Developing an AI-Based Application for Linguistic Analysis of Deaf Learners' L2 Writing

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Abstract

The teaching of written language as a second language (L2) to deaf students remains a critical challenge in bilingual education. This is also the case for written Portuguese in Brazil, where difficulties persist particularly in the analysis of students' written production and its use in pedagogical decision-making. This paper presents the ongoing development of a Minimum Viable Product (MVP) aimed at supporting the qualified linguistic analysis of texts produced by deaf learners. Rather than functioning as a correction tool, the system is conceived as a pedagogically oriented analytical assistant, designed to identify patterns related to formal aspects of writing and their functional-communicative impact. The proposed model is structured around three analytical subdimensions (FORM_PROD, FORM_IMP, and FORM_FUN) and implemented through a prompt-based architecture using a Large Language Model (LLM). Preliminary results from a pilot study with five learner texts suggest the feasibility of distinguishing between formal instability and communicative effectiveness, generating interpretable and pedagogically relevant outputs. These findings point to the potential of AI to support language teaching in bilingual contexts involving deaf learners.

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1 Introduction

The teaching of writing as a second language (L2) to deaf students remains one of the critical dimensions of bilingual deaf education. In Brazil, despite significant legal advances, such as the establishment of parameters for bilingual deaf education (Decree No. 5.626/2005) and its institutionalization as an educational modality (Law No. 14.191/2021), a gap persists between public policies and pedagogical practices. In everyday school contexts, these advances have not been consistently translated into consolidated methodologies, appropriate teaching materials, or structured teacher education programs capable of addressing the specificities of writing development among deaf students.

At the core of this issue lies a linguistic and educational challenge: how to teach a written language to learners whose first language is visual-gestural-spatial in nature. In the Brazilian context, deaf students have Brazilian Sign Language (Libras) recognized as their first language (L1), while written Portuguese is introduced as L2 under conditions often marked by delayed exposure to language, limited access to linguistic input, and pedagogical

practices insufficiently oriented toward bi/multilingualism. Consequently, the difficulties observed in these students' written productions are often interpreted from deficit-based perspectives, rather than being understood as manifestations of complex, bi/multilingual and multimodal linguistic repertoires [25, 26].

In this context, teachers tend to rely on generalized impressions of students' writing, without access to analytical tools capable of adequately and pedagogically identifying the linguistic patterns underlying these productions. This situation reveals a disconnection among three central dimensions of teaching practice: the analysis of students' productions, the assessment of their linguistic needs, and the planning of pedagogical interventions. Such disconnection compromises the effectiveness of teaching strategies and contributes to the maintenance of low expectations regarding deaf students' learning. Advancing the teaching of Portuguese as an L2, in this context, requires shifting the focus from generalized assessments to processes of linguistic analysis grounded in actual production data.

From this perspective, linguistic analysis [3], understood as a reflective and theoretically grounded practice focused on language in use, emerges as a promising methodological alternative. By shifting the focus from error correction to the identification of patterns related to textual organization, cohesion, enunciation, and argumentation, this approach enables a more qualified understanding of students' writing. However, its implementation in everyday school contexts is constrained by the concrete conditions of teaching work, particularly the limited available time for analyzing student productions and the lack of tools capable of systematically organizing and interpreting the linguistic data produced in the classroom.

Within this scenario, Generative Artificial Intelligence (GenAI) can be mobilized as a resource to support teaching practices, particularly with regard to the systematization and analysis of written productions. When designed in a critical and context-sensitive manner, AI-based tools can support the identification of linguistic patterns, contributing to more precise diagnoses of learning needs and to more informed pedagogical decision-making. Such technologies do not replace teachers' work; rather, they extend it by supporting analytical tasks while preserving the teacher's role in interpretation, mediation, and instructional design.

