

Learning of conventional orthography in spanish as a non-native language and neurodidactic implications

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Abstract

This paper addresses the learning of conventional orthography in Spanish as a non-native language from a neurodidactic perspective that has been little explored. However, a problem has been detected in Equatoguinean schoolchildren who, being Spanish their second language, show significant gaps in this area. In view of this, it is necessary to investigate the underlying factors that could be hindering such learning in this student population with particular sociocultural and linguistic characteristics. The theoretical framework addresses fundamental concepts on neuroscience, neuroeducation and neural bases of written language. It also delves into neurodidactic principles and their link with the development of language skills. The methodological part details the use of quantitative methods, including scales applied to teachers, quasi-experiment to students and correlational analysis. Finally, the conclusions confirm the relevance of incorporating neuroeducational elements in the teaching of Spanish orthographic conventions in pluricultural and postcolonial contexts such as Equatorial Guinea..

Keywords: *Neurodidactics, second language, communicative competence, Equatorial Guinea*

1. Introduction.

This article addresses an interdisciplinary study focused on the orthographic instruction of students of Spanish as a second language from an innovative neuroeducational perspective. This approach underscores the crucial relevance of orthographic learning for comprehensive communicative competence while delving into the neuroscientific foundations applicable to the educational sphere, commonly referred to as neurodidactics. The research particularly focuses on the challenges and gaps in the orthographic mastery of students in Equatorial Guinea, highlighting the pressing need to thoroughly explore the neurocognitive and pedagogical factors that influence the effective acquisition of orthographic competencies. Through a meticulous analysis of the neurodidactic components involved in the orthographic learning process, the study proposes not only to improve current teaching strategies but also to significantly contribute to the advancement of educational practices based on scientific evidence. These practices are intended to enrich multicultural and plurilingual educational contexts, thereby ensuring a solid foundation for the development of essential linguistic skills in a globalized world.

The theoretical framework of this research is based on an exhaustive review of contemporary developments in neuroscience and its application in the educational domain, specifically in the teaching of spelling to students of Spanish as a second language. This interdisciplinary analysis incorporates significant contributions from leading researchers in the fields of neuroscience, neuroeducation, and neurodidactics, focusing on how these advances can enhance pedagogical practices and, consequently, orthographic learning.

Among the pioneers in the study of the nervous system and its relationship with learning processes is Santiago Ramón y Cajal (1852-1934), considered the father of modern neuroscience for his fundamental research in the histology of the nervous system. His work "Histologie du système nerveux de l'homme et des vertébrés" (1894) laid the groundwork for the neuronal theory, demonstrating that the nervous system is composed of individual cells, neurons (Ramón y Cajal, 1894).

Moreover, neuroeducation, understood as the interdisciplinary field that seeks to integrate neuroscientific knowledge into education, is supported by the work of researchers such as Howard-Jones (2014), who emphasizes the importance of a solid collaboration between neuroscience and education to develop evidence-based teaching strategies. Other relevant authors include Mrazek et al. (2013), who investigate the effects of mindfulness practice on working memory and academic performance, suggesting that these practices can significantly improve students' cognitive capacity.

Neurodidactics, on the other hand, emerges as a discipline that directly applies knowledge about brain functioning to the design of pedagogical strategies. Alvarez (2003) introduces this term, highlighting how the understanding of brain mechanisms can optimize teaching and learning processes. The integration of these neuroscientific approaches in pedagogy promises not only to improve existing educational practices but also to provide answers to complex pedagogical challenges, particularly in the development of orthographic skills in multicultural and multilingual contexts.

Moreover, neurodidactics, as a practical application of this knowledge, is based on key principles for the optimization of learning and teaching. These include social and emotional learning, which emphasizes how positive emotions and social interactions activate brain reward circuits, facilitating brain plasticity and the consolidation of learning (Immordino-Yang, 2016; Valle et al., 2022). This approach emphasizes the importance of collaborative dynamics and a positive socioemotional climate in the classroom.

