Teaching of physics applied to engineering higher education by using English language: a literature review

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Abstract. The use of English as a second language is an increasing trend in higher education focused on non-native speakers, particularly for engineering programs interested in becoming actors inserted into the international academic context. However, the dual condition of both teaching engineering curriculum contents, and simultaneously using English language in non-native speaking contexts, entails risks and challenges that should be deeply understood. Considering this, results from a literature review are presented, built on articles from academic databases regarding use of two approaches, English as a medium of instruction and Content and language integrated learning, in engineering at higher education institutions, with specific interest in physics teaching, because of its relevance in engineering body of knowledge. As a finding, this topic has not been sufficiently studied in academic literature, and two focuses to carry out further research are suggested to contribute to the understanding of how to teach physics by using English language in non-native speaking contexts.

1. Introduction

English language has become world’s lingua franca, its influence has permeated social and cultural spheres, and the academic sector is not an exception: as of 2018, the number of refereed academic journals listed in Ulrich’s Periodicals Directory reached 77,218 published in part or fully in English language [1]. In this scenario, higher education institutions in non-English speaking countries are under pressure to rapidly update their pedagogical framework by offering bilingual programs and courses to be appealing for students and high-level professors [2].

Learning a second language while studying subject content may improve motivation, learning strategies, and self-confidence in comparison to monolingual students [2]. Even though, the decision of using English in non-language courses is particularly challenging in engineering programs because of, among others, the level of mathematics and physics involved [3], and this pedagogical choice entails some problems as Hincks R [4] detected when analyzing a group of 14 English fluent (C1/B2) master’s students of engineering in Sweden: she found that speaking rate in English was 23% slower in comparison to lessons in their first language.

Using a second language to teach a highly complex body of knowledge without compromising learning outcomes is a difficult task, as Airey J and Linder C [5] found in a sample of 22 undergraduate physics students at two universities in Sweden: they asked and answered fewer questions when the class was led in English, and they had more problems when simultaneously listening to professors and taking notes. In addition, dealing with using English and teaching content is highly demanding for professors, and resistance may raise against this new dual role, as Airey J [6]
identified in qualitative research carried out with ten physics lecturers from four Swedish universities involved in English taught courses, and as a result, none of them conceived themselves as language teacher.

In this scenario, nevertheless, Thøgersen and Airey [7] states a small number of studies about the consequences of using English language, through observation or experimental designs, have been carried out, and Kukkonen P [8] considers that, although language acquisition and the learning of physics are topics intensively studied, there is a lack of articles about English as a second language to teach physics. The aim of this paper is to conduct a literature review process in order to identify if there is a research gap regarding how English language is used, in non-native speaking contexts, to teach Physics in engineering higher education.

2. Background

In this study two main approaches oriented to use English language while teaching subject content will be addressed: English as a medium of instruction (EMI) and content and language integrated learning (CLIL); they both aim to help students to improve their proficiency in a second language while learning disciplinary knowledge, but CLIL teaching implies an equal focus on content and language whereas EMI contexts are more interested in teaching subject contents, and language learning becomes a secondary priority [9].

2.1. English as a medium of Instruction in higher education

English as a medium of instruction is defined as “the use of the English language to teach academic subjects (other than English itself) in countries or jurisdictions where the first language (L1) of the majority of the population is not English” [10]. The increasing interest to offer EMI programs in higher education is context-dependent and related to efforts to gain prestige, to attract foreign students (due to falling of home students’ applications), to counteract external sources’ investment cutting, and to embrace English as a status language (particularly in research publications) [10]. Although the implementation of EMI in higher education has rapidly been growing worldwide, academic research aimed to understand its effectiveness has been lagged behind [11], and analytic research to understand classroom interaction in higher education with English as a Medium of Instruction is scarce [12].

Moreover, opposition to use EMI in class is increasing, and Başibek N, et al. [13] brought up teaching in English without appropriate curricula might foster feelings of confusion and insecurity between professors and students; regarding that, Başibek N, et al. [13] compiled six arguments against EMI approach: lower ability to understand concepts, reduced knowledge about subjects, it is time-consuming process, raising of feelings of alienation and separation, participation is classes decreases, and EMI might be seen as “a vehicle for creating an elite class” by limiting the involvement of students with no prior access to education in English.

2.2. Content and language integrated learning in higher education

CLIL is defined as “a dual-purpose approach” that combines teaching curriculum content and simultaneously a second language (L2) in an integrated manner [14]. According to Wewer T [15], CLIL’s purpose is to strengthen the language repertoire by using the second language as a medium of teaching and learning contents across the curriculum, and its popularity has been thriving in the last decades in Latin America and Asia as a language instruction approach.

Among the advantages, Banegas DL and del Pozo Beamund M [14] compiled studies from experts reporting benefits in features such as motivation, intercultural awareness and linguistic development in young learners and high education students.

