

Article

Structured vs. Conventional Collaborative Learning: Effects of Jigsaw and Linguistic Scaffolding on Language and Content Acquisition in ESP Engineering Education

Celia Gomar-Rodrigo ¹, Rubén Simeón ^{2,*}, Alba Agenjos-Moreno ² and Alberto San Bautista ²

¹ Departamento de Lingüística Aplicada, Universitat Politècnica de València, 46022 Valencia, Spain; cgomrod2@upv.edu.es

² Centro de Investigación del Regadío y Agrosistemas Mediterráneos (CIRAM), Universitat Politècnica de València, 46022 Valencia, Spain; alagmo@etsiamn.upv.es (A.A.-M.); asanbau@prv.upv.es (A.S.B.)

* Correspondence: rusibro@etsiamn.upv.es

Abstract

The use of the English scientific literature in Agronomy education poses challenges for students with heterogeneous English Language proficiency. This study presents an innovative ESP (English for Specific Purposes) instructional model that uses collaborative dynamics and linguistic scaffolding to reduce cognitive barriers and promote equitable access to complex academic discourse in an English-Medium Instruction (EMI) context. This research evaluated the effects of two collaborative methodologies, Jigsaw (structured) and Conventional (non-structured) group work, and the use of a linguistic guide to provide contextualized lexical and syntactic scaffolding for reading scientific texts, on linguistic competence and content learning. Seventy Master's students were classified into three English proficiency levels (A1–A2, B1–B2 and C1–C2) and assigned to Jigsaw or Conventional groups, with or without linguistic guidance. Linguistic competence and scientific content comprehension were assessed through pre-tests and post-tests. Results showed that both linguistic and content performance increased with English level in pre- and post-tests. Learning gains in linguistic competence were mainly explained by English proficiency, with the highest improvements observed in lower-level students (up to 46.97%). However, neither the collaborative methodology nor the availability of the linguistic guide had a significant effect on linguistic improvement. In contrast, content learning gains were significantly influenced by instructional group, linguistic guide availability, and English level. The Jigsaw groups showed higher content improvement than Conventional groups (11.38% vs. 3.98%), while students with access to the linguistic guide also outperformed those without it (9.38% vs. 5.98%). These findings suggest that combining Jigsaw methodology with targeted linguistic support can enhance content learning from Scientific Publications in Agronomy, while short-term linguistic improvement remains primarily associated with students' initial English proficiency.

Keywords: Jigsaw; English language; linguistic guide; agronomy; teaching



Academic Editors: Jacek Stańdo and Jacek Pyżalski

Received: 16 June 2026

Revised: 20 July 2026

Accepted: 25 September 2026

Published: 27 September 2026

Copyright: © 2026 by the authors.

Licensee MDPI, Basel, Switzerland.

This article is an open access article distributed under the terms and conditions of the [Creative Commons Attribution \(CC BY\)](https://creativecommons.org/licenses/by/4.0/) license.

1. Introduction

The production and expansion of scientific knowledge globally are currently monopolized by the English language. Approximately 98% of scientific publications are in English, particularly in the fields of natural and basic sciences; thus, its status as the undisputed lingua franca of science is already secure [1]. Indeed, under current pressures, science

has adopted English as the only acceptable language for scientific communication [2,3], a trend that has reinforced the field's growing monolingualism [4]. Scientific publishing is characterized by a structural trend toward monolingualism, which is largely determined by the concentration of journals and the logic of international indexing. Therefore, even proponents of multilingualism recognize that using English is practically mandatory to ensure the dissemination and relevance of research [5].

This linguistic centrality implies direct consequences for an academic career: the success of a scientist is directly related to their ability to publish in English [6]. It is only through publication in this language that research findings are acknowledged within the elite scientific community [4]. For this reason, even highly relevant results may go unnoticed or become lost because they have been published in a language other than English. This is why an increasing number of non-native researchers feel compelled to publish their findings in English [7].

Recognizing this reality, the Spanish educational system has aimed to improve students' linguistic capacity through early learning and CLIL (Content and Language Integrated Learning) programs [8], making English a crucial language to master during university studies. The teaching of English as the language of instruction, known as EMI (English-Medium Instruction), has seen massive growth in Spanish higher education institutions since 2007. Particularly, in the post-pandemic era, this expansion of EMI has intensified the need for innovative pedagogical strategies that move beyond traditional content delivery to support diverse learner needs.

Globally, classrooms are increasingly characterized by cultural diversity and a variety of mother tongues [9]. In today's educational settings, where linguistic and cultural differences are the norm, limited attention has been given to bridging the linguistic and cultural gaps between students and professors [10]. Traditional teaching methods, such as lectures, are increasingly considered insufficient because they often fail to provide the foundation for student motivation and active learning [11,12]. In answer to this, the educational approach has shifted towards a humanistic paradigm that values active participation, leading to the development of cooperative learning strategies [13].

One of the most notable strategies in this field is the Jigsaw teaching technique, developed by Aronson to address educational challenges [14]. This methodology is particularly relevant for overcoming the challenges that arise in diverse classrooms.

From an academic perspective, the Jigsaw strategy has demonstrated significant benefits over traditional methods. By engaging students in cognitive and metacognitive areas, this cooperative approach helps them set goals and achieve higher levels of self-efficacy and success [15].

Integrating the Jigsaw teaching technique with a tailored pedagogical resource not only benefits students in a specific context but also presents a replicable model that can be applied to other disciplines. Since English is the lingua franca of science, the creation of a linguistic guide enables the study to provide students with a useful tool to understand scientific articles, thereby improving their reading skills. Crucially, while this methodology is implemented within a Spanish context, its pedagogical framework addresses a global challenge in STEAM education, offering a replicable model for non-English-speaking higher education institutions worldwide.

The aim of this experiment is to evaluate the effects of implementing the Jigsaw cooperative learning technique and providing a linguistic support guide in an Agricultural Engineering Master's course on students' ability to read and comprehend a scientific article in English. Specifically, the study examines gains in linguistic comprehension and content understanding, comparing outcomes across instructional conditions: Jigsaw (structured) and Conventional (non-structured) group work and support conditions (guide vs. no

guide). As specific objectives, this work addresses: the study of the influence of the main effect of learning methodology, Jigsaw (structured) and Conventional (non-structured) group work on the improvement of specific linguistic competence; the evaluation of linguistic support through a support guide to improve language proficiency and the particular content of the subject under study; the analysis of the effect of the English proficiency level (A1–A2; B1–B2; C1–C2) on the teaching–learning process regarding linguistic matters; and the study of the synergies between cooperative learning and linguistic support in the improvement of results.

Accordingly, students' performance is compared across the conditions in terms of linguistic comprehension and understanding of the article's content, allowing us to test the main effects of cooperative learning and linguistic support depending on the English level, as well as their combined contribution. In this context, the hypothesis proposed in this work is based on the improvement of learning outcomes for specific linguistic competencies among students when working with scientific publications in English, using Jigsaw cooperative learning methodologies along with linguistic support guides, especially for those students with a lower level of proficiency in this language.

2. Literature Review

2.1. *English as a Lingua Franca on the Rise in EMI in Higher Education*

The predominance of English in high-impact journals reinforces structural inequalities, placing additional demands on non-native scholars [16]. As a result, valuable research in applied sciences is often overlooked due to language limitations [6]. In fact, evidence suggests that including research published in other languages could boost the diversity of biodiversity studies by 12% to 25% [17].

As a response to this imbalance, higher education has seen a massive rollout of English-Medium Instruction (EMI) programs in non-anglophone countries [18]. In Europe, this shift was driven by the Bologna Process and the push for cross-border curriculum alignment [19]. Since 2007, Spain has rapidly expanded EMI, from 415 programs in 2018 to 995 across 77 institutions by 2021 [20,21]. While intended to attract global talent, enhance employability, and improve rankings, the rapid expansion of EMI has often outpaced pedagogical planning [22].

Adopting EMI models is a double-edged sword. On the one hand, it facilitates international decision-making, global mobility [23,24], better career prospects [25], and the integration of English for specific purposes (ESP) [20]. On the other hand, there are documented risks, such as the 'westernization' of the curriculum [26], the erosion of local academic language use, and a potential decline in content learning [27].

In agronomy and agricultural engineering, students must grasp complex concepts while mastering specialized ESP terminology essential for their careers [28]. Even students confident in general English often struggle with technical jargon and the rhetorical style of research papers [29]. These findings highlight the urgent need for properly adapted teaching materials [30].

2.2. *Cognitive Load Theory and L2 Reading*

Students' difficulties with the scientific literature in English can be explained through Cognitive Load Theory (CLT), originally developed by Sweller and later expanded [31,32]. CLT explains how new information is processed, emphasizing the limited capacity of working memory.

At its core, CLT suggests that meaningful learning (such as understanding an academic paper) requires active processing in working memory to transfer information into long-term memory as organized mental structures [33]. When task demands exceed this capacity,

cognitive overload occurs, impairing learning and reducing motivation [34]. Educational neuroscience breaks this load down into three overlapping categories, and the goal is to ensure their sum does not outstrip a person's mental resources [35]. The first category is called Intrinsic Load. This is the effort tied to the inherent difficulty of the material itself. In fields like agronomy, this load is naturally high because it involves complex, interconnected concepts. You cannot really simplify science; you can only manage how it is presented [36].

The second category is the extrinsic load, caused by poor instructional design. When reading in a second language (L2), understanding technical vocabulary and complex syntax adds cognitive demand, competing with content comprehension [37,38]. Lastly, the third category is the Germane Load, the productive effort dedicated to building long-term mental maps. To enable this, extrinsic load must be minimized so the brain can focus on learning [34].

In L2 academic reading, processing technical content in a foreign language increases extrinsic load [39]. Reading scientific papers in English strains working memory, as processing L2 language competes with content understanding, hindering deep comprehension [38].

The split-attention effect adds another layer of complexity to this challenge [40,41]. This effect occurs when students must process separate, unintegrated information (e.g., switching between a complex text and a dictionary), which consumes cognitive resources and hinders deep understanding [42].