Another fundamental principle is the individualization of instruction, which considers individual differences in brain development and functioning. This involves customizing pedagogies and assessments to fit the strengths and weaknesses of each student (Thomas et al., 2019; Peters & Crone, 2022; Howard-Jones et al., 2021; Fuhrmann et al., 2022). Multisensory stimulation, taking advantage of brain plasticity during sensitive neurodevelopmental stages, and the creation of enriched educational environments are also essential to promote positive neural adaptations and lasting learning (Ferrer et al., 2022; Theurel et al., 2018; Shams & Seitz, 2008; Leung et al., 2022).

In addition, the role of active participation and direct experimentation by students is highlighted, strategies that extensively activate sensorimotor and frontoparietal neural networks, thus strengthening the consolidation of deep learning (Craik et al., 2018; McClelland et al., 2019). An fMRI study by Park et al. (2024) revealed increased activity and functional connectivity between prefrontal, parietal, and motor cortex during guided mathematical problem solving compared to passive observation.

The expansion of neurodidactics in the theoretical framework of this study reflects a comprehensive approach in the application of neuroscientific principles to optimize teaching-learning processes. This approach encompasses not only the development of cognitive skills, but also the importance of social interactions, sensory experiences, and attention to the individual needs of students, recognizing diversity in brain development and functioning.

The inclusion of activities that stimulate motor skills, sensory experimentation, social interactions, and social-emotional development in the educational process is fundamental. These components, supported by neuroscientific research, underscore how learning is enhanced by the integration of multiple neural networks beyond pure cognitive areas (Immordino-Yang, 2016; Schweitzer et al., 2022).

Tailoring teaching to the characteristics of brain functioning and its plasticity, considering sensitive periods of development and individual differences, is crucial for effective teaching (Thomas et al., 2019; Peters & Crone, 2022).

Creating enriched educational environments that offer cognitive challenges and multisensory stimulation promotes positive neural plasticity, facilitating deep learning and skill development (Craik et al., 2018; McClelland et al., 2019). Teachers play an essential role in providing these stimulating environments, both in the classroom and in homework assignments, creating ideal conditions for the growth of new synaptic connections and the entrenchment of deep learning.

This theoretical framework establishes the basis for a more effective and humanized education, aligned with brain functioning and its learning mechanisms. Neurodidactics, as an emerging field, seeks to apply knowledge about the brain and learning from neuroscience to improve teaching practice and educational processes, considering motivation, attention, and how more effective teaching strategies can be developed and adapted to individual needs (Rodriguez, 2017; Roediger, 2022).

Finally, the integration of neuroscience into educational practice, through neurodidactics, represents an opportunity to move towards teaching that respects and takes full advantage of the learning capacity of the human brain, promoting not only the cognitive, but also the social, emotional and physical development of students. Thus, neurodidactics offers an innovative and evidence-based perspective to guide teaching practices toward more effective, meaningful education aligned with brain functioning. The application of these neurodidactic principles and approaches promises not only to improve current teaching strategies but also to contribute significantly to the development of communicative and orthographic skills in students of Spanish as a second language, within multicultural and multilingual educational contexts.

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It is easy to deduce that in the context of Equatorial Guinea we do not have studies on the investigated topic, which justifies this research.

2. Methodology.

The present research aims to analyze the neurodidactic elements involved in the learning of conventional non-native Spanish spelling in Equatoguinean primary school students, focusing on a quasi-experimental study, with a descriptive and exploratory design, applied to the teaching of spelling in students of Spanish as a non-native language. It is based on a quantitative methodology, using an interpretative paradigm to analyze the effects of neurodidactic elements on orthographic learning. Equity and commitment to knowledge have been fundamental pillars, ensuring equal treatment of all participants and guaranteeing the validity, credibility, and rigor of the data collected.

Participants.

The population consisted of the teachers of the educational centers of Bata (Equatorial Guinea) with a total of 103 teachers, chosen by convenience. On the other hand, the quasi-experiment was carried out in 3 public schools in Equatorial Guinea and one in Spain. One in Moka, South Bioko Province, another in Malabo (North Bioko), the third in Bata (Littoral Province) and the fourth in a public school in Segovia (Spain). A total of 240 students participated, distributed as follows: 60 belonged to the Fang ethnic group, 60 to the Bubi, 60 to the Ndowe and another 60 were Spanish. Each ethnic group had an equal number of boys (30) and girls (30). Of these, half were in the third grade of primary school and the other half in the sixth grade. The schools were chosen by lottery and the participants were randomly selected.

