

Natural Language Processing in Teaching Arabic Syntactic Analysis: A Systematic Literature Review of Its Strengths and Weaknesses in Indonesian

Natural Language Processing dalam Pembelajaran Analisis Sintaksis Bahasa Arab: Sebuah Systematic Literature Review tentang Keunggulan dan Kelemahan di Indonesia

Muhammad Abdul Ghofur¹, Choiruddin² Kamal Ramdani³

^{1.2.3.} Muhammad Ali Shodiq Islamic College

*Corresponding author: choiruddinmail@gmail.com

Abstract:

This study is motivated by the increasing integration of Artificial Intelligence (AI), particularly Natural Language Processing (NLP), in Arabic language education, which has shifted traditional manual approaches to Arabic syntactic analysis (nahwu) and increased learners' reliance on automated grammatical processing. The study aims to analyze the strengths and weaknesses of NLP in teaching Arabic syntactic analysis through a Systematic Literature Review (SLR) approach. A qualitative design was employed using the PRISMA 2020 framework, with data collected from scholarly articles published in SINTA-accredited journals between 2024 and 2026 related to NLP, Arabic syntax analysis, and grammar instruction. Data were analyzed using thematic analysis to identify patterns of strengths and limitations. The findings indicate that NLP provides significant advantages in enhancing syntactic analysis efficiency, accelerating grammatical structure identification, and delivering automated feedback in Arabic language learning. However, it also presents limitations, including reduced independent grammatical reasoning, increased dependency on AI systems, and weakened analytical thinking processes in nahwu learning. The study concludes that NLP should be positioned as a cognitive partner rather than a replacement for manual grammatical analysis, ensuring a balance between technological efficiency and the development of learners' grammatical reasoning skills

Keyword: *Natural Language Processing, Arabic grammar learning, syntactic analysis, artificial intelligence, Systematic Literature Review*

Abstrak:

Penelitian ini dilatarbelakangi oleh meningkatnya integrasi *Artificial Intelligence* (AI), khususnya *Natural Language Processing* (NLP), dalam pembelajaran bahasa Arab yang mulai menggeser pendekatan manual dalam analisis struktur nahwu dan memunculkan ketergantungan peserta didik terhadap analisis otomatis. Penelitian ini bertujuan untuk menganalisis keunggulan dan kelemahan pemanfaatan NLP dalam pembelajaran analisis struktur nahwu melalui pendekatan *Systematic Literature Review* (SLR). Penelitian ini menggunakan metode kualitatif dengan desain SLR yang mengikuti protokol PRISMA 2020 dengan sumber data berupa artikel ilmiah dari jurnal terakreditasi SINTA pada rentang tahun 2024–2026 yang relevan dengan NLP, analisis sintaksis bahasa Arab, dan pembelajaran nahwu. Analisis data dilakukan dengan teknik *thematic analysis* untuk mengidentifikasi pola keunggulan dan kelemahan NLP. Hasil penelitian menunjukkan bahwa NLP memiliki keunggulan dalam meningkatkan efisiensi analisis sintaksis, mempercepat identifikasi struktur gramatikal, serta menyediakan umpan balik otomatis dalam pembelajaran bahasa Arab, namun di sisi lain memiliki kelemahan berupa penurunan kemampuan berpikir gramatikal mandiri, ketergantungan terhadap sistem AI, dan melemahnya proses penalaran nahwiyah peserta didik. Penelitian ini menyimpulkan bahwa NLP seharusnya diposisikan sebagai *cognitive partner* dalam pembelajaran nahwu, bukan sebagai pengganti proses analisis manual, sehingga integrasinya dapat tetap menjaga keseimbangan antara efisiensi teknologi dan penguatan kemampuan berpikir gramatikal.

Kata Kunci: *Natural Language Processing, pembelajaran nahwu, analisis sintaksis,*

History:

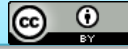
Submission: 07/07/2026

Accepted: 25/09/2026

Published: 02/10/2026

Publisher: Published by the Arabic Education Department, Miftahul Ulum Islamic institute of Pamekasan.