Nevertheless, in their research about the teaching of a physical law by using English language, Kääntä L, et al. [16] claimed there is limited literature on physics education in a CLIL classroom, and they state, as a main result from the study, it is necessary to coordinate multilingual and multimodal practices to succeed in this dual challenge. In accordance with that, Kääntä L and Kasper G [17] pointed at the difficulty to determine exactly what understanding is gained by students to future use.
3. Methodology
In order to get a better understanding on conditions related to English as a second language to teach physics in Engineering at tertiary education, a four steps literature review was carried out by turning to Scopus and ScienceDirect as bibliographic sources, and the review process and summary frameworks were designed by following Fontina, et al. [18] proposal; both Scopus and ScienceDirect were chosen as providers of reliable peer-reviewed articles, and an unrestricted period was considered due to study’s highly specific scope. Search process was developed as follows. Firstly, literature search was based on four keywords used in conjunction, connected by the Boolean “AND”:

- Keyword 1: “English as a medium of instruction” (and its variation “English medium instruction”) and content language and Integrated learning (and its variation “CLIL”). Additionally, to get a wider scope, “English as a foreign language (EFL)” and “English as a second language (ESL)” were used too.
- Keyword 2: “engineering”.
- Keyword 3: “physics”.
- Keyword 4: “higher education” (and its variations “tertiary education”, “university”).

Secondly, and based on the abovementioned keywords, articles from journals were collected and duplicate ones were removed. After that, titles and abstracts for preliminary articles were carefully read to discard those ones unrelated to this study scope for reasons such as they are not oriented to pedagogical issues, or they are unconnected to either engineering or physics. Later, articles that passed the filter were read in-depth to identify any relation to the study’s topic, dropping all of them with no direct connection. Finally, the remaining articles were used to write a descriptive analysis presented in discussions.

The methodology and criteria used to identify articles are concisely described in Table 1, and the number of articles identified during search process is showed in Table 2 (both based on frameworks proposed by Fontina, et al. [18]).

Table 1. Summary of the literature review process.

| Step | Finding and evaluation of articles |
|------|-----------------------------------|
| Step 1 | Electronic databases: Scopus (scopus.com) and ScienceDirect (sciencedirect.com) |
| and | Search period: unrestricted time period |
| Step 2 | Inclusion criteria: articles written in English language with title and abstract related to the aim of this paper, based on four keywords, and finally chosen after a full review of their contents |
| | Exclusion criteria: articles unrelated to the four keywords used in conjunction, and articles not available in English language |
| Search string | “EMI / CLIL” AND “Engineering” AND “Physics” AND “Higher education” |

Table 2. Summary of the literature review search process.

| Search string | Articles identified | Articles post removing duplicates | Articles post abstract review | Articles post full text review |
|---------------|--------------------|----------------------------------|-----------------------------|-----------------------------|
| “EMI / CLIL / EFL / ESL” AND “Engineering” | 130 | 92 | 15 | 4 |
| Total | | | | |

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4. Discussions

From an initial sample of 92 articles identified in the literature review process, 15 were chosen to be read in-depth, written from 1985 [1] to 2021[5,8,10]. After the post full text review, 11 of them were discarded because, although they all offer relevant information about challenges of using English as a second language, their contributions to understand the object of this study were not significant.

From these 11 papers, 3 of them are oriented to reflect upon students’ learning process by systematizing their perceptions of language abilities and needs [19], by processing how English vocabulary is learned [20], or by comparing courses taught in a second language with conventional ones [21]. Other 4 articles are focused on discussing theoretical models and descriptors [22], exploring literacy support [23], or using strategies such as arts and humanities [24] or flipped classroom [25] in tertiary education courses. Finally, 4 papers aim to analyze specific variables like disciplinary cultures [26], ambiguity tolerance [27], supervisory feedback [28], and speaking rate [7] and how they affect learning processes.

From the sample of 15 articles, 4 of them contain relevant insights to understand the chosen topic. Furthermore, there is only one article whose title, abstract and content fully matches to the study scope, and the other three papers offer more limited contributions to the object of study.

The above-mentioned significant article was written by Tatzl D and Messnarz B [29] with the aim to investigate “the influence of English as the examination language on the solution of physics and science problems by non-native speakers in tertiary engineering education” in a degree program of aviation at the FH Joanneum University of Applied Sciences (Graz, Austria) whose students are involved in aeronautical engineering and aviation management. Non-native speakers of English, according to Tatzl D and Messnarz B [29], are leaned to be part of English taught programs as a way to get a more competitive and employable work profile. Likewise, Tatzl D and Messnarz B [29] remarks a difference between Austrian students, in comparison to other countries, regarding previous knowledge of the language, because an English level B2 is expected in prospects entering to tertiary education.

As a result, Tatzl D and Messnarz B [29] suggests that “the impact of English as a foreign language skill on mathematical problem-solving in science and physics is ambiguous, to say the least” and his investigation could not validate his initial assumption that non-native speakers would need additional time and aids to solve engineering physics problems in English; from Tatzl D and Messnarz B [29] perspective, tailor-made learning proposals should be designed to each group of learners because, apparently, a second language does not affect solving numerical problems, but achievement rates are affected if written descriptions are required [29].