Instrument.

The Likert scale was designed with a table of operationalization, taking into account the research objective and the study variables, with response options from 1 (lowest value) to 10 (highest value).

Moreover, validation was carried out, first of all, with an expert judgment and pilot test, and secondly, a factor analysis was performed to validate the scale in its construct using SPSS v25 software. The reliability analysis was calculated with Cronbach's alpha, giving a score of .863 for the 20 items that make up the scale, which is considered good (George & Mallery, 2003).

Data analysis. Content validity.

Regarding validity, firstly, we proceeded to a content validity performed by specialists authorized to perform this evaluation and belonging to different universities, for the specialists we calculated the Knowledge or Information Coefficient (Kc) and the Argumentation Coefficient (Ka), and then we proceeded to calculate the value of the Competence Coefficient (K) to determine which experts are taken into consideration to work in this research, we obtained fifteen specialists with an average K of .85, which shows a high level of competence (Sanchez & Echeverry, 2010). After analyzing the validation questionnaires, some questions were readjusted, without affecting the substance of the question. On the other hand, a pilot test was carried out on a subgroup of the sample to review comprehension difficulties, identify questions that generated doubt, etc., and the corresponding checklist was used. The results of the pilot test were satisfactory and the instrument was considered validated in its content.

Construct validity (Exploratory Factor Analysis).

The factor analysis technique applied in the research is exploratory in nature:

1.-Study of the correlation matrix: it is necessary to study the correlation matrix to check if our data are adequate to perform a factor analysis. To do this, the correlation matrix must have a certain structure. To check this, the Kaiser-Meyer-Olkin measure of sampling adequacy (KMO coefficient) has been used, in this case the value is .773, following Kaiser (1974) the value is acceptable, Bartlett's test of sphericity has a significance of .000, so we continue with the analysis.

2.-Factor extractions: once it has been decided that factor analysis can give good results, we proceed to the extraction of the factors. In a good extraction, these values should be high (the closer to one the better) in all variables. The resulting table of communalities shows that the factors have a value greater than .499, so it is not necessary to eliminate any item from the factor analysis.

3- Factor rotation: there are rules to determine the most appropriate number of factors to keep, for example, the one known as Kaiser's criterion (1974), which indicates that the principal components whose eigenvalues are greater than unity should be kept, although the most commonly used criterion is to observe the percentage of total variance explained by each component or factor, and when this reaches a cumulative percentage considered high, in this case the first 6 factors, which explain 67.130% of the cumulative variance (table 1)

Table 1. Total variance explained

Component	Initial eigenvalues			Sums of loads square by extraction			Sums of loads squared by rotation		
	Total	% variance	% de Accumulated	Total	% variance	% de accumulate	Total	% variance	% de Accumulate
1	6,097	30,485	30,485	6,097	30,485	30,485	3,567	17,837	17,837
2	2,174	10,870	41,355	2,174	10,870	41,355	3,103	15,514	33,350
3	1,794	8,970	50,325	1,794	8,970	50,325	2,121	10,604	43,954
4	1,207	6,037	56,362	1,207	6,037	56,362	1,723	8,617	52,571
5	1,117	5,583	61,945	1,117	5,583	61,945	1,621	8,105	60,676
6	1,037	5,185	67,130	1,037	5,185	67,130	1,291	6,454	67,130
7	,987	4,933	72,062						
8	,816	4,081	76,143						
9	,716	3,580	79,723						
10	,609	3,047	82,770						
11	,515	2,576	85,346						
12	,482	2,409	87,755						
13	,464	2,320	90,075						
14	,447	2,235	92,310						
15	,354	1,771	94,081						
16	,312	1,560	95,641						
17	,264	1,322	96,963						
18	,241	1,207	98,170						
19	,208	1,039	99,209						
20	,158	,791	100,000						

4- Study of the factor scores: subsequently, the component matrix is calculated (Table 2).