Based on these premises, this paper presents the development of an AI-integrated application, which aims to support a qualified linguistic analysis of written productions by deaf learners of written Brazilian Portuguese. Grounded in Corpus Linguistics approaches and in the principles of linguistic analysis in education, the proposed system seeks to contribute to overcoming the gap between diagnosis and pedagogical action by (i) identifying recurrent linguistic patterns in learners' writing and (ii) supporting teachers in the design of pedagogical strategies responsive to these patterns. By articulating principles from Applied Linguistics, language technologies, and Artificial Intelligence, this work engages with the fields of Human-Human Languages (HHL) and Human-Computer Languages (HCL), particularly in relation to the development of language technologies oriented toward supporting the analysis of written production and pedagogical decision-making in inclusive educational contexts.

2 Theoretical background

2.1 Deaf education and the teaching of writing

The teaching of writing to deaf students has been approached from different perspectives that articulate linguistic [37, 10, 8, 9], cognitive [22], pedagogical [7, 32, 34, 20], and technological dimensions [29, 35]. Overall, these studies converge on the understanding that writing development in this context is closely related to access to sign language [2, 30, 1], the

development of metalinguistic competencies [23, 39], and the adoption of pedagogical practices that are sensitive to the visual-gestural nature of communication used by deaf students [32, 13, 26]. In this sense, writing instruction tends to be more effective when grounded in bi/multilingual and multimodal approaches [12, 17, 25, 26], oriented toward language use and articulated with the integration of educational technologies.

Despite these advances, important gaps persist in the field, particularly with regard to teacher education and the consistency of pedagogical practices. Teachers frequently report not feeling prepared to teach writing to deaf students, especially in contexts marked by language deprivation [38, 36]. This is reflected in practices that remain insufficiently consistent, often centered on superficial revisions and with limited explicit instruction on aspects such as text genres and argumentation [37]. In addition, the integration of sign language and written language remains a recurring challenge [6], highlighting difficulties in implementing bi/multilingual approaches, both in defining the roles of languages and in developing coherent curricula [33].

From a linguistic perspective, structural differences between sign language and written language pose challenges, particularly with regard to morphosyntactic organization and textual cohesion [15]. At the same time, there is a lack of systematically evaluated and disseminated methods for teaching writing centered on deaf learners [14], as well as a scarcity of assessment instruments that take bi/multilingualism into account and avoid deficit-oriented biases [24]. In the technological domain, available educational resources are often incomplete, not intuitive, and difficult for teachers to implement [21]. At the same time, empirical evidence on the impact of emerging technologies, such as Artificial Intelligence and multimodal approaches, on the writing development of deaf students remains limited [19].

In the Brazilian context, these issues take on specific characteristics related to the historical trajectory of deaf education and the conditions for implementing bilingual education. Although legal frameworks have recognized Brazilian Sign Language (Libras) as the first language and established bilingual education as an educational modality, a significant gap remains in teacher education, particularly in preparing teachers to teach Portuguese as a second language to deaf students. Teacher education curricula tend to prioritize structural aspects of Libras at the expense of pedagogical approaches focused on writing instruction [27]. Furthermore, classroom practices often reproduce models oriented toward hearing students [10], overlooking the specificities of deaf bi/multilingualism and limiting the use of approaches based on the linguistic analysis of students' productions [28]. As a consequence, recurrent difficulties in writing, often described in generic terms, are not accompanied by systematic analyses that enable more precise and responsive pedagogical interventions and guidance. It is within this context that the proposal of qualified linguistic analysis of deaf learners' written production is situated, through an AI-integrated application conceived as a theoretical-methodological approach to support teaching practices in Portuguese as an L2 in bilingual contexts.

2.2 AI technologies in education

Recent advances in Artificial Intelligence (AI) have expanded the use of technologies in the teaching of reading and writing. Machine learning models, particularly those based on deep learning architectures, enable the identification of patterns in large volumes of linguistic data [5, 18]. In educational contexts, the growing adoption of generative AI tools has raised important questions about their impact on teaching and assessment practices, especially in areas centered on textual production [11, 16]. Rather than restricting their use, current discussions emphasize the need to integrate these technologies critically into pedagogical practices, with the aim of enhancing learning processes and rethinking assessment strategies.