The second article identified in this review stressed on teachers’ beliefs about using translanguaging (coexistence of multiple languages as a communication system) as pedagogical practice [30]. The research includes semi-structured interviews, classroom observations, and analyses of teaching and assessment material from four teaching staff in Iraqi universities. As a result, Alhasnawi S [30] considers adopting a ‘one-size-fits-all’ perspective on EMI limits our understanding on how non-native speakers interact with English language, ignoring geopolitical and socio-cultural implications, considering both limited proficiency in English and in mathematics in the Iraqi context (for instance, one of the professors expressed he teaches 80% of physics content in Arabic instead of English). Likewise, Alhasnawi S [30] encourages developing serious research on using languages for academic purposes and pedagogical skills related to disciplinary practice.

In the third article, Reus L [31] stresses on how EMI may counteract Latin American students’ “language exchange isolation”. According to Reus L [31], in that region EMI is still in an early stage, but it is growing because of the interest of universities to attract foreign students and to climb positions in international rankings. This study was developed in a Chilean engineering school by using multivariate analysis of tests and final grades in two economics-related courses, and as a result, there are not negative effects on content acquisition, but the author remarks it is not possible to extrapolate this result to other areas as physics because students who enjoy economics do not necessarily enjoy math [31].
Finally, in the fourth article, written communication as a core competence for higher education students is the focus in Bylander J and Gustafsson M [32] investigation: experimental lab-report writing assignments in English in a quantum engineering course written by master’s-level physics were studied, and the author considers his proposed method might be used in other STEM disciplines. Although this study is more oriented to “learning to write” activities for academic purposes, Bylander J and Gustafsson M [32] detects the implications of uneven student groups’ English skills and peer-feedback in writing high quality reports in English.

According to the literature review results, the use of English as a second language to teach physics in engineering higher has not been sufficiently analyzed: The only article that fully matches to that scope, written by Tatzl D and Messnarz B [29], is focused on a specific process (examination) for a sample of proficient students (English level B2 or more) enrolled in the same undergraduate program in a high-income country (Austria). Based on this finding, two focuses to carry out further research are suggested.

The first focus is related to identify how professors modify their English as a second language approaches to teach physics in engineering according to the educational moment (lecturing, classroom discussions, testing), and the type of content, either math-oriented courses (such as theoretical physics courses) or observation-oriented ones (as Bylander J and Gustafsson M [32] point at analyzing experimental lab-reports). The alignment between language training and content skills in engineering education, according to Tatzl D and Messnarz B [29], rests on interaction between content and language instructors, so to investigate about this multidisciplinary relation would provide useful insights to improve curriculum planning and implementation.

The second focus emerges from the lack of significant studies about challenges to adapt approaches such as EMI or CLIL to teach physics in engineering programs in contexts with low (or uneven) proficiency from students and professors. Differences between these both approaches should be documented to develop research-informed pedagogical practices [12], therefore, it recommendable to undertake specific research in how to teach physics from an engineering perspective in order to not extrapolate outcomes based on experiences from another body of knowledge (as Reus L [31] warns). Finally, further studies should be performed in medium or low-income countries because using English as a second language in these contexts demands more flexible frameworks, as Alhasnawi S [30] urges for Iraqi universities, taking into account affective factors that have not been traditionally involved in physics instruction [8].

5. Conclusion

From the literature review process, it can be concluded there is a knowledge gap regarding how English language is used, in non-native speaking contexts, to teach physics applied to engineering higher education. From 92 papers identified in the preliminary search process, and after an abstract review, 15 of them were considered suitable for a full text review, and as a result, just 4 articles were identified as sources of relevant insights, but only one of them fully fitted the topic of interest.

Based on the literature review and the descriptive analysis showed in previous chapters, it has been identified lack of experimental studies about two main educational challenges in physics: How professors manage teaching approaches such as English as a medium of instruction and content and language integrated learning when leading physics courses for engineering programs; and how English language should be applied to teach physics in engineering courses in developing countries, where both second language command and math skills are limited.

Developing curriculum adjustments to effectively teach physics relies on available information from well-documented best practices, and the lack of data-driven decisions might hinder full insertion of students and professors in both international research networks and postgraduate programs. Therefore, university physics and engineering departments must lead research regarding how English language is actually used in their different learning stages, as a way to systematize their experiences by documenting new knowledge to be shared within academic community.
Learning a second language is a motivating but frightening experience, and learning physics is a challenging endeavor itself, so combining both activities is quite difficult task. Particularly for Colombia, whose citizens have low English literacy (according to EF English proficiency index) and whose results in mathematics are lower than in comparable countries (according to the Organization for Economic Cooperation and Development), this study exhorts to combining both activities is quite difficult task.

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