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INTRODUCTION

Artificial Intelligence (AI) has enabled students to perform Arabic syntactic analysis beyond their natural cognitive capabilities. Whereas Arabic syntactic analysis previously required learners to identify sentence constituents, apply grammatical rules (*qawā'id naḥwiyyah*), and engage in step-by-step grammatical reasoning, many students now increasingly rely on AI to obtain instant analytical results. With a single prompt, AI systems can identify word classes, explain syntactic functions, and even generate complete *ī'rāb* automatically through Natural Language Processing (NLP) technologies. While these capabilities offer new opportunities for Arabic grammar instruction, they also raise concerns that learners may become more dependent on AI-generated outputs than on developing independent grammatical reasoning grounded in the principles of Arabic syntax.

The rapid advancement of Artificial Intelligence (AI) has significantly transformed educational practices, including language learning (Holmes et al., 2022). One of the most influential AI technologies is Natural Language Processing (NLP), a branch of artificial intelligence that enables computers to understand, analyze, and generate human language automatically (Jurafsky & Martin, 2024). In Arabic language education, NLP has been widely applied to morphological analysis, part-of-speech tagging, syntactic parsing, machine translation, and the development of intelligent tutoring systems (Habash, 2010; Inoue et al., 2021). These technological developments have created new opportunities for teaching Arabic syntactic analysis, which has traditionally relied on memorizing grammatical rules and conducting manual sentence analysis.

Research on Natural Language Processing (NLP) for the Arabic language has grown rapidly and can generally be classified into three major directions. First, numerous studies focus on developing Arabic parsing algorithms to improve the accuracy of syntactic analysis, including the development of I3rab: Arabic Dependency Treebank, which employs traditional Arabic grammatical theory as the foundation for constructing Arabic syntactic corpora (Halabi et al., 2020), comparative analyses of Arabic syntactic analyzers to evaluate their accuracy, strengths, and limitations (Saadiyeh et al., 2025), the development of the Noor pipeline framework for parsing Classical Arabic using a hybrid approach (Nashir et al., 2025), and transformer-based models for Arabic grammatical error correction (Ismail et al., 2025). Second, a growing body of research evaluates the performance of NLP technologies and Large Language Models (LLMs) in Arabic syntactic analysis while assessing their potential as language-learning tools (AlKhamissi et al., 2024). Third, recent studies have begun integrating AI into Arabic language education through digital learning media, intelligent tutoring systems, and automated language assessment (Tlili et al., 2025). Despite these developments, existing studies remain predominantly technology-oriented, emphasizing algorithm development, parser performance, or language-skill instruction such as reading, writing, speaking, and vocabulary acquisition. Relatively few studies have specifically examined the pedagogical application of NLP in teaching Arabic syntactic analysis, and even fewer have systematically synthesized its strengths and weaknesses. This indicates a substantial gap between advances in computational linguistics and the pedagogical needs of teaching *qawā'id naḥwiyyah*, highlighting the need for a comprehensive review that bridges these two domains.

Based on this research gap, the present study aims to conduct a Systematic Literature Review (SLR) of previous studies on the application of Natural Language Processing (NLP) in teaching Arabic syntactic analysis, with particular emphasis on identifying its strengths and weaknesses. By synthesizing findings from existing research, this study seeks to provide a

comprehensive understanding of the potential, limitations, and challenges of NLP in teaching Arabic syntactic analysis. The primary contribution of this study lies in providing a conceptual and evidence-based foundation that can guide educators, researchers, and educational technology developers in utilizing NLP more appropriately. Consequently, NLP can serve not merely as a tool for producing instant grammatical analyses but also as a means of fostering learners' independent grammatical reasoning based on the established principles of Arabic grammar.

RESEARCH METHODS

This study employed a qualitative approach using a Systematic Literature Review (SLR) design. This approach was selected because it enables researchers to systematically identify, evaluate, and synthesize findings from previous studies, thereby providing a comprehensive understanding of the strengths and weaknesses of Natural Language Processing (NLP) in teaching Arabic syntactic analysis (Snyder, 2019; Xiao & Watson, 2019). The review process followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines, which consist of four sequential stages: *identification*, *screening*, *eligibility*, and *inclusion* (Page et al., 2021).