In language education, such technologies have been used both to support writing and to assist teachers in text analysis and activity design [4]. However, their application in bilingual contexts involving deaf students remains limited, particularly with regard to addressing the linguistic specificities of this population. In this context, the use of AI to support the identification of linguistic patterns and the organization of data derived from students' written productions [31] emerges as a relevant possibility, provided it is guided by clear pedagogical objectives and closely aligned with teaching practice. This is the direction taken in this paper, which explores the use of AI to support the qualified linguistic analysis of deaf learners' writing and the design of pedagogical interventions based on these data.

3 Proposed approach: AI-supported linguistic analysis for deaf education

3.1 System design

As a feasibility-oriented pilot study, the prompt proposed for the FORM dimension was applied to five short texts (T1 to T5) written by deaf learners of Brazilian Portuguese as L2. The objective of this initial stage was not to evaluate the performance or validity of the system, but rather to investigate whether the proposed analytical framework could be consistently applied across multiple texts, generating interpretable, transparent, and pedagogically relevant outputs. Therefore, the results presented here should be understood as preliminary evidence of feasibility rather than as a validation of the analytical model.

The current stage of this work involves the development of a Minimum Viable Product (MVP) aimed at supporting qualified linguistic analysis of written productions by deaf learners of Brazilian Portuguese as a second language (L2). Rather than functioning as an automatic correction tool, the system has been conceived as a pedagogically oriented analytical assistant, with the potential to support teachers in identifying relevant linguistic patterns and translating these findings into instructional decisions.

The first development cycle prioritizes the FORM dimension (formal aspects of writing). This decision is based on three considerations: (i) formal features are more directly observable at the textual surface and can therefore be more consistently operationalized in prompt-based analyses; (ii) patterns such as orthographic instability, verb inflection, agreement, segmentation, punctuation, and basic syntactic organization can be systematically detected in early-stage prototypes; and (iii) these aspects may affect textual readability and school-based assessment processes, making them a relevant starting point for supporting teaching practices.

The FORM dimension is subdivided into three complementary analytical layers, allowing for a distinction between formal deviation and functional/communicative issues:

- **FORM_PROD:** productive patterns that support textual construction;
- **FORM_IMP:** recurrent unproductive patterns that hinder textual functioning;
- **FORM_FUN:** the actual functional-communicative impact of formal difficulties.

3.2 Technical environment and development workflow

The prototype is being developed in a Python environment, selected for its accessibility, low infrastructure cost, collaborative potential, and compatibility with Python-based Natural Language Processing workflows. The current version relies on the GPT-5.5 Large Language Model (LLM) accessed via API. This architecture enables rapid prototyping, prompt refinement, and iterative testing prior to a planned migration to a specialized Small Language Model (SLM).

3.3 Analytical workflow

The current workflow consists of submitting the learner text in .txt format to the model along with a structured prompt, followed by the analysis of the FORM_PROD, FORM_IMP, and FORM_FUN subdimensions. The system then generates structured output including scoring, textual evidence, diagnostic interpretation, and pedagogical suggestions. The results are subsequently stored in JSON for further use and analysis.