2.3. Collaborative Learning and the Jigsaw Technique in Higher Education

To address the hurdles identified by Cognitive Load Theory, cooperative learning stands out as a pedagogical framework that can reshape how students learn complex academic material. Within this paradigm, the Jigsaw technique is one of the most structured and empirically proven methods in higher education [43,44]. But it was originally designed to bridge social divides [45]; its core strength lies in positive interdependence, which means that an individual's academic success is tied directly to the collective success of their group [46].

The Jigsaw model creates opportunities for students from diverse backgrounds to cooperate and have equal access to learning, promoting mutual understanding [47]. This method encourages interaction and attention to peers, fostering empathy and perspective-taking [48,49]. Research shows that the Jigsaw approach can increase deep learning by approximately 15–25% [50,51], and improve academic motivation and learning outcomes compared to traditional lectures [52,53]. The technique works by breaking content into manageable parts. Students begin in 'home groups' and move to 'expert groups' to analyze and master a specific section [43]. They then return to their original groups as 'teachers' to explain their part and rebuild a complete understanding of the material [45].

Evidence supports the effectiveness of Jigsaw in higher education and STEM, with positive effects on academic achievement [54] and adaptations such as the 'Subject Jigsaw' for advanced learning [55]. Its effectiveness in STEM is linked to the structured nature of these disciplines, which aligns with its modular design and enhances collaboration [56].

From a psychological perspective, Jigsaw reduces academic anxiety [57] by fostering a supportive rather than competitive environment, which lowers defensive barriers and strengthens social bonds in diverse classrooms [58,59].

In EMI contexts, Jigsaw distributes cognitive and emotional load, preventing students from facing complex texts individually [44]. Expert groups provide a supportive space to validate understanding, enhancing confidence and reducing fear of failure [60].

2.4. Linguistic Scaffolding in ESP/EMI Environments

Scaffolding draws on Vygotsky's Zone of Proximal Development (ZPD) and, in the context of bilingual learning, aligns with Sweller's Cognitive Load Theory [61]. Linguistic scaffolding involves providing temporary, structured support to guide students through syntactic hurdles that would otherwise prevent them from grasping the actual content [62,63]. This support is eventually phased out as the student's skills become more automatic, which drives their independence [62].

In university EMI and English for Specific Purposes settings, which are often characterized by dense, complex scientific vocabulary, scaffolding is imperative. Research shows that it shifts the strain on working memory away from 'useless' extrinsic load and toward the productive management of intrinsic and germane load [64]. While a teacher cannot change the inherent complexity of a field like Agronomy (the fixed intrinsic load), they can use scaffolding to clear the overwhelming extrinsic barriers that block students from remembering what they learn [62].

Applied linguistics research highlights several effective tools. Bilingual glossaries support the front-loading of terminology by linking L2 to L1 [38], reducing difficulties with technical vocabulary [28] and minimizing the split-attention effect [38,40]. Syntactic support, through templates that model academic conventions, stabilizes working memory and reduces the difficulty of structuring ideas in English [65].

Graphic organizers allow information to be encoded alongside written text [66], supporting the transition from abstract concepts to structured understanding and long-term memory [67]. Translanguaging practices, recognized as a multilingual strategy [68,69], allow the use of the native language (e.g., during the 'expert phase' of Jigsaw) to ensure conceptual understanding before expression in English, supporting epistemic accuracy [69].

Recent findings highlight the impact of these guides. A 2025 study by Mitina et al. [61] showed that scaffolding in bilingual STEM subjects reduces struggling students and increases high-level technical mastery, with the largest gains among lower-level students, supporting its role in promoting equity. By reducing extrinsic load through lexical and syntactic scaffolding [38], students can redirect their mental energy toward Germane load [64], enhancing critical thinking [70], analytical skills [29], and their ability to engage in demanding academic and professional contexts.

3. Materials and Methods

3.1. Participants and Educational Context

This was a quasi-experimental factorial design conducted on students from the Master's program in Agricultural Engineering. The sample consisted of 70 students ($n = 70$) (57.1% male and 42.9% female) from the first academic year of the 'Productivity and management in agricultural systems' course.

To ensure balanced groups, students completed a language skills survey prior to the activity. In this survey, participants were asked about their perceived level of English proficiency and whether they held an English language certificate. English proficiency was distributed as follows: 20.0% at level A, 41.4% at level B, and 38.6% at level C. Additionally, a pre-test of linguistic knowledge was carried out, and the score obtained also served as a measure of their language skills. The linguistic pre-test allowed the creation of more refined groups, as it provided a more accurate assessment of their English level rather than relying solely on the students' self-perception of their level.

3.2. Materials

The review article titled "Synergies between biostimulants and plant nutrients: a review of eco-friendly nutrient management in crop production" by Basar et al. (2025) [71]

was selected as the main teaching resource for this activity due to its focus on sustainable agricultural practices, which aligns with the learning objectives of the subject. This text was suitable for the Jigsaw teaching technique due to its modular structure, which classifies biostimulants into three main categories: humic substances (HS), seaweed extracts (SWE), and protein hydrolysates (PHS). This division enabled an even distribution of sections among the expert groups. In addition, the article provides a detailed analysis of the complex physiological mechanisms and nutrient interactions, offering the depth necessary to challenge graduate students.

To support the reading of the scientific article on biostimulants, a linguistic guide was created (see Appendix A). This resource contains contextualized explanations of the most relevant lexical and syntactic sections of the academic language used in the paper. The guidelines of Olusegun et al. (2020) [72] were followed in preparing the guide and adapted to meet the needs of the paper. Only students from the three groups of Conventional and Jigsaw had access to this guide during the session, while the remaining groups worked on the original text without this additional support.

3.3. Implementation of the Jigsaw Technique

3.3.1. Selection of Materials and Preparation Phase

The research team conducted the planning and preparation phase prior to implementing the classroom activity during an English for Specific Purposes (ESP) seminar. The intervention and data collection procedures were carried out with prior coordination among the researchers to ensure consistency in the sequence of sessions, the instructions provided to students, the timing of the activities, the administration of the pre- and post-tests, and the management of the linguistic support materials. The process was supervised by the head of the research group, a Full Professor in the subject area with extensive experience in university teaching and research. First, a strategic selection of the scientific article was made, ensuring that its linguistic and conceptual complexity was appropriate for the participants' postgraduate level.

Based on this material, two fundamental assessment tools were designed for the activity: the pre-test and the post-test. The pre-test consisted of two multiple-choice exams (a to d) divided into content and linguistic competence based on the selected article, with a total of 20 questions (10 per exam). The goal of this test was to assess the students' prior knowledge before the collaborative activity.

On the other hand, the post-test was structured differently. It had 40 questions (20 per exam) divided into two blocks. In the first block, there were 10 identical questions to those used in the pre-test. The goal of this block was to enable a comparison to assess the net learning gain and retention of basic concepts. In the second block, ten new questions were added, all of which were designed to be more difficult. The objective of this block was to assess students' ability to apply the knowledge they had acquired to new or more complex questions, thereby measuring the depth of their reading and technical comprehension.

A visual presentation was also prepared, detailing the work sequence and the rules of the Jigsaw technique. This material was designed to ensure that students understood which groups they would be placed in and what they would do for the next 90 min.

All participants were Spanish nationals and native Spanish speakers. Before entering the Master's Degree in Agricultural Engineering, they had completed a Bachelor's Degree in Agri-Food Engineering. This linguistic and academic profile was particularly relevant to the study, as the students were required to engage with scientific and technical English in an Agricultural Engineering context where English was the language of instruction.

3.3.2. Jigsaw Technique

The students were divided into fourteen groups based on the survey and pre-test results. The distribution consisted of seven Jigsaw groups ($n = 5$ each) and seven Conventional groups ($n = 5$). To assess the impact of the linguistic guide on learning outcomes, this material was given exclusively to three of each, Conventional and Jigsaw, a total of 6 groups with the guide (Figure 1).

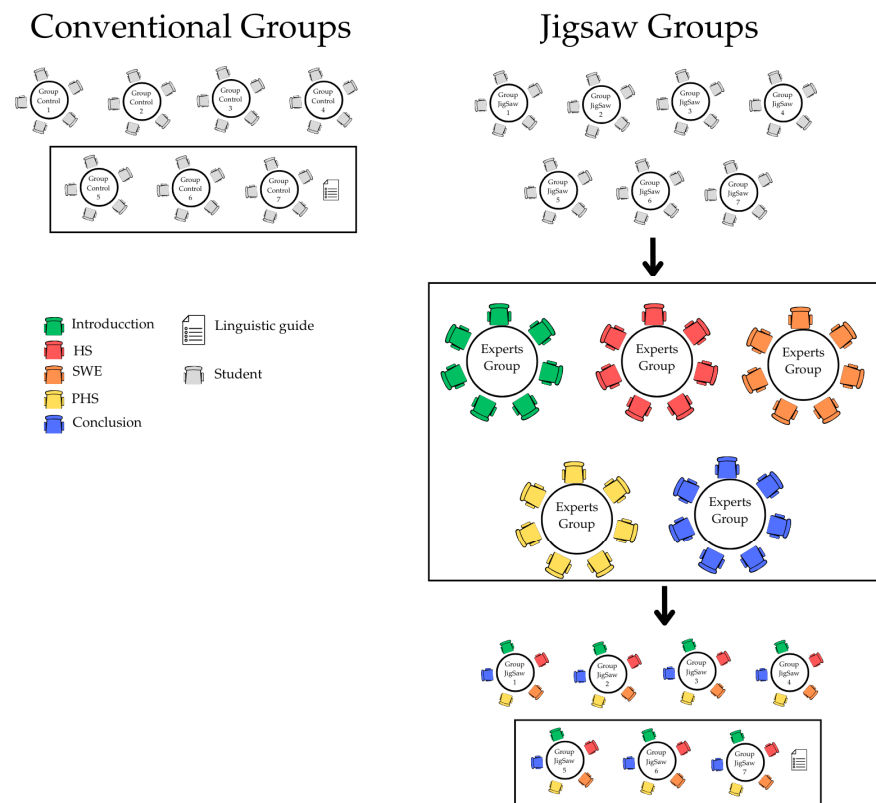


Figure 1. Steps of methodology employed for Conventional and Jigsaw experimental groups and linguistic guide distribution.