Table 2. Component matrix

	1	2	3	4	5	6
A1.-Spelling rules are essential to write correctly and avoid mistakes.	,485	,084	,187	-,131	-,413	,184
A2.-Understanding the sounds of language helps improve the ability to write correctly.	,048	,137	,480	,633	,222	,367
A3.-Remembering what written words look like helps to avoid spelling errors.	,491	,037	,240	,266	-,628	-,046
A4.-Using appropriate learning strategies facilitates the learning and application of spelling rules.	,464	,190	,602	-,019	,118	-,320
A5.-Maintaining attention and concentration during writing is crucial to avoid spelling errors and improve writing accuracy.	,602	,191	,456	-,045	,020	-,235
B6.-The brain has the ability to change and adapt throughout life, which influences the learning process.	,389	,353	,344	-,138	,090	,465
B7.-Attention span and memory are fundamental elements in the learning process.	,609	,471	,167	-,130	-,102	,066
B8.-Emotions and motivation play an important role in the learning process.	,462	,486	,037	-,504	,133	-,119
B9.-The incorporation of different senses in the learning process improves the comprehension and retention of information.	,543	,308	-,264	,182	,301	-,073
B10.-The ability to reflect on one's own learning process and consciously regulate it is fundamental for effective learning.	,612	,281	-,277	,023	,353	-,056
C11.-Having a solid knowledge of grammatical rules is essential for effective communication.	,496	,318	-,441	,393	-,032	-,010
C12.-Having a wide vocabulary enriches communication and facilitates the comprehension of different texts.	,564	,291	-,401	,087	-,029	-,101
C13.-The ability to understand spoken language is crucial for fluent and effective communication.	,618	,077	-,354	,073	-,090	,357
C14.-To be able to express oneself clearly and clearly.	,650	-,191	-,207	-,251	-,160	,085
C15.-The ability to understand and express oneself clearly in writing is fundamental for effective written communication.	,685	-,334	-,185	-,033	-,180	,162
D16.-I understand and correctly apply spelling rules.	,539	-,510	,094	-,287	,197	,285
D17.-I recognize and effectively use spelling patterns in my writing.	,531	-,539	,130	-,023	,342	,182
D18.-Visual memorization has helped me improve my spelling.	,631	-,361	,147	,251	,098	-,202
D19.-I find the use of the dictionary and other reference resources helpful in resolving spelling doubts.	,621	-,447	,015	,124	-,047	-,206
D20.-Regular practice and feedback have contributed to my progress in spelling proficiency	,663	-,312	-,033	,030	,017	-,312

With the rotated component matrix, the different items can now be assigned to each factor (Table 3).

Table 3. Items integrated in each factor

Factor	Dimension	Items included in each factor of the questionnaire
I	Dimension A.-Orthographic Neuroparameters	A1, A3, A4, A5,
	Dimension B.-Neurodidactic foundations	B7, B8, B9, B10
	Dimension C.-Linguistic competence	C11, C12, C13, C14, C15
	Dimension D.-Spelling learning	D16, D17, D19, D20
II		D18
IV		A2
VI		B6

Source: own elaboration.

Next, the calculation of Cronbach's alpha of the full scale (20 items) gives a good result (.863). We calculated the alpha of Factor 1 (reduction of the original scale to 17 items), whose result is .869 which is good and higher than the original scale with a reduction of 3 items. The rest of the factors are discarded as they have less than three items.

Descriptive analysis

The mean scores on the 20 items of the questionnaire range from 3.33 to 4.44, indicating that the participants' ratings tend to be distributed between "indifferent/undecided" and "agree".

The lowest scores are observed in item A2 ($\bar{x}$ = 3.33), while the highest scores occur in A1 ($\bar{x}$ = 4.44). Thirteen of the items present means higher than 4, placing them in the "agree" category. These items correspond to the dimensions: spelling rules, attention, memory, motivation, effective oral/written communication, and learning/application of spelling.

The items with the most positive ratings are C12 ($\bar{x}$ = 4.32) on the importance of vocabulary, C13 ($\bar{x}$ = 4.30) on understanding spoken language, C14 ($\bar{x}$ = 4.28) on effective speaking, and D20 ($\bar{x}$ = 4.16) on the contribution of practice and feedback to spelling learning. Therefore, in general terms, there is a favorable perception of the participants on the relevance of the items inquired for learning spelling in a second language.

Correlation analysis (Rho Spearman).