The data sources consisted of research articles published in SINTA-accredited national scientific journals. The literature search was conducted through the SINTA portal and the official websites of accredited journals using the following keywords: *Natural Language Processing*, *NLP*, *Arabic Language*, *Nahwu*, *Sharaf*, *Arabic Parser*, *Arabic Syntax*, *Arabic Grammar*, *Artificial Intelligence*, and *Arabic Language Learning*. The retrieved articles were selected based on their relevance to the application of NLP, Arabic syntactic analysis, and the teaching of Arabic grammar (*nahwu*). The inclusion criteria were as follows: (1) articles published in SINTA-accredited journals; (2) studies addressing NLP, artificial intelligence, or computational technologies related to the Arabic language; (3) availability of the full-text article; and (4) direct relevance to the objectives of the present study. Following the screening process, ten articles met all inclusion criteria and were included in the final analysis, as presented in **Table 1**.

Table 1. Selected Articles Included in the Systematic Literature Review

No.	Article Title	Journal	Research Focus
1	<i>Pemanfaatan Natural Language Processing (NLP) untuk Analisis Kesalahan Tata Bahasa Arab Nahwu dan Sharaf pada Skripsi Mahasiswa</i>	<i>Qismul Arab: Journal of Arabic Education</i>	NLP-based analysis of Arabic grammatical errors in <i>nahwu</i> and <i>sharaf</i> .
2	<i>Sintaksis Nahwu dalam Linguistik Bahasa Arab Kontemporer</i>	<i>Hijai: Journal on Arabic Language and Literature</i>	Arabic syntactic theory (<i>nahwu</i>) and its relevance to NLP.
3	<i>Integration of Natural Language Processing in a Web-Based Translanguaging System for Arabic-Indonesian Language Learning</i>	<i>Jurnal Informatika (SINTA)</i>	Integration of NLP into Arabic language learning.
4	<i>Evaluasi Pembelajaran Bahasa Arab Berbasis Deep Learning: Model, Tantangan, dan Peluang di Era Digital</i>	<i>Jurnal Pendidikan</i>	Artificial Intelligence in Arabic language education.
5	<i>Computational Linguistics and Natural Language Processing Techniques for Semantic Field Extraction in Arabic</i>	<i>Jurnal Linguistik</i>	NLP applications in Arabic language processing.

	<i>Online News</i>				
6	<i>Indonesian–Arabic Academic Journal Pendidikan Bahasa Arab</i>	<i>Translation Quality: A Comparative Content Analysis of ChatGPT and Google Translate</i>	AI-assisted translation.	Arabic	
7	<i>Natural Language Processing (NLP) untuk Mengetahui Hukum Bacaan Al-Qur'an</i>	<i>Jurnal Informatika</i>	NLP applications for Arabic text analysis.		
8	<i>Keterampilan Berbahasa Arab dalam Literatur Akademik Indonesia: Tren Penelitian dalam Jurnal Terakreditasi SINTA</i>	<i>Borneo Journal of Language and Education</i>	Research trends in Arabic language studies.		
9	<i>Integrasi Ilmu Ashwat dan Nahwu dalam Pembelajaran Bahasa Arab: Systematic Literature Review</i>	<i>Jurnal Pendidikan</i>	Integration of <i>ashwat</i> and <i>nahwu</i> in Arabic language teaching.		
10	<i>Studi Kontrasif Kalimat Verbal Bahasa Arab–Bahasa Indonesia dan Implikasinya dalam Pengajaran Nahwu</i>	<i>Buletin Al-Turas</i>	Syntactic analysis and the teaching of <i>nahwu</i> .		

The extracted data included publication characteristics, research objectives, methodological approaches, research subjects, NLP technologies employed, principal findings, reported strengths, identified limitations, and recommendations for future research. These data served as the basis for synthesizing evidence regarding the application of NLP in teaching Arabic syntactic analysis.

Data were analyzed using reflexive thematic analysis, following the framework proposed by Braun and Clarke (2006, 2021). The analytical procedure involved several stages, including data familiarization, coding, category development, theme generation, interpretation, and synthesis (Braun & Clarke, 2006; Byrne, 2022). Initially, all findings related to the application of NLP in teaching Arabic syntactic analysis were carefully examined and coded according to their conceptual similarities. Similar codes were subsequently grouped into broader analytical categories, from which overarching themes representing the strengths and weaknesses of NLP were developed. Finally, these themes were synthesized into a conceptual framework that explains the potential, limitations, and pedagogical challenges of employing NLP in teaching Arabic syntactic analysis. To enhance the credibility and trustworthiness of the findings, the analysis was conducted iteratively by continuously comparing evidence across the selected studies until consistent patterns and well-supported interpretations emerged.