3.4 Prompt structure and scoring procedure

The current prototype relies on a structured prompt designed to operationalize the analytical framework proposed for the FORM dimension. Rather than requesting a general evaluation of learner writing, the prompt guides the model through a sequence of predefined analytical steps aligned with the pedagogical objectives of the project. The prompt is organized into three analytical subdimensions: FORM_PROD (productive formal resources), FORM_IMP (unproductive formal patterns), and FORM_FUN (functional-communicative impact). For each learner text, the model is instructed to: (i) identify productive linguistic resources that contribute to textual construction; (ii) identify recurrent formal difficulties that may affect textual functioning; and (iii) evaluate the extent to which these difficulties actually compromise communicative effectiveness. To increase transparency and interpretability, the prompt requires the generation of textual evidence supporting each analytical judgment. The output is structured into predefined sections, including general characterization of the text, numerical scores, textual evidence, pedagogical diagnosis, teaching priorities, and instructional recommendations. This design aims to support teachers not only in identifying linguistic patterns but also in translating analytical findings into pedagogical action. Scores are assigned on a five-point ordinal scale. For FORM_PROD, higher scores indicate a greater presence of productive resources that support textual construction. For FORM_FUN, higher scores indicate greater preservation of communicative effectiveness. In contrast, the logic of FORM_IMP is inverted: lower scores indicate a higher recurrence and impact of unproductive patterns, whereas higher scores indicate fewer relevant formal difficulties. The scoring procedure is descriptor-based rather than statistically derived. Each score corresponds to a predefined qualitative description associated with the observed linguistic patterns. Consequently, the generated scores should be interpreted as pedagogical indicators intended to support qualitative analysis rather than as psychometric measurements. At the current stage, the analyses are performed using a general-purpose Large Language Model accessed through an API. Model parameters were maintained at their default configuration during the pilot study. Because the system relies on generative AI, minor variations in textual explanations may occur across different executions. However, the analytical framework seeks to reduce variability by constraining the model through explicit instructions, predefined analytical categories, and structured output requirements.

3.5 Incremental strategy toward a specialized SLM

The current prompt-based version represents an exploratory stage within a broader strategy aimed at developing a specialized SLM, fine-tuned on manually annotated texts produced by deaf learners. It is expected that such specialized model will improve analytical consistency, reduce processing costs, and enhance control over the privacy of educational data.

The MVP currently under development is designed as a web-based application focused on the qualified linguistic analysis of learner texts. In this initial implementation cycle, priority is given to rapid prototyping, methodological validation, and iterative refinement of the analytical model, before any future scaling.

The application builds on previous experiences developed by the research team (FAPESP n.2022/05908-0) in the field of automated analysis of referential chains and anaphoric networks, in which Generative AI was integrated with structured prompts for the analysis of textual cohesion.

4 Preliminary results

As a pilot study, the prompt proposed for the FORM dimension was applied to five short texts (T1 to T5) written by deaf learners of Brazilian Portuguese as L2. The objective of this initial stage was not to establish the definitive performance of the system, but to verify whether the same analytical criteria could be consistently applied across multiple texts, producing interpretable and pedagogically relevant outputs.

The analyses were organized into three complementary subdimensions: FORM_PROD (productive patterns), FORM_IMP (unproductive patterns), and FORM_FUN (functional-communicative impact). This structure enabled the system to move beyond undifferentiated error detection by distinguishing linguistic resources, recurrent formal difficulties, and their actual effects on communication.

Scores ranged from 1 to 5 and were assigned based on previously defined descriptors for each subdimension. It is important to note that the logic of FORM_IMP is inverted: lower scores indicate a higher presence of recurrent unproductive patterns, whereas higher scores indicate a lower incidence of relevant difficulties.

Table 1 Scoring Rubric for the FORM Dimension.

Score	FORM_PROD	FORM_IMP*	FORM_FUN
5	Systematic and consistent productive resources	Absence of relevant unproductive patterns	Communication preserved
4	Frequent productive resources with minor variation	Localized and occasional difficulties	Minor difficulties, comprehension maintained
3	Partial and irregular productive resources	Irregular difficulties with localized impact	Partial comprehension
2	Incipient productive resources	Frequent difficulties with relevant impact	Communication significantly impaired
1	Absence of productive resources	Systematic difficulties with high impact	Communication severely compromised
* In FORM_IMP, lower scores indicate greater recurrence or impact of difficulties.			

Across the five texts (T1 to T5 - Table 2), some degree of productive linguistic resources was identified in all cases, particularly lexical items and semantic cues that enabled the recovery of overall meaning. At the same time, recurrent unproductive patterns were consistently detected, especially those related to verbal morphology, agreement, orthographic instability, punctuation, and syntactic organization.