Since the paper worked in class does not follow IMRAD's basic structure. Figure 1 illustrates how the article's content was divided among the groups that used the Jigsaw technique. The Conventional groups did not receive any content division, as they were free to work on the paper as they saw fit. Participants were required to read the entire text before the session; the class activity focused on consolidating this prior theoretical knowledge through teammates' explanations and critical discussions of specific assigned sections.

The organization of the groups and the activity timeline are summarized in Figure 2. The time distribution during the activity was fixed at 50 min for all groups. However, the internal distribution of this time changed depending on the methodology used. On the one hand, Conventional groups worked collaboratively on the scientific article in their assigned groups for the entire 50 min, without switching members. On the other hand, time in Jigsaw groups was divided into two sequential phases of equal duration. During the first 25 min, the expert phase began. Here, students met with experts from other groups (seven participants each) to analyze their assigned section. In this new group, the members share a thematic relationship. Each of them must be informed about the topic and present it so that, when they return to their original group, they can handle it with ease, and each can explain their section to the rest of the members of the original group. When the time passed, the experts returned to their original group, and the reporting phase started. They had another 25 min to explain their part and complete their overall understanding of the

article. Each member of the original group learned about the other sections from their teammates so that, in the end, all participants were experts on all topics.

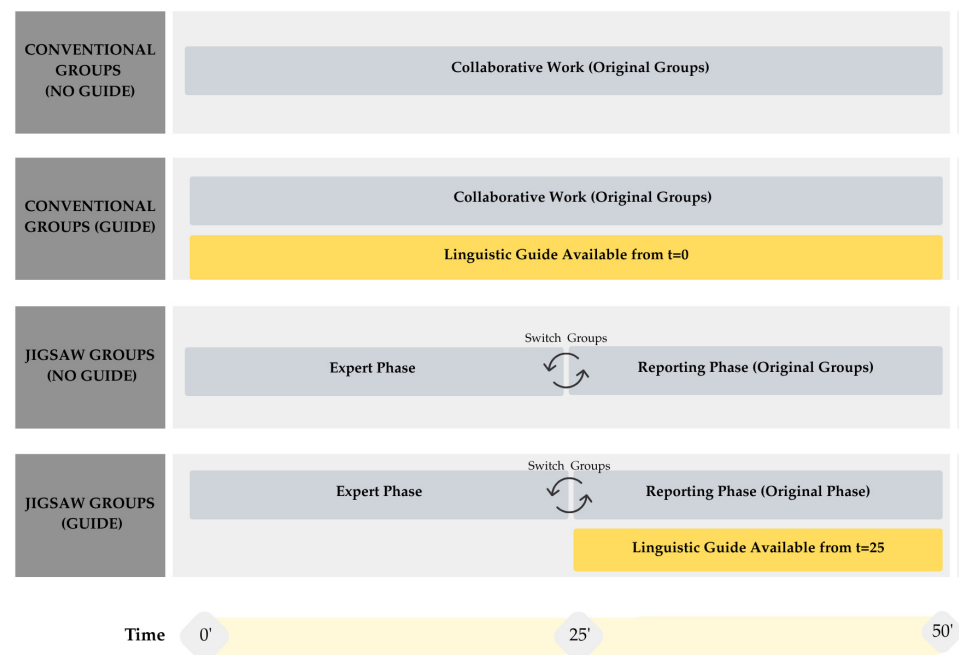


Figure 2. Group dynamics and activity timeline across conditions (Conventional vs. Jigsaw; Guide vs. No guide).

Immediately after the 50 min task was completed, students were asked to return to their seats, ensuring that the post-test was carried out independently. During the post-test, it was stated that the students who had the linguistic guide could not use it while taking the exam.

3.3.3. Linguistic Guide Management

As described in Section 3.2, three Conventional groups and three Jigsaw groups received a linguistic guide as additional support. This tool included lexical and syntactic explanations, together with contextualized examples drawn from the scientific article, in order to facilitate students' comprehension of academic and scientific English during the reading activity. The examples were used as illustrative instances of general linguistic features commonly found in scientific texts, rather than as a resource designed exclusively for the specific article.

In both instructional conditions assigned to the guide treatment, the linguistic guide was available from the beginning of the collaborative activity ($t = 0$). Therefore, Conventional groups with the guide were able to use it throughout the 50 min collaborative work period, while Jigsaw groups with the guide could also use it during both phases of the activity: the expert phase and the reporting phase. Students assigned to the no-guide condition did not receive this additional support.

Thus, the guide condition was implemented consistently across Conventional and Jigsaw groups in terms of availability time. The difference between instructional conditions was therefore not related to the duration of access to the guide, but to the organization of the collaborative work: unstructured work on the complete article in the Conventional groups versus expert-group analysis and peer reporting in the Jigsaw groups.

3.4. Data Collection

Statistical analyses were performed using R software (version 4.2.3). Students completed linguistic and content pre-tests and post-tests, scored on a 0–10 scale. Differences among English proficiency levels were analyzed using one-way ANOVA, followed by Tukey's HSD post hoc test ($p < 0.05$). Learning gains were calculated as the percentage difference between post-test and pre-test scores. Improvement in linguistic competence and content knowledge was analyzed using a three-way fixed-effects ANOVA, with instructional group (Conventional vs. Jigsaw), linguistic guidance (Guide vs. No guide), and English level (A1–A2, B1–B2, C1–C2) as between-subject factors. The effect size was estimated as the percentage of the sum of squares.

4. Results

4.1. Relations Between English Level and Academic Results

70 students completed four exams: two pre-tests and two post-tests. The pre-tests evaluated students' linguistic competence (linguistic test) and their scientific comprehension of the assigned reading (content test). Both tests consisted of 20 questions and were scored on a 0–10 scale.

4.1.1. Linguistic Results

At the start of the study, linguistic performance increased consistently with the English level of the student (Figure 3a). Mean scores were lowest for A1–A2 (3.90), intermediate for B1–B2 (7.90), and highest for C1–C2 (8.50); post hoc analysis indicated that Group A (b) differed significantly from Groups B and C (both a).

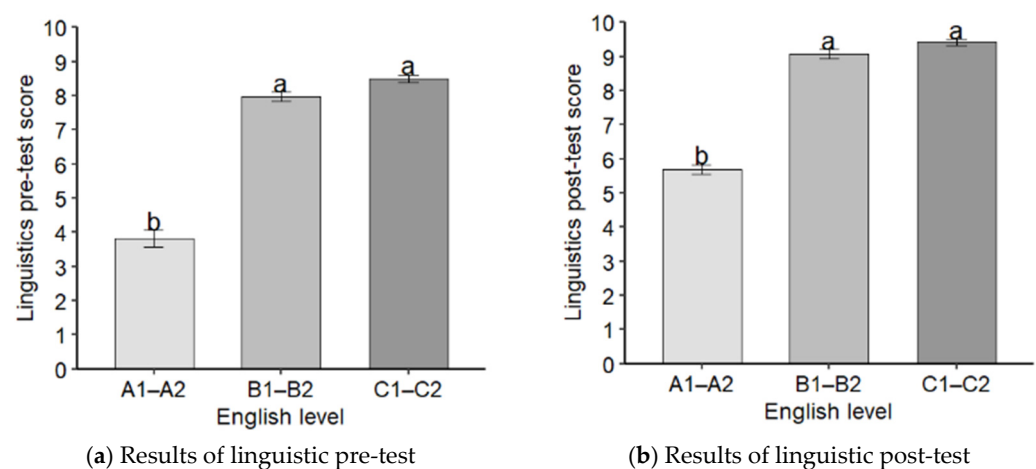


Figure 3. Results of linguistic pre-test (a) and linguistic post-test (b) depending on the English level of the students. Different letters indicate significant differences (one-way ANOVA followed by Tukey's HSD, $p < 0.05$).

A similar pattern emerged for linguistic results on the post-test (Figure 3b). Notably, the statistical differences between the groups remained consistent, mirroring the pre-test results. All students passed the post-test, achieving higher averages for each level of English than in the previous test, with results by level of A (5.80), B (8.95), and C (9.15).

The linguistic competence exam was split into two content domains (Lexicon and Syntax). Pre-test and post-test outcomes by English competence level are shown in Figure 4, with scores expressed as the percentage of correct answers (mean $\pm$ standard error).

