terminology has recently been reported as a key element in English-medium writing assessment (Dafouz, 2020). The content lecturers of this study informed the author of this paper that students had been provided with some lists of specialized vocabulary related to laboratory materials and procedures throughout the course as part of the course disciplinary content. Thus, if the participants of this study were assessed by virtue of content proficiency, these results suggest that those texts which contain a higher number of technical words are judged by the lecturers as showing greater content knowledge and, therefore, are scored higher than those with a lower rate of this type of vocabulary.

These findings foreground the relevance of disciplinary-literacy skills for academic success in EMI programmes, where these have often been overlooked (Airey 2011, 2012; Breeze & Dafouz, 2017; Fortanet-Gómez, 2013; Lyster, 2017; Sert, 2008). They evidence the inextricably entwined nature of disciplinary literacy and disciplinary content in English-medium writing (Airey 2011, 2012; Lyster, 2017), with disciplinary literacy being indeed a significant indicator from which to judge, at least, partially, content proficiency. These findings suggest that the command of disciplinary literacy may be a marker of how well a student is embedded in a discipline, and that such degree of belonginess may influence content lecturers' judgements of perceived content proficiency. Therefore, content specialists, curricular planners, and university administrators should be aware of the paramount need to consider disciplinary literacy within EMI course syllabi and to provide students with subject-specific English language and literacy support for their successful academic development in EMI courses.

It is noteworthy that, in the personal interview, the content lecturers of this study reported explicitly having disregarded language and literacy-related issues both in their lessons and when assessing the students' written texts, since, as often argued in EMI settings, these were not included within the course teaching objectives (Breeze & Dafouz, 2017; Dafouz, 2020; Schmidt-Unterberger, 2018). However, our results suggest that the content lecturers might have implicitly taken disciplinary literacy into account when grading lab reports, perhaps within criteria c (appropriate use − and description - of the laboratory methods and materials) or d (clear writing) (c.f. section 4.1). This may be another reason for the relatively high predictive value of the disciplinary-literacy variables, especially at the levels of text structure, cohesion and technical vocabulary. The content lecturers might have addressed these aspects within the assessment criteria, but with a different metalanguage. Perhaps what literacy specialists might label under academic or disciplinary literacy, content specialists consider simply as part of the content knowledge. Further studies might explore content lecturers' perceptions and conceptions in this area.

Whilst these findings provide valuable insights into disciplinary literacy-variables that predict content proficiency in English-medium laboratory report writing, it should be noted that this study follows a quantitative approach where only frequency rate is addressed. Further analyses that include other quantitative and/or qualitative variables (e.g., error analysis,

writing strategies, students and/or lecturers' perceptions of writing developments and outcomes, etc.) would be desirable to obtain a more comprehensive view of the factors that may be indicative of content proficiency in English-medium writing.

7. Conclusions

This study has sought to fill an existing research gap by analysing the relationship between the use of disciplinary-literacy variables and content proficiency in English-medium laboratory report writing, an underexplored association in EMI studies. Our results have unveiled a positive relationship between the frequency of occurrence of disciplinary-literacy variables and students' academic marks when they are assessed by virtue of content proficiency. In particular, they have showed that disciplinary-literacy variables at the level of text structure (moves), cohesion (cohesive devices), vocabulary (technical words), and grammar (passive voice) are statistically significant indicators of content proficiency in English-medium laboratory report writing. These results underscore the often-neglected relevance of language and disciplinary-literacy skills for academic success in English-medium contexts, and evidence empirically the inextricably entwined nature of disciplinary literacy and disciplinary content in English-medium writing.

From a pedagogical viewpoint, this study suggests that disciplinary literacy should be explicitly included within the teaching goals and assessment criteria in EMI courses. English-medium teaching in higher education should therefore be redirected to more ICLHE-oriented practices whereby language, and particularly, disciplinary-literacy skills, have their place in a full appreciation of EMI content syllabi (Sánchez-Pérez & Salaberri, 2017; Wilkinson, 2018). The results of this study reveal that those students who show higher awareness of the linguistic elements related to the genre, discourse, and register features of the laboratory report obtain more successful results in English-medium writing when they are assessed by virtue of content proficiency. To develop disciplinary-literacy skills for English-medium writing, we suggest that a pedagogical focus on genre awareness may be a useful scaffolding strategy to help students to produce discursive frameworks which allow them to organise their disciplinary content, while creating and developing an identity as academic and disciplinary writers (Hyland, 2006). HEIs engaged in EMI should, therefore, ponder on reframing their instructional practices through possible pedagogical initiatives such as the development of specific ICLHE teacher training and professional development programmes focused on genre-based pedagogies (Ruiz-Madrid & Valeiras-Jurado, 2020; Sánchez-Pérez, 2020), ESP/EAP pre-sessional or embedded courses (Schmidt-Unterberger, 2018), specific academic and disciplinary writing programmes (Basturkmen, 2017; Breeze, 2012), or teaching collaboration between content and language experts (Airey, 2012; Fortanet-Gómez, 2013; Lasagabaster, 2018; Lyster, 2017, pp. 7—14; Pavón & Gaustad, 2013), to support EMI students in the development of disciplinary-literacy skills for successful academic development in such fast-growing university contexts.

With regards to the limitations of this study, it must be acknowledged that this analysis has focused only on a specific academic genre (i.e., laboratory report) within a particular disciplinary course and an EMI context. Therefore, and because EMI has been shown to be highly context-specific (Rose et al., 2019), the generalization of these findings should be made with caution. Additionally, the disciplinary variables of analysis are only a representative sample of the most-conventionalized genre and specialized-language features of the laboratory report, thus the analysis of further text types and/or variables might yield different results. Furthermore, as this is a correlative and regressive type of study, only frequency rate was addressed, and no error or further qualitative variables were considered. Accordingly, prospective studies should expand to other EMI contexts, disciplinary areas, academic genres, disciplinary-literacy elements and/or qualitative variables, or focus on error analysis to reveal further issues regarding the relationship between disciplinary literacy and content proficiency in English-medium writing. Finally, it would also be interesting to conduct a similar study on L1-medium laboratory report writing to check whether disciplinary-literacy variables attributed to laboratory report writing in a different language affect content proficiency in L1-medium instruction contexts similarly. This study could serve as a baseline for such future research directions in these increasingly internationalised higher education contexts.

Declaration of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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