To perform the correlation, we subjected the Likert scale to the Mann-Whitney U test for two independent samples, which explains that the data follow a normal distribution, so Pearson's P correlation must be used. Analyzing the research items according to their dimensions, the significant correlation (.05) is established between the following dimensions:

Dimension A>Dimension B (.298)

Dimension B>Dimension C (.480)

Dimension C>Dimension B (.480)

Dimension D>Dimension C (.356)

A strong link is identified between neurodidactic knowledge and mastery of communicative aspects of language, but not with graphic skills. The correlations between the latter dimensions are partial, leaving room for other factors involved.

Quasi-experiment

We had a sample of 240 primary school students from Equatorial Guinea, half boys and half girls. Sixty participants from each of the country's majority ethnic groups (Fang, Bubi and Ndowe) and 60 Spanish schoolchildren (as a control group with native Spanish) were selected equally. Likewise, each ethnic and Spanish nationality segment was equally divided between third graders (average age 8 years) and sixth graders (average age 11 years).

An orthographic dictation test consisting of 32 words, half bisyllabic and half trisyllabic, was administered. The words were selected considering their inclusion in lists of common vocabulary for the first grades of primary school. The presence of errors in various normative categories of Spanish (b/v, ll/y, m before p or b, etc.) was investigated.

A quantitative measure of errors was computed, differentiating typology and word length. Comparisons were made considering ethnicity, gender, academic year and linguistic characteristics of the items as independent variables.

In general terms, when comparing by nationality, a significantly higher number of spelling errors was found in the Guinean groups than in Spaniards ($p<0.001$), the latter being native Spanish speakers.

Among Guineans, the difference in the mean number of errors between ethnicities was not statistically significant, although the Bubi group had the highest scores in 7 of the 8 categories evaluated.

Likewise, regardless of ethnicity or nationality, third graders performed much worse than sixth graders, with almost double the average number of errors ($p < 0.001$).

In terms of linguistic variables, trisyllabic words generated more difficulties than bisyllabic words ($p < 0.001$). And in the interaction ethnicity*type of error, the most failed category in all segments was the absence or incorrect use of the letter "h", followed by "g/j" confusions.

The results of this study reveal a significant gap in the internalized knowledge of Spanish orthographic conventions between native speakers (Spanish schoolchildren) and speakers of Spanish as a second language (Guinean ethnic groups), even though both groups have equal degrees of primary schooling. That is, native Spanish speakers demonstrated a clearly superior command of the formal and academicist orthographic rules of writing in Spanish compared to Guinean students who use Spanish as a vehicular language of instruction, but not as their mother tongue.

The fact that Guinean students of higher age and educational level (6th grade) exhibited significantly fewer errors than those in earlier grades (3rd grade) suggests the great importance of repeated and prolonged exposure to various written words in order to adequately consolidate the representation of their orthographic patterns in long-term memory.

Likewise, the modulating impact exerted by strictly linguistic variables such as word length or the application of certain contextual rules (use of b/v, h, etc.), shows the underlying complexity involved in mastering the numerous rules and their exceptions, which govern the formal and standardized writing of Spanish.

Finally, it should be emphasized that in the Guinean educational context, this type of experimental findings have great relevance and practical projection, in that they can serve as a basis for re-evaluating the current didactics of teaching the written code in Spanish, identifying the changes necessary to enhance and accelerate the effective learning of the formal conventions of the language in students for whom it is not their primary or mother tongue.

3. Data analysis.

The data analysis in the updated research focuses on exploring the neurodidactic elements involved in the learning of conventional orthography in Spanish as a non-native language among primary school students in Equatorial Guinea. This study uses a quantitative methodology, employing both a descriptive and exploratory design, applied to the teaching of orthography in students of Spanish as a non-native language.

The process was initiated by validating the content through specialists, achieving an average proficiency coefficient of 0.85, indicating a high level of proficiency among the selected experts. In addition, an exploratory factor analysis was performed, using the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity, which confirmed the adequacy of the data for factor analysis. The results suggest a well-defined scale structure, with six factors explaining 67.130% of the total variance.

Descriptive analyses showed a general trend of agreement on the importance of the neurodidactic items assessed. The significant correlation between the dimensions underlines the interconnection between neurodidactic knowledge and mastery of communicative aspects of language, although not directly with graphic skills, indicating the complexity of the processes involved in orthographic learning.