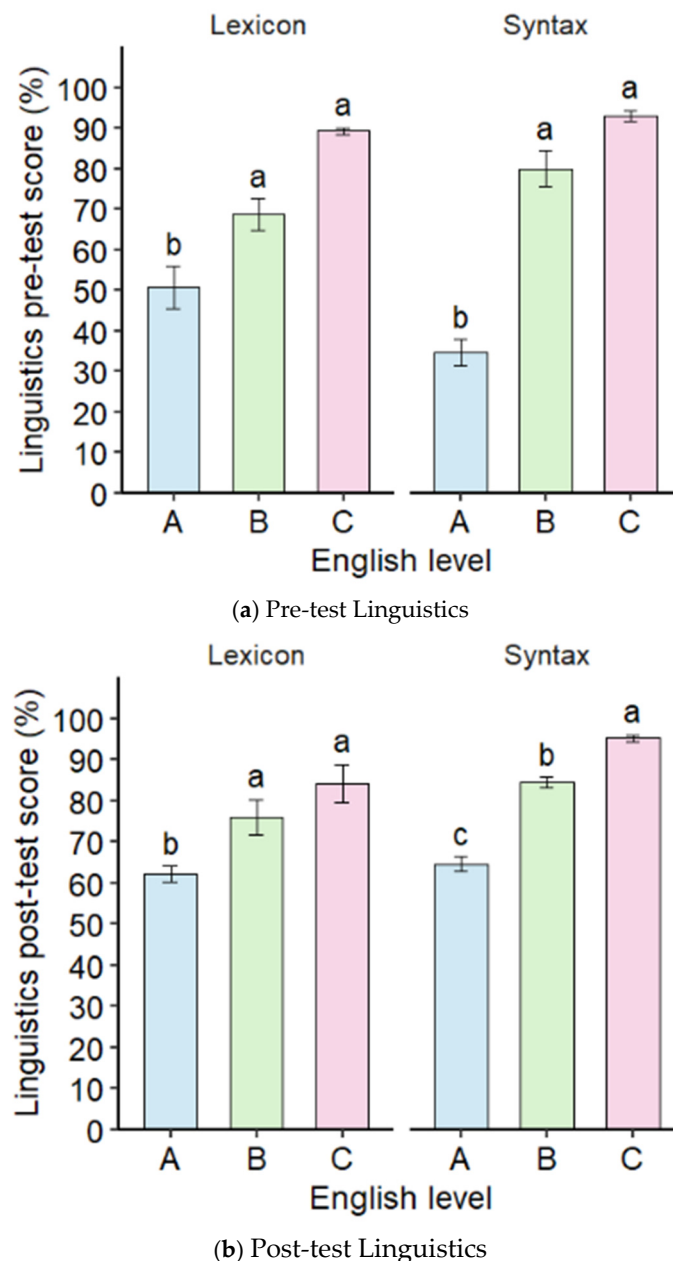


Figure 4. Pre (a) and post-test (b) scores across English levels in linguistic content exams (Lexicon and Syntax). Bars represent means $\pm$ standard error. Different letters indicate statistically significant differences between English proficiency levels within each subtest (Tukey HSD, $p < 0.05$).

In the pre-test, performance differed significantly by English level in both domains. Regarding Lexicon, students at level A obtained markedly lower scores (50%) than those at levels B (68%) and C (90%), which did not differ from each other (Tukey HSD, $p < 0.05$). Similarly, Syntax scores showed that level A had the lowest performance (35%), while levels B (80%) and C (93%) achieved substantially higher marks. Overall, Syntax proved to be the most challenging component for level A students in the pre-test.

In the post-test, scores increased across proficiency levels, with the strongest gains concentrated among lower-proficiency learners. Level A improved to 60% in Lexicon and 65% in Syntax, which reflects a clear enhancement of linguistic competencies after the activity. Nevertheless, significant differences remained across English levels, characterized by a consistent gradient $A < B < C$ in both Lexicon (60%, 75%, 92%) and Syntax (65%, 85%, 95%) (Tukey HSD, $p < 0.05$). These results suggest that, although students

improved overall—particularly those starting at lower proficiency—the proficiency-related gap persisted at the end of the study period.

4.1.2. Content Results

Content learning performance was analyzed by English proficiency level (A, B, and C) for the pre-test and post-test (Figure 5). Scores are reported as means $\pm$ standard error, and different letters denote statistically significant differences among proficiency levels (one-way ANOVA followed by Tukey's HSD, $p < 0.05$).

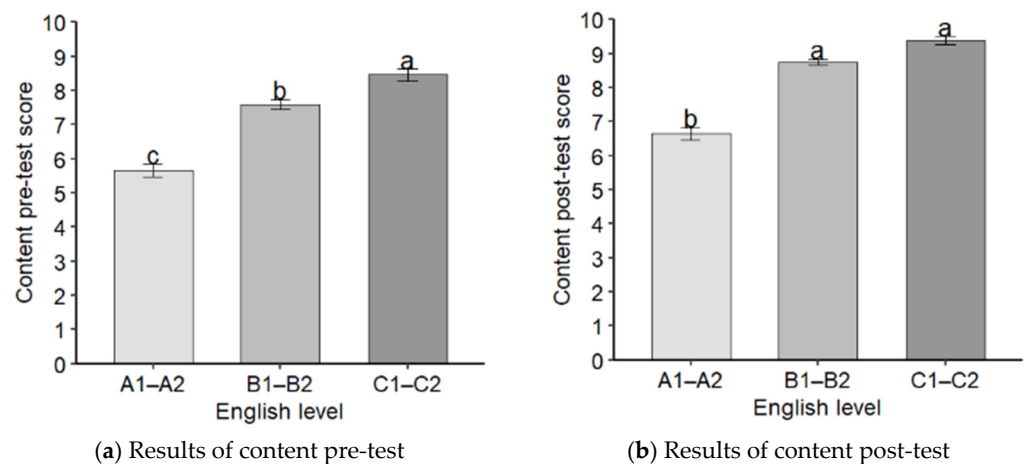


Figure 5. Results of the content pre-test (a) and post-test (b) depending on the English level of the students. Different letters indicate significant differences (one-way ANOVA followed by Tukey's HSD, $p < 0.05$).

In the pre-test (Figure 5a), overall content scores increased with English level, with A showing the lowest performance (5.75), followed by B (7.65) and C (8.30), and all three levels differed significantly (Tukey, $p < 0.05$). In the post-test (Figure 5b), overall content scores increased across levels, reaching 6.6 (A), 8.8 (B), and 9.4 (C). Level A remained significantly lower than B and C, whereas B and C were not significantly different (Tukey, $p < 0.05$).

Figure 6 shows the students' results on the content tests, which were divided into thematic sections (Introduction, HS, SWE, PHS and Conclusion). The results of the pre-test, illustrated in Figure 6a, present a consistent proficiency gradient, with level A scoring lowest across sections (approximately: Introduction 55%, HS 45%, SWE 73%, PHS 50%, Conclusion 59%), while levels B and C were higher (around 75–95%), and significant differences were indicated in each section by letter groups. In the post-test results (Figure 6b), section scores increased, and high-proficiency students approached ceiling values in several sections (e.g., SWE and Conclusion for level C were around 100%); in contrast, level A improved notably (approximately: Introduction 85%, SWE 74%, PHS 62% and Conclusion 61%) but remained significantly below higher levels in most sections (Tukey, $p < 0.05$).

4.2. Effects of Instructional Group, Linguistic Guide and English Proficiency on Learning Gains

A three-way fixed-effects ANOVA was conducted on improvement (difference between post-test and pre-test scores, %) for both linguistic competence and content knowledge, with Group (Conventional vs. Jigsaw), Guidance (Guide vs. No guide), and English level (A1–A2, B1–B2, C1–C2) as between-subject factors (Table 1). The analysis partitions the variability in learning gains into the contribution of each factor and their interactions. The percentage of sum of squares (% SS) is reported to indicate the relative contribution of each factor to the total variability in learning gains.

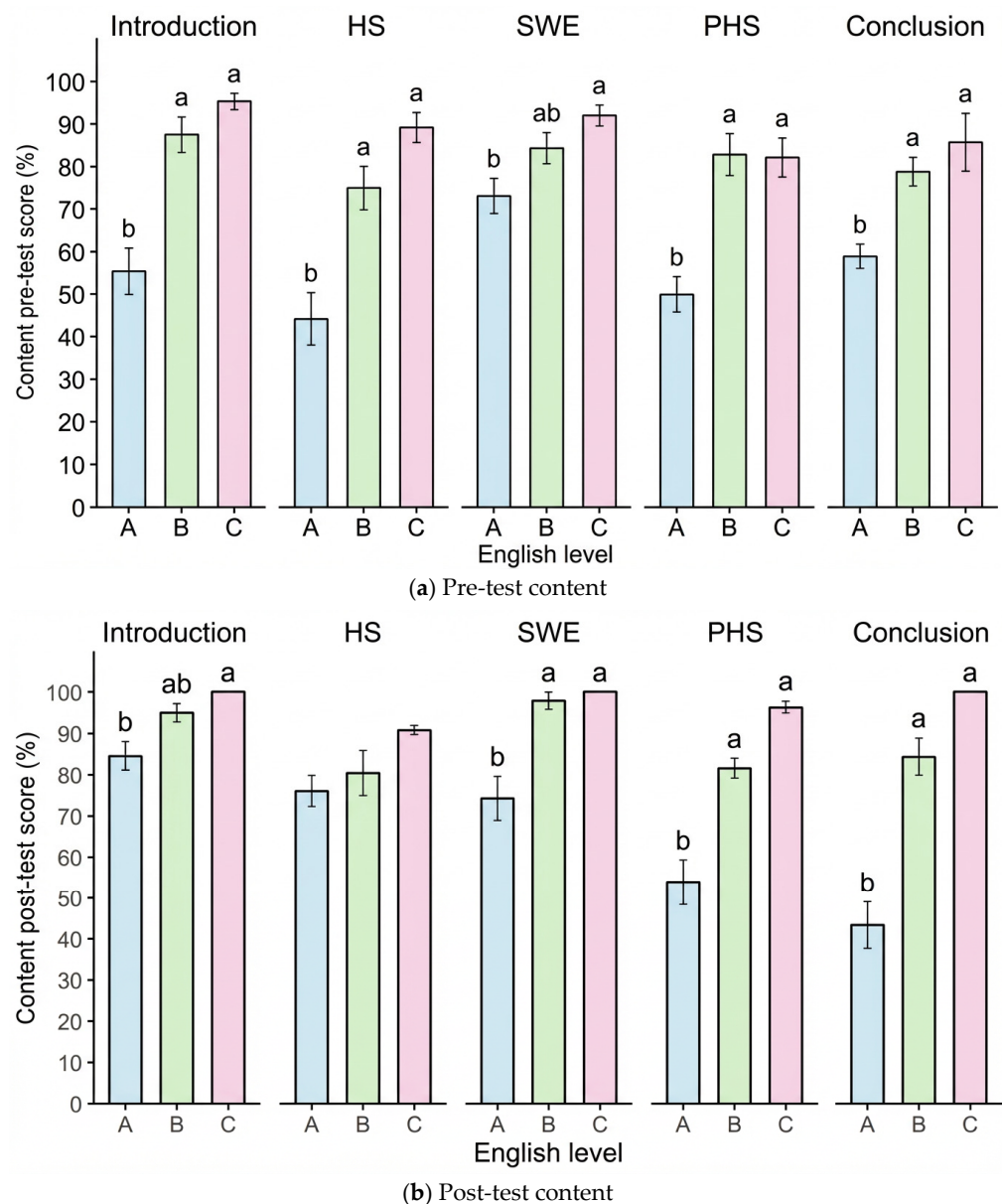


Figure 6. Pre-test (a) and post-test (b) scores across English levels in content exams divided into thematic sections. Bars represent means $\pm$ standard error. Different letters indicate statistically significant differences between English proficiency levels within each subtest (Tukey HSD, $p < 0.05$).