A relevant finding concerns the distinction between formal instability and communicative impact. Although FORM_IMP scores remained relatively similar across texts, FORM_FUN scores showed more variation. This suggests that frequent formal irregularities do not automatically imply communicative failure. Some texts with recurrent formal difficulties still preserved communicative intent and recoverable meaning.

This result is relavant, as traditional school-based assessments often reduce non-standard writing to a homogeneous category of deficit. In contrast, the proposed framework distinguishes textual resources, formal instability, and actual communicative effect. This

Table 2 Pilot Results for the FORM Dimension.

Text	FORM_PROD	FORM_IMP	FORM_FUN	General Interpretation
T1	3	2	3	Partial productive resources; frequent formal difficulties; partial comprehension
T2	3	2	4	Partial productive resources; frequent formal difficulties; communication largely preserved
T3	3	2	4	Partial productive resources; recurrent difficulties; overall meaning preserved
T4	3	2	3	Partial productive resources; frequent formal difficulties; meaning recoverable with partial comprehension
T5	2	2	3	Incipient productive resources; frequent formal difficulties; meaning recoverable with partial comprehension

distinction is particularly relevant in bilingual deaf education contexts, in which texts may reflect processes of linguistic interaction (sign language-written language) rather than a lack of conceptual competence.

Table 3 Pedagogical Priorities Generated by the Automated Analysis.

Text	Main Teaching Priorities	Suggested Pedagogical Focus
T1	Verb inflection; sentence organization; functional words	Guided rewriting; sentence expansion; use of connectors
T2	Number and subject-verb agreement; verbal regularity; orthographic revision	Contrastive revision; second version production
T3	Verb inflection; connectors; lexical revision	Rewriting routines; explicit relational markers
T4	Verb inflection; cohesion; agreement	Sentence reconstruction; context-oriented grammar
T5	Temporal organization; verb inflection; punctuation	Narrative sequencing; punctuation support activities

Another relevant result concerns the pedagogical usefulness of the generated reports (Table 3). Rather than merely listing formal issues, the system translated analytical findings into teaching priorities and classroom-oriented intervention strategies tailored to each text. This suggests that GenAI can support not only linguistic diagnosis but also responsive pedagogical decision-making.

The text excerpts (evidence T1 to T5 – Table 4) reinforce that the system does not rely solely on numerical scores. Instead, each analytical judgment is linked to textual evidence, enhancing interpretability, transparency, and pedagogical usefulness. This feature is particularly important in educational applications, where teachers require understandable justifications for analytical outputs.

Table 4 Illustrative Textual Evidence from the FORM Analysis.

Text	Subdimension	Textual Evidence	Interpretation
T1	FORM_PROD	"Eu sonho muito viagem"	Lexical resources support the reconstruction of an intended life project
T1	FORM_IMP	"Eu quero ganha"	Instability in verb inflection affects formal adequacy
T1	FORM_FUN	"Melhor minha vida"	Overall meaning remains recoverable, though requiring inference
T2	FORM_IMP	"uma carro novo"	Recurrent instability in noun phrase construction
T3	FORM_FUN	"manter guardando o dinhoao=[dinheiro]"	Communicative intent is preserved despite formal instability
T4	FORM_IMP	"emprestado do dinheiro deixa-lá"	Syntactic organization and lexical choice reduce readability
T5	FORM_FUN	"mas perdeu infelizmente dinheiro"	Narrative progression is recoverable despite low formal stability

5 Conclusions – challenges and limitations

The results of the pilot study are promising; however, it is important to highlight the limitations of the current stage. The dataset is small and exploratory, and the outputs depend on prompt design, potentially varying across models or API configurations. Comparisons with expert analyses have not yet been conducted, although this is a planned step in the research. Therefore, the current findings should be interpreted as preliminary evidence of feasibility rather than as definitive validation.

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