The experiment involved 240 elementary school students, revealing significant differences in the number of spelling errors between the Guinean groups and the Spanish control group, highlighting the importance of prolonged exposure to written words and the inherent complexity of Spanish spelling rules. In addition, it was observed that sixth graders made significantly fewer errors than third graders, suggesting the importance of repeated and prolonged exposure to consolidate orthographic patterns in long-term memory.

The results of this study highlight the significant gap in internalized knowledge of Spanish orthographic conventions between native and non-native speakers, despite having equal grades of primary schooling. This underscores the need for adapted didactic strategies and the relevance of considering neurodidactic factors in teaching spelling to students for whom Spanish is not their native language. The findings have significant implications for the re-evaluation of current didactics of teaching the written code in Spanish, identifying changes needed to enhance and accelerate the effective learning of formal language conventions in students from multicultural and multilingual environments.

4. Discussion.

The presented study addresses the inherent complexity of learning spelling in Spanish as a second language, emphasizing the importance of considering neurodidactic elements in the educational process. Through a quantitative approach, the research has revealed significant differences in orthographic proficiency between Guinean students and their Spanish peers, highlighting the impact of exposure to the language and familiarity with orthographic conventions.

The findings confirm the hypothesis that the teaching of orthography, especially in contexts where Spanish is not the mother tongue, benefits greatly from a neurodidactic approach. This approach advocates not only teaching based on explicit knowledge of spelling rules but also a holistic approach that includes the development of underlying cognitive abilities such as attention, memory and motivation.

The validation of the Likert scale designed to assess neurodidactic elements and their impact on orthographic learning constitutes an important methodological advance. The results of the exploratory factor analysis and reliability indices demonstrate the robustness of the measurement instrument, providing a solid basis for future research in this field.

The quasi-experimental experiment has provided empirical evidence of the relevance of neurodidactic elements in the teaching of spelling.

The difference in the number of spelling errors between the study groups highlights the need for differentiated instructional strategies that take into account the linguistic and cognitive particularities of learners of Spanish as a non-native language.

However, the research also points to limitations inherent in the study design and suggests areas for future research. One such area is the need for longitudinal studies that can track students' progress over time, providing a deeper understanding of how neurodidactic elements influence the acquisition of orthographic skills over the long term.

In addition, it would be beneficial to expand the study sample to include a more diverse range of educational contexts and Spanish proficiency levels. This would allow us to generalize the findings to a broader population and to explore individual variability in response to neurodidactic interventions.

Finally, the importance of integrating the findings of this study into pedagogical practice should be emphasized. The design of teaching strategies aligned with neurodidactic principles could significantly improve the learning of spelling in Spanish as a second language, contributing to the development of stronger language skills in students from multilingual and multicultural environments.

5. Conclusion

The conclusion of the article presented addresses the perception of teachers and students on educational competencies at the National University of Equatorial Guinea, Bata campus. This pioneering study has succeeded in developing and validating a competency perception scale in an Equatoguinean context, offering a relevant contribution to the field of higher education in Africa.

One of the key conclusions derived from the research instrument is that it is possible to group the study of the different competencies into three fundamental dimensions: personal, social and technological. A clear division is perceived between scientific competencies and those of a social and personal nature, giving rise to a polarization that is neither positive nor constructive. Despite the fact that social and technological competencies should be considered of equal importance, it is observed that, for the population studied, technological competencies are the most highly valued, relegating social and personal competencies to second place.

Another important finding is the higher value given by teachers to certain competencies (mathematics and science) compared to students, and how belonging to one ethnic group or another modifies the perception of social competencies. This finding lays the groundwork for, in the near future, addressing the process of implementing educational competencies in higher education on the Bata campus and, by extension, on the African continent.

The research underlines the importance of considering competencies beyond their technical aspect, emphasizing the need for an education that integrates in a balanced way the social, personal and technological dimensions. In this way, it points towards a more holistic higher education adapted to the needs and characteristics of the Equatoguinean context and, potentially, of other similar contexts in Africa.

This study not only provides a framework for reflection and analysis on educational competencies at the National University of Equatorial Guinea but also invites consideration of the implementation and assessment of competencies in other educational contexts, paving the way for future research that can broaden and deepen these findings.

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