For linguistic improvement, English level was the only significant main effect, explaining the largest share of variability (57.49% of the sum of squares; $p < 0.01$), in contrast to the non-significant Group (2.10%) and Guidance (0.62%). For content improvement, significant main effects were detected for Group (27.49% SS; $p < 0.05$), Guidance (5.80% SS; $p < 0.05$), and English level (16.77% SS; $p < 0.05$). No interaction terms (Group $\times$ Guidance, Group $\times$ English level, Guidance $\times$ English level) were significant for either outcome (all $p > 0.05$), which indicates that factor effects were largely additive.

For content improvement, Jigsaw showed higher gains than Conventional (Linguistic: 28.17% vs. 19.75%; Content: 11.38% vs. 3.98%), and the Guide condition outperformed No guide (Linguistic: 26.25% vs. 21.67%; Content: 9.38% vs. 5.98%). By English level, the A1–A2 subgroup exhibited the largest improvements (Linguistic: 46.97%; Content: 10.91%) and differed from B1–B2 and C1–C2, which showed lower and comparable gains (Linguistic: 12.53–12.38%; Content: 6.61–5.50%), consistent with the post hoc grouping letters (same letters indicate non-significant differences at $\alpha = 0.05$).

Table 1. Three-way ANOVA (Group $\times$ Linguistic guide $\times$ English level) on improvement (%) in linguistic competence and content knowledge, with descriptive means and post hoc grouping letters. (*) Indicates significant differences at $p < 0.05$; (**) indicates significant differences at $p \leq 0$.

	Improvement (%)			
	Linguistic		Content	
Group				
Conventional	19.75		3.98	b
Jigsaw	28.17		11.38	a
Linguistic guide				
Guide	26.25		9.38	a
No guide	21.67		5.98	b
English level				
A1–A2	46.97	a	10.91	a
B1–B2	12.53	b	6.61	b
C1–C2	12.38	b	5.50	b
ANOVA	% Sum of squares			
Factor (df)				
G (1)	2.10		27.49	*
g (1)	0.62		5.80	*
NI (2)	57.49	**	16.77	*
G*g (1)	7.16		0.05	
G*NI (2)	8.61		4.65	
g*NI (2)	3.15		1.83	
Residuals (11)	5.23		1.81	

Across outcomes, the ANOVA revealed distinct patterns within each domain. Linguistic improvement varied significantly by English level, with the A1–A2 group showing the highest gains, whereas Group and Guidance were not significant, and no interaction terms were detected. In content improvement, significant differences were observed for Group, Guidance, and English level, with higher gains under Jigsaw and in the Guide condition, and in A1–A2 compared with the higher-level groups. No significant interactions were found for either outcome.

5. Discussion

Developing strong reading abilities is a fundamental requirement for achieving academic goals [73]. Since reading comprehension serves as the essential framework for acquiring knowledge in any discipline, it is unlikely that students will achieve high levels of success in other curricular subjects if they have not first mastered this skill [74]. In the context of this study, the results clearly show that both linguistic competence and content comprehension are strongly conditioned by the students' level of English. These findings reveal a persistent challenge in bilingual programs where the extra effort needed to handle the language often forces students to focus only on basic comprehension. Consequently, they cannot engage deeply with the scientific content, suggesting that English acts as a barrier to participation rather than a tool for communication [1,6]. Although we analyzed reading comprehension associated with content and linguistic capacity, there are external factors that are difficult to measure but influence how a student approaches the task.

The fact that a text is written in a foreign language can complicate comprehension and may generate high levels of anxiety [75]. This issue is particularly relevant for students with lower English proficiency, given that anxiety interferes with the learner's cognitive capacity to absorb, process, and produce a foreign language [76–79]. Such cognitive interference creates a barrier that prevents students from performing at their true academic potential,

implying that bilingual programs in Agronomy might accidentally penalize students for their language level rather than their scientific knowledge. Consequently, there is an urgent need for a more supportive teaching design that accounts for the linguistic reality of the Spanish EMI context [22].

This phenomenon aligns closely with Cognitive Load Theory [80], which suggests that the human brain has a limited amount of processing power. For students with low English proficiency, a large proportion of this cognitive capacity is devoted to decoding and translating linguistic forms (extraneous load) rather than learning agronomy content (germane load) [81], thereby leaving very little room for meaningful learning of scientific content. In this sense, instructional strategies that reduce linguistic processing demands may help reallocate cognitive resources toward content understanding. However, we must ask if simplifying the task is enough. Our results show that even with support, the difficult concepts of Agronomy remain out of reach if the student does not meet a minimum language level [31,34], which indicates that the intrinsic load of a discipline like Agronomy cannot be bypassed solely through pedagogical techniques.

As shown in Figure 3, students' lower performance at the A1–A2 levels across both linguistic and content assessments can be attributed to the lack of a sufficiently high language threshold. Research by Masrai et al. (2019) [82] suggests that while advanced readers use a wide range of vocabulary to understand text, those with lower proficiency rely on basic high-frequency words, thereby limiting their ability to grasp complex academic material. Furthermore, students at these levels often struggle to maintain the logical flow of scientific arguments because they are frequently overwhelmed by grammatical structures and lack the necessary metacognitive depth [83]. This creates a cognitive imbalance whereby students' mental energy is largely consumed by the mechanical process of decoding the language instead of focusing on the subject matter [84]. This asymmetry confirms a gap in bilingual environments. Students who already know English continue to deepen their knowledge, while those at lower levels remain in a cycle of basic translation that prevents them from ever reaching the higher-level thinking required in science [84,85].

The data presented in Figure 5 mirror the trends observed in Figure 3, reinforcing the hypothesis that a minimal linguistic threshold is vital for effective learning in English-mediated environments. Despite overall improvements in post-test performance, significant differences between proficiency levels remained, indicating that academic success is deeply intertwined with the student's ability to efficiently process and understand complex texts [85]. The fact that the performance gap increased in the conclusion section is particularly revealing, as it demonstrates that while students can recall descriptive data, they remain excluded from the critical analysis of the results. This disparity implies that current scaffolding is more effective for data recall than for integrating complex concepts.

As indicated by the results, students who lack a solid vocabulary and sufficient prior linguistic knowledge struggle to draw logical conclusions or fully grasp instructional materials. This performance gap can be explained by the concept of cognitive resource allocation. According to Segalowitz et al. (2003) [84], when a learner reaches a high level of linguistic fluency or automaticity, typically observed in intermediate and high-level students, the brain can shift its focus from language processing to content integration. Therefore, although lower-proficiency students showed significant gains from pre-test to post-test, the persistence of lower overall scores confirms that language remains a key limiting factor in learning the content.

Since the activity focused on the comprehension of a scientific article, English proficiency emerged as a critical variable. Content post-test results indicated that students with medium and high proficiency levels achieved higher scores, while those with lower proficiency continued to struggle (Figure 6). Although the performance gap narrowed in

sections such as the introduction and SWE, it increased notably in the conclusion, which is the core of a scientific article that synthesizes key findings and original contributions. Difficulties in understanding this section suggest that linguistic barriers continue to limit deeper levels of academic comprehension for lower-proficiency students, even when surface-level understanding improves.

The aim of the present study was to compare student performance based on the instructional technique (structured Jigsaw versus collaborative group work) and to examine the effect of a linguistic guide. When analyzing the improvement (Table 1), students exposed to the Jigsaw technique showed significantly greater gains in content knowledge than the Conventional groups, whereas no significant differences were observed in linguistic improvement. These findings partially support the theories presented by Blasco Margarer et al. (2022) [86] regarding the efficacy of the Jigsaw method. However, the Jigsaw technique functions as a shortcut for students to access scientific material. While it allows students to understand science by relying on the ‘positive interdependence’ of their peers [43], it does not fix their underlying language problems. While Jigsaw is a powerful tool for equity in content access, it is not sufficient on its own for developing formal language in STEM contexts.

An important methodological consideration concerns the potential confounding between the Jigsaw technique and text segmentation. In the present study, the Jigsaw condition involved dividing the scientific article into smaller thematic sections, which students explored in expert groups before teaching their peers, whereas Conventional groups worked on the full text without structured segmentation. While this may appear as a confounding factor, it is important to note that text segmentation is not an independent instructional variable but a defining feature of the Jigsaw methodology itself. The pedagogical logic of Jigsaw is inherently based on breaking complex content into manageable units, assigning expert roles, and reconstructing knowledge through peer teaching. From a cognitive perspective, this process aligns with Cognitive Load Theory, as it reduces processing demands and facilitates deeper understanding. Therefore, the observed effects should be interpreted as the result of the Jigsaw approach as a whole, including both structured collaboration and content segmentation. Nevertheless, the absence of an equivalent segmented condition in the Conventional group limits the ability to isolate the specific contribution of text division alone.