RESULTS

The systematic literature review identified ten articles that met all predetermined inclusion criteria and were subsequently included in the final analysis. Overall, the selected studies indicate a growing interest in the application of Natural Language Processing (NLP) to Arabic language studies and education. The reviewed articles encompass a wide range of research topics, including Arabic grammatical error detection, syntactic analysis (*nahwu*), computational linguistics, AI-assisted language learning, machine translation, and intelligent educational technologies. Although these studies differ in their objectives and methodological approaches, they consistently demonstrate the expanding role of NLP in supporting Arabic language analysis and instruction. However, only a limited number of studies explicitly examine

the pedagogical implications of NLP for teaching Arabic syntactic analysis. Most existing research primarily emphasizes technological development, algorithm performance, or the implementation of AI-based language applications. Based on the thematic synthesis of the selected studies, two major themes emerged: (1) the strengths of NLP in teaching Arabic syntactic analysis and (2) its limitations in supporting learners' grammatical reasoning and syntactic competence.

Strengths of Natural Language Processing (NLP) in Teaching Arabic Syntactic Analysis

The thematic synthesis revealed that the primary strength of Natural Language Processing (NLP) lies in its ability to improve the efficiency, accuracy, and accessibility of Arabic syntactic analysis. Across the reviewed studies, NLP-based technologies consistently demonstrated their capacity to automatically identify grammatical categories, determine syntactic functions, detect grammatical errors, and generate *i'rāb* with considerably greater speed than conventional manual analysis. These capabilities not only reduce the time required to analyze Arabic sentence structures but also provide learners with immediate and consistent feedback, thereby facilitating independent learning. Furthermore, the integration of NLP into educational applications enables interactive learning environments through intelligent tutoring systems, automated assessment, and digital language-learning platforms. Several studies also highlighted that NLP supports the visualization of syntactic relationships by presenting dependency structures and grammatical connections among lexical units, allowing learners to comprehend complex sentence patterns more systematically. Collectively, these findings suggest that NLP has considerable potential to enhance the effectiveness of teaching Arabic syntactic analysis by transforming traditional grammar instruction into a more efficient, interactive, and technology-enhanced learning process.

Table 2. Synthesized Strengths of Natural Language Processing (NLP) in Teaching Arabic Syntactic Analysis

No.	Strength Theme	Supporting Articles	Evidence/Key Findings
1	Automated syntactic analysis	1, 2, 5	NLP automatically identifies sentence structure, grammatical functions, and <i>i'rāb</i> , thereby reducing manual analysis.
2	Arabic grammatical error detection	1, 5	NLP facilitates automatic detection and correction of grammatical errors in <i>nahwu</i> and <i>sharaf</i> .
3	Faster grammatical analysis	1, 3, 5	NLP substantially reduces the time required for syntactic analysis compared with conventional methods.
4	AI-assisted Arabic language learning	3, 4, 6	AI technologies support self-directed learning through intelligent tutoring, machine translation, and digital learning platforms.
5	Improved learning efficiency	3, 4, 9	NLP enhances learning effectiveness by providing immediate feedback and automated language support.

6	Digitalization of Arabic language instruction	3, 4, 6, 9	NLP enables the integration of Arabic grammar instruction into digital and AI-based educational environments.
7	Support for computational linguistic analysis	2, 5, 10	NLP provides systematic analysis of Arabic syntax and linguistic structures through computational approaches.

Weaknesses of Natural Language Processing (NLP) in Teaching Arabic Syntactic Analysis

Despite the considerable potential of Natural Language Processing (NLP) in enhancing Arabic syntactic analysis, the thematic synthesis also reveals several significant limitations that should be carefully considered in educational contexts. The reviewed studies indicate that NLP systems continue to face challenges in accurately interpreting contextual meanings, resolving syntactic ambiguities, and analyzing complex Arabic sentence structures that require deeper grammatical reasoning. Although recent advances in artificial intelligence have substantially improved the performance of Arabic parsers and grammatical analysis systems, their effectiveness remains highly dependent on the quality of linguistic corpora, annotation standards, and computational models used during system development. Beyond these technical limitations, the literature consistently highlights pedagogical concerns arising from