When comparing the Jigsaw technique with and without the linguistic guide, the data suggest a consistent pattern. Students who used the linguistic guide achieved significantly greater gains in content knowledge, while no significant effects were found for linguistic improvement. The absence of significant linguistic gains may reflect the short-term and content-oriented nature of the intervention, as second-language development generally requires sustained and repeated exposure, and instructional time has been identified as a significant moderator of language-learning outcomes in EMI contexts [87]. Although the statistical analysis showed no interaction effects, this supports it qualitatively, as it appears particularly relevant for students with lower initial English proficiency, who face the dual challenge of understanding complex agronomic concepts while processing a foreign language. In this context, the linguistic guide acts as a scaffold. It does not replace the learner’s cognitive effort but provides targeted support that helps lower-proficiency students engage more effectively with the text. Rather than equalizing final performance levels, the guide helps reduce linguistic barriers that would otherwise prevent access to core disciplinary knowledge. Simultaneously, the Jigsaw model further contributes to a more inclusive learning environment by ensuring that English proficiency does not determine learning opportunities. This pattern of differential gains suggests that the combination of cooperative learning and linguistic scaffolding is particularly beneficial

for students with lower English proficiency, while higher-level students may rely more on their existing linguistic and academic skills. These findings align with Wachyunni et al.'s conclusion 2016 [88] that scaffolding within cooperative learning strategies is significantly more effective at improving comprehension than non-scaffolded approaches. In the post-pandemic era, where classrooms are increasingly diverse, such creative approaches to scaffolding are essential for transforming the English language curriculum into a more inclusive and accessible space.

Taken together, these results highlight the need to integrate linguistic scaffolding into active learning methodologies within ESP settings to reduce proficiency-related barriers and promote more equitable access to disciplinary knowledge presented in English. Since these language barriers universally restrict academic mobility and professional growth, this combined approach offers a transferable model for international STEAM programs.

6. Conclusions

The dominance of English in scientific communication is a major barrier for non-native students, often preventing them from reaching their full academic potential. This study demonstrated that the implementation of the Jigsaw cooperative learning technique and the provision of a linguistic guide were effective in improving content knowledge, with both interventions outperforming better results than the unstructured groups. However, the results showed a clear difference between content knowledge and linguistic competence.

Although the activities helped students understand the subject matter effectively, they did not improve their English proficiency more than the traditional method. Linguistic competence remained largely determined by the students' initial proficiency, with A1–A2 students showing the highest relative gains. This suggests that this technique helps students access the content effectively, even if they do not significantly speed up English learning in the short term.

The results of this study contribute to integrating structured cooperative learning as a complementary tool within the teaching strategy for improving scientific content comprehension in STEM Master's education. The results suggest that the Jigsaw technique enhances the acquisition of specific competencies in Agricultural and Biological Engineering domains. However, the Jigsaw condition combined text segmentation, expert-group collaboration, and peer teaching, the present study does not isolate the individual contribution of each component, and the findings therefore reflect the methodology as an integrated instructional approach. In addition, the use of a single scientific review article during one academic year, within one course at one university, limits the generalizability of the findings. Further research should replicate the intervention across institutions, STEM disciplines, course formats, larger samples, and different scientific texts.

Despite the lack of statistical interaction, the qualitative impact of the linguistic guide was particularly relevant for lower proficiency students. For this group, the guide served as a necessary scaffold, preventing the language barrier from hindering comprehension. By showing that a linguistic guide helps students master complex subjects even with limited English skills, this study provides a practical way to make bilingual programs more effective and accessible for all learners. Consequently, this study highlights the urgent need to integrate active learning with linguistic support in English-Medium Instruction. Doing so creates a more inclusive environment where limited English proficiency does not prevent academic success, supporting the idea that all students have equal opportunities to engage with scientific texts, regardless of their English proficiency.

Author Contributions: Conceptualization, C.G.-R., A.A.-M., R.S. and A.S.B.; methodology, C.G.-R., A.A.-M. and R.S.; software, C.G.-R., A.A.-M. and R.S.; validation, C.G.-R.; formal analysis, C.G.-R., A.A.-M. and R.S.; investigation, C.G.-R., A.A.-M. and R.S.; resources, C.G.-R. and A.S.B.; data curation,

A.S.B.; writing—original draft preparation, C.G.-R., A.A.-M., R.S. and A.S.B.; writing—review and editing, C.G.-R., A.A.-M., R.S. and A.S.B.; visualization, C.G.-R. and A.A.-M.; supervision, R.S. and A.S.B.; project administration, A.S.B.; funding acquisition, A.S.B. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: The study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of the Universitat Politècnica de València (protocol code P09_29-07-2025; date of approval: 22 September 2025).

Data Availability Statement: The test exams and other data supporting the conclusions of this article will be made available by the authors upon request.

Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

Linguistic Guide for Reading Scientific Articles: Biostimulants Case Study.

1. Lexical Features (WORDS)

This section focuses on the specific vocabulary, terminology, and data chosen by the authors to convey precision and scientific meaning.

1. Use of Long or Compound Words: The text utilizes multi-syllabic and compound words to describe complex biological concepts and materials efficiently.
 - The use of biostimulants has shown great promise in this regard and could pave the way for reducing the reliance on inorganic fertilizers with no significant reduction in crop yield.
 - A biostimulant is a term used to signify a diversity of compounds which have been described in multiple ways as biogenic stimulants, metabolic enhancers, plant conditioners, phytostimulators, or biofertilizers.
 - Protein hydrolysates are obtained by the chemical or enzymatic hydrolysis of different agro-industrial byproducts or animal-derived waste. . .
2. Use of Nominal Words: The text frequently turns verbs or adjectives into nouns (nominalization). This allows processes to be discussed as abstract concepts.
 - Management (from “manage”): This review aims to highlight the use of biostimulants in crop nutrient management and their effectiveness in reducing the use of chemical fertilizers.
 - Deterioration (from “deteriorate”): In addition, the emerging challenges of diminishing natural resources, land degradation, environmental deterioration, and climate change further complicate the situation. . .
 - Mobilization (from “mobilize”): . . .promoting soil microorganisms to enhance the mobilization of nutrients from organic sources. . .
3. Use of Technical Terms: The text relies on specific jargon that requires domain knowledge in agronomy and biology.
 - The impacts of climate change are particularly concerning, as these could aggravate the intensity of different biotic and abiotic stresses. . .
 - . . .improving one of the following characteristics of the plant or plant rhizosphere: (i) nutrient use efficiency, (ii) tolerance to abiotic stress. . .
 - Seaweed extract also affects nutrient uptake by promoting the hyphal growth of arbuscular mycorrhizal fungi (AMF). . .

- Humic substances increase the activity of H⁺-ATPase enzyme in plant roots which increases the pumping of H⁺ in the rhizosphere. . .

2. Syntactic Features (GRAMMAR)

This section focuses on how sentences are constructed, how ideas are connected, and the grammatical choices that establish an objective academic tone.

1. **Frequent Use of the Passive Voice:** The passive voice is used to focus on the research or the object, rather than the person doing the action.
 - These products are primarily obtained from different natural sources. . .
 - Findings from different studies on the interactive effects of different biostimulants and essential plant nutrients have been extensively reviewed. . .
 - Biostimulants were first defined by Zhang et al. as the ‘materials that, in minute quantities, improve plant growth.
2. **Frequent Use of Declarative Sentences:** The text uses statements of fact to convey information clearly and authoritatively.
 - Soil fertility and soil health are the major drivers for successful crop production. . .
 - In fact, synthetic fertilizers play a critical role in augmenting crop productivity in fields under both optimal and suboptimal conditions.
3. **Frequent Use of Present Tense:** The simple present tense is used to describe established scientific facts, definitions, and the current state of knowledge.
 - This review aims to highlight the use of biostimulants in crop nutrient management. . .
 - Biostimulants enhance nutrient absorption by activating various plant and soil processes. . .
 - Organic matter plays a critical role in soil functionality. . .
4. **Use of Prepositional Phrases:** Phrases starting with prepositions (of, in, to, for) are used to add detail and precision.
 - This requires a shift from intensive use of fertilizers to a more eco-friendly system using alternative sustainable inputs.
 - In addition, the emerging challenges of diminishing natural resources, land degradation. . .
 - In addition, fertilizer manufacturing is a highly energy-intensive process which not only considerably contributes to greenhouse gas (GHG) emissions. . .
5. **Use of Logical Connectors:** Transitional words are used to show the logical relationship (contrast, result, addition) between sentences.
 - **Result/Consequence:**
 - Therefore, current efforts need to be directed towards finding sustainable alternatives. . .
 - Thus, combining marginal inputs of essential nutrients with SWE presents a promising strategy. . .
 - . . .does not always synchronize with crop demand; hence, synthetic fertilizers are frequently used. . .
 - **Contrast/Concession:**
 - However, the success of GR was greatly dependent on the input of non-renewable resources. . .
 - Nevertheless, balancing the trade-offs between crop production and ecosystem conservation is challenging. . .
 - Alternatively, the use of biostimulants is a promising tool. . .

- Addition:
 - In addition, the emerging challenges of diminishing natural resources. . . further complicate the situation. . .
 - Furthermore, HS chelate micronutrients through their diverse functional groups. . .
- 6. Use of modal verbs: The text uses modal verbs to express scientific caution or possibility, rather than absolute certainty.
 - The impacts of climate change are particularly concerning as these could aggravate the intensity of different biotic and abiotic stresses, which could lead to yield losses. . .
 - This may be explained by the variable composition of the HS, the variable response of different cultivars. . .
 - This can create uncertainty for farmers and manufacturers.

References

1. Gordin, M.D. *How Science Was Done Before and After Global English*; Scientific Babel; University of Chicago Press: Chicago, IL, USA, 2015.
2. Burgess, S.; Gea-Valor, M.L.; Moreno, A.I.; Rey-Rocha, J. Affordances and constraints on research publication: A comparative study of the language choices of Spanish historians and psychologists. *J. Engl. Acad. Purp.* **2014**, *14*, 72–83. [\[CrossRef\]](#)
3. Bocanegra-Valle, A. “English is my default academic language”: Voices from LSP scholars publishing in a multilingual journal. *J. Engl. Acad. Purp.* **2014**, *13*, 65–77. [\[CrossRef\]](#)
4. Hamel, R.E. The dominance of English in the international scientific periodical literature and the future of language use in science. *AILA Rev.* **2007**, *20*, 53–71. [\[CrossRef\]](#)
5. Hynninen, N.; Kuteeva, M. Researchers’ language practices concerning knowledge production and dissemination: Discourses of mono- and multilingualism. In *Language Perceptions and Practices in Multilingual Universities*; Kuteeva, M., Kaufhold, K., Hynninen, N., Eds.; Palgrave Macmillan: Cham, Switzerland, 2020; pp. 323–350. [\[CrossRef\]](#)
6. Ramírez-Castañeda, V. Disadvantages in preparing and publishing scientific papers caused by the dominance of the English language in science: The case of Colombian researchers in biological sciences. *PLoS ONE* **2020**, *15*, e0238372. [\[CrossRef\]](#)
7. Kuteeva, M. If not English then what? Unpacking language hierarchies at university. In *Language Perceptions and Practices in Multilingual Universities*; Kuteeva, M., Kaufhold, K., Hynninen, N., Eds.; Palgrave Macmillan: Cham, Switzerland, 2020; pp. 27–55. [\[CrossRef\]](#)
8. Lasagabaster, D. El papel del inglés en el fomento del multilingüismo en la universidad. *ELIA* **2017**, *12*, 13–44.
9. Järnlström, M.; Piekkari, R.; Pilke, N.; Turpeinen, H. Perceptions of language (mis)fit at a multilingual workplace: The case of the University of Vaasa. In *Language Perceptions and Practices in Multilingual Universities*; Kuteeva, M., Kaufhold, K., Hynninen, N., Eds.; Palgrave Macmillan: Cham, Switzerland, 2020; pp. 293–322. [\[CrossRef\]](#)
10. Kolosai, N. Meeting cultures and languages in the classroom: Rethinking Aronson’s method. *Neveléstudomány* **2021**, *9*, 83–103. [\[CrossRef\]](#)
11. Karimi Moonaghi, H.; Mohammady, A.; Salehmoghaddam, A.; Gholami, H.; Karshki, H.; Zamanian, N. Comparing the effects of cooperative learning to lecture trainings on the motivational beliefs and self-regulating learning strategies. *Iran. J. Med. Educ.* **2014**, *14*, 393–402. Available online: <http://ijme.mui.ac.ir/article-1-3096-fa.html> (accessed on 1 March 2026).
12. Muenks, K.; Wigfield, A.; Yang, J.S.; O’Neal, C.R. How true is grit? Assessing its relations to high school and college students’ personality characteristics, self-regulation, engagement, and achievement. *J. Educ. Psychol.* **2017**, *109*, 599. [\[CrossRef\]](#)
13. Abrami, P.C.; Bernard, R.M.; Borokhovski, E.; Waddington, D.I.; Wade, C.A.; Persson, T. Strategies for teaching students to think critically: A meta-analysis. *Rev. Educ. Res.* **2015**, *85*, 275–314. [\[CrossRef\]](#)
14. Thurston, A.; Topping, K.J.; Tolmie, A.; Christie, D.; Karagiannidou, E.; Murray, P. Cooperative learning in science: Follow-up from primary to high school. *Int. J. Sci. Educ.* **2010**, *32*, 501–522. [\[CrossRef\]](#)
15. Tran, V.D. The effects of cooperative learning on the academic achievement and knowledge retention. *Int. J. High. Educ.* **2014**, *3*, 131. [\[CrossRef\]](#)
16. Navarro, F.; Lillis, T.; Donahue, T.; Curry, M.J.; Ávila Reyes, N.; Gustafsson, M.; Zavala, V.; Lauría, D.; Lukin, A.; McKinney, C.; et al. Rethinking English as a lingua franca in scientific-academic contexts. A position statement. *J. Engl. Res. Publ. Purp.* **2022**, *3*, 143–153. [\[CrossRef\]](#)

17. Amano, T.; Berdejo-Espinola, V.; Christie, A.P.; Willott, K.; Akasaka, M.; Báldi, A.; Berthinussen, A.; Bertolino, S.; Bladon, A.J.; Chen, M.; et al. Tapping into non-English-language science for the conservation of global biodiversity. *PLoS Biol.* **2021**, *19*, e3001296. [\[CrossRef\]](#)
18. Murata, K. (Ed.) *English-Medium Instruction from an English as a Lingua Franca Perspective: Exploring the Higher Education Context*, 1st ed.; Routledge: Londres, UK, 2018. [\[CrossRef\]](#)
19. Mauranen, A. Signaling and preventing misunderstanding in English as lingua franca communication. *Int. J. Sociol. Lang.* **2006**, *177*, 123–150. [\[CrossRef\]](#)
20. Macaro, E.; Curle, S.; Pun, J.; An, J.; Dearden, J. A systematic review of English medium instruction in higher education. *Lang. Teach.* **2018**, *51*, 36–76. [\[CrossRef\]](#)
21. British Council. *The Changing Landscape of English-Taught Programmes*; British Council: London, UK, 2021.
22. Fernández Costales, A.; Lasagabaster Herrarte, D. English-Medium Instruction in Spanish universities: A systematic review. *Rev. Educ.* **2024**, *403*, 259–290. [\[CrossRef\]](#)
23. Sandström, A.-M.; Hudson, R. *The EAIE Barometer: Internationalisation in Europe*, 2nd ed.; European Association for International Education (EAIE): Amsterdam, The Netherlands, 2018.
24. Marinoni, G. *Internationalization of Higher Education: An Evolving Landscape, Locally and Globally*; International Association of Universities 5th Global Survey; Duz Medienhaus/International Association of Universities: Paris, France, 2019.
25. Chapple, J. Teaching in English Is Not Necessarily the Teaching of English. *Int. Educ. Stud.* **2015**, *8*, 1–13. [\[CrossRef\]](#)
26. Leask, B. *Internationalizing the Curriculum*; Routledge: London, UK, 2015.
27. Wilkinson, R. English-Medium Instruction at a Dutch University: Challenges and Pitfalls. In *English-Medium Instruction at Universities: Global Challenges*; Doiz, A., Lasagabaster, D., Sierra, J.M., Eds.; Multilingual Matters: Bristol, UK, 2013; pp. 3–26.
28. Sobirova, M. The importance of ESP in teaching English to students of the agricultural sector. *Int. J. Sci. Technol.* **2025**, *2*, 76–78. [\[CrossRef\]](#)
29. Hermawati, D.A. Meeting the needs of agribusiness students in an ESP-reading context. *J. Res. Engl. Lang. Learn. (J-REaLL)* **2022**, *3*, 55–60. [\[CrossRef\]](#)
30. Prasetyanto, M.; Maharddhika, R.; Trimus, S.E.P.L. The digital-mediated extensive reading on English Language learning of agriculture students. *J. Educ. Learn. (EduLearn)* **2024**, *18*, 107–115. [\[CrossRef\]](#)
31. Sweller, J.; van Merriënboer, J.J.G.; Paas, F.G.W.C. Cognitive Architecture and Instructional Design. *Educ. Psychol. Rev.* **1998**, *10*, 251–296. [\[CrossRef\]](#)
32. Skulmowski, A.; Xu, K.M. Understanding Cognitive Load in Digital and Online Learning: A New Perspective on Extraneous Cognitive Load. *Educ. Psychol. Rev.* **2022**, *34*, 171–196. [\[CrossRef\]](#)
33. Beelders, T.R.; Stott, A.E. Bilingual and scientific text reading: An eye gaze study of South African township learners. *S. Afr. J. Child. Educ.* **2025**, *15*, a1688. [\[CrossRef\]](#)
34. Sweller, J.; van Merriënboer, J.J.G.; Paas, F. Cognitive Architecture and Instructional Design: 20 Years Later. *Educ. Psychol. Rev.* **2019**, *31*, 261–292. [\[CrossRef\]](#)
35. Clark, R.C.; Nguyen, F.; Sweller, J. *Efficiency in Learning: Evidence-Based Guidelines to Manage Cognitive Load*; Pfeiffer: San Francisco, CA, USA, 2006.
36. Tremblay, R.; Alicea-Roman, P.; Anaya-Reyes, A.; Duclerc-Rodas, S.; Medina-Tirado, I. Evidence of artificial selection: Are orchids in cultivation an effective ex situ conservation strategy? *Lankesteriana Int. J. Orchid.* **2022**, *22*, 263–284. [\[CrossRef\]](#)
37. Keysar, B.; Hayakawa, S.L.; An, S.G. The foreign-language effect: Thinking in a foreign tongue reduces decision biases. *Psychol. Sci.* **2012**, *23*, 661–668. [\[CrossRef\]](#)
38. Zhonggen, Y.; Ying, Z.; Zhichun, Y.; Wentao, C. Student satisfaction, learning outcomes, and cognitive loads with a mobile learning platform. *Comput. Assist. Lang. Learn.* **2019**, *32*, 323–341. [\[CrossRef\]](#)
39. Kalyuga, S.; Plass, J.L. Cognitive load as a local characteristic of cognitive processes: Implications for measurement approaches. In *Cognitive Load Measurement and Application: A Theoretical Framework for Meaningful Research and Practice*; Zheng, R.Z., Ed.; Routledge/Taylor & Francis Group: London, UK, 2018; pp. 59–74. [\[CrossRef\]](#)
40. Chandler, P.; Sweller, J. The split-attention effect as a factor in the design of instruction. *Br. J. Educ. Psychol.* **1992**, *62*, 233–246. [\[CrossRef\]](#)
41. Zhang, S.; de Koning, B.B.; Paas, F. Effects of finger and mouse pointing on learning from online split-attention examples. *Br. J. Educ. Psychol.* **2022**, *93*, 287–304. [\[CrossRef\]](#)
42. Kalyuga, S.; Chandler, P.; Sweller, J. Managing split-attention and redundancy in multimedia instruction. *Appl. Cogn. Psychol.* **1999**, *13*, 351–371. [\[CrossRef\]](#)
43. Aronson, E.; Blaney, N.; Stephan, C.; Sikes, J.; Snapp, M. *The Jigsaw Classroom*; Sage: Beverly Hills, CA, USA, 1978.
44. Diani, A.H.; Dwijanto, D. Mathematical creative thinking ability observed from student learning motivation in Jigsaw Cooperative Learning assisted by problem cards. *Unnes J. Math. Educ.* **2020**, *9*, 66–73. [\[CrossRef\]](#)

45. Roseth, C.J.; Lee, Y.-K.; Saltarelli, W.A. Reconsidering jigsaw social psychology: Longitudinal effects on social interdependence, sociocognitive conflict regulation, motivation, and achievement. *J. Educ. Psychol.* **2019**, *111*, 149–169. [\[CrossRef\]](#)
46. Slavin, R.E. *Student Team Learning: A Practical Guide to Cooperative Learning*; National Education Association: Washington, DC, USA, 1991.
47. Jeppu, A.K.; Kumar, K.A.; Sethi, A. 'We work together as a group': Implications of jigsaw cooperative learning. *BMC Med. Educ.* **2023**, *23*, 734. [\[CrossRef\]](#)
48. Andújar Ruzafa, P.; Giménez-Meseguer, J.; Ferriz-Valero, A.; López-Bautista, I.; Baena-Morales, S. A pilot mixed-methods study on the impact of Aronson puzzle and body expression on motivation and classroom social climate in primary education. *Retos* **2025**, *71*, 114–125. [\[CrossRef\]](#)
49. Wilson, E.; Demetriou, H. New teacher learning: Substantive knowledge and contextual factors. *Curric. J.* **2007**, *18*, 213–229. [\[CrossRef\]](#)
50. Hedeon, T. The reverse jigsaw: A process of cooperative learning and discussion. *Teach. Sociol.* **2003**, *31*, 325–332. [\[CrossRef\]](#)
51. Van Tran, D. The effects of jigsaw learning on students' attitudes in a Vietnamese higher education classroom. *Int. J. High. Educ.* **2012**, *1*, 9. [\[CrossRef\]](#)
52. Muhammad, Z. Effect of cooperative learning method jigsaw type to learning motivation and learning outcome in student. *J. Keperawatan* **2018**, *9*, 65–71.
53. Namdol, N.; Chauhan, M.; Kanojia, D.; Kandari, H.; Rana, J.; Singh, J.; Kumar, M. Students learning outcomes in response to lecture method and jigsaw teaching methods. *IOSR J. Nurs. Health Sci.* **2015**, *4*, 78–83.
54. Stanczak, A. Is the "Puzzle Class" Method Effective in Improving Learning? Ph.D. Thesis, Clermont Auvergne University, Clermont-Ferrand, France, 2020.
55. Doymus, K. Effects of a cooperative learning strategy on teaching and learning phases of matter and one-component phase diagrams. *J. Chem. Educ.* **2007**, *84*, 1857–1860. [\[CrossRef\]](#)
56. Bhardwaj, S. Jigsaw strategy's impact on student achievement and social skills across educational levels: A meta-analytic review. *Int. J. Res. Rev.* **2025**, *12*, 250–265. [\[CrossRef\]](#)
57. American College Health Association. *National College Health Assessment III: Undergraduate Reference Group: Executive Summary*; American College Health Association: Silver Spring, MD, USA, 2019.
58. Kilic, D. The effect of the Jigsaw technique on learning the concepts of the principles and methods of teaching. *World Appl. Sci. J.* **2008**, *4*, 109–114.
59. Oludipe, D.; Awokoya, J.O. Effect of Cooperative Teaching Strategy on the Reduction of Students' Anxiety for Learning Chemistry. *J. Turk. Sci. Educ.* **2010**, *7*, 30–36. Available online: <https://www.tused.org/index.php/tused/article/view/501> (accessed on 14 March 2026).
60. Wei, H.; Zhao, L. Effects of jigsaw cooperative learning on college students' academic achievement in China. *High. Educ. Res. Dev.* **2019**, *38*, 1092–1105.
61. Mitina, T.; Afanasenkova, I.; Bazarnova, N.; Shaikhova, B.; Oyamo, M. Cognitive-linguistic scaffolding as a tool for activating argumentative writing skills in the process of teaching analytical chemistry in English language. *Int. J. Innov. Res. Sci. Stud.* **2025**, *8*, 2171–2186. [\[CrossRef\]](#)
62. Van Merriënboer, J.J.; Kirschner, P.A.; Kester, L. Taking the load off a learner's mind: Instructional design for complex learning. *Educ. Psychol.* **2003**, *38*, 5–13. [\[CrossRef\]](#)
63. Koole, T.; Elbers, E. Responsivity in teacher explanations. A conversation analytical perspective on scaffolding. *Linguist. Educ.* **2014**, *26*, 175–191. [\[CrossRef\]](#)
64. Martin, S. Measuring cognitive load and cognition: Metrics for technology-enhanced learning. *Assess. Educ. Princ. Policy Pract.* **2014**, *20*, 592–621. [\[CrossRef\]](#)
65. Frey, N.; Fisher, D.; Almarode, J. *How Scaffolding Works: A Playbook for Supporting and Releasing Responsibility to Students*; Corwin: Thousand Oaks, CA, USA, 2023.
66. Mayer, R.E.; Fiorella, L. Theoretical Foundations. In *The Cambridge Handbook of Multimedia Learning*, 3rd ed.; Mayer, R.E., Fiorella, L., Eds.; Cambridge University Press: Cambridge, UK, 2021; pp. 55–142.
67. Bruning, R.; Schraw, B.; Norby, M.; Ronning, R.R. *Cognitive Psychology and Instruction*, 4th ed.; Pearson: Upper Saddle River, NJ, USA, 2004.
68. García, O. *Bilingual Education in the 21st Century: A Global Perspective*; Wiley-Blackwell: Malden, MA, USA, 2009.
69. Canagarajah, A.S. Codemeshing in Academic Writing: Identifying Teachable Strategies of Translanguaging. *Mod. Lang. J.* **2011**, *95*, 401–417. [\[CrossRef\]](#)
70. Thao, T.Q.; Tham, D.M. The Difficulties in ESP Reading Comprehension Encountered by English-Majored Students. *VNU J. Foreign Stud.* **2018**, *34*, 10–23. [\[CrossRef\]](#)
71. Basar, N.U.; Shahid, M.A.; Primo, A.S.B.; Kadyampakeni, D.M. Synergies between biostimulants and plant nutrients: A review of ecofriendly nutrient management in crop production. *Discov. Agric.* **2025**, *3*, 150. [\[CrossRef\]](#)

72. Oladele Jegede, O. Linguistic features of English for science and technology. *Br. Int. Linguist. Arts Educ.* **2020**, *2*, 265. [[CrossRef](#)]
73. Levine, A.; Ferenzo, O.; Reves, T. EFL academic reading and modern technology: How can we turn our students into independent critical readers? *TESL-EJ* **2000**, *4*, 75–91.
74. Granda-Asencio, L.J.; Ordoñez-Ocampos, B.P.; Aguirre-Labanda, J.E. Importancia de la comprensión lectora en las áreas básicas del aprendizaje. *Rev. Portal Cienc.* **2023**, *4*, 256–269. [[CrossRef](#)]
75. Horwitz, E.K.; Horwitz, M.B.; Cope, J. Foreign language classroom anxiety. *Mod. Lang. J.* **1986**, *70*, 125–132. [[CrossRef](#)]
76. MacIntyre, P.D.; Gardner, R.C. Investigating language class anxiety using the focused essay technique. *Mod. Lang. J.* **1991**, *75*, 296–313. [[CrossRef](#)]
77. MacIntyre, P.D.; Gardner, R.C. Language anxiety: Its relationship to other anxieties and to processing in native and second languages. *Lang. Learn.* **1991**, *41*, 513–534. [[CrossRef](#)]
78. MacIntyre, P.D.; Gardner, R.C. The effects of induced anxiety on three stages of cognitive processing in computerized vocabulary learning. *Stud. Second. Lang. Acquis.* **1994**, *16*, 1–17. [[CrossRef](#)]
79. MacIntyre, P.D.; Gardner, R.C. The subtle effects of language anxiety on cognitive processing in the second language. *Lang. Learn.* **1994**, *44*, 283–305. [[CrossRef](#)]
80. Sweller, J. Cognitive load during problem solving: Effects on learning. *Cogn. Sci.* **1988**, *12*, 257–285. [[CrossRef](#)]
81. Paas, F.; Van Merriënboer, J.J.G. Cognitive-load theory: Methods to manage working memory load in the learning of complex tasks. *Curr. Dir. Psychol. Sci.* **2020**, *29*, 394–398. [[CrossRef](#)]
82. Masrai, A. Vocabulary and reading comprehension revisited: Evidence for high, mid, and low-frequency vocabulary knowledge. *SAGE Open* **2019**, *9*, 2158244019845182. [[CrossRef](#)]
83. Li, H.; Gan, Z. Reading motivation, self-regulated reading strategies and English vocabulary knowledge: Which most predicted students' English reading comprehension? *Front. Psychol.* **2022**, *13*, 1041870. [[CrossRef](#)]
84. Segalowitz, N. Automaticity and second languages. In *The Handbook of Second Language Acquisition*; Doughty, C., Long, M., Eds.; Oxford University Press: Oxford, UK, 2003; pp. 368–408.
85. Grabe, W.; Stoller, F.L. *Teaching and Researching Reading*; Longman: Harlow, UK, 2002.
86. Blasco-Magraner, J.S.; Català-Saiz, A.; Marín-Liéban, P. El aprendizaje cooperativo y la técnica del puzle de Aronson en el aula de música en secundaria. *Praxis* **2023**, *18*, 50–67. [[CrossRef](#)]
87. Peng, J.-E.; Xie, X. English-Medium Instruction as a Pedagogical Strategy for the Sustainable Development of EFL Learners in the Chinese Context: A Meta-Analysis of Its Effectiveness. *Sustainability* **2021**, *13*, 5637. [[CrossRef](#)]
88. Wachyuni, S. The effectiveness of scaffolding strategy in EFL reading comprehension. In *Proceedings of the Ninth International Conference on Applied Linguistics (CONAPLIN 9)*; Atlantis Press: Paris, France, 2016; pp. 149–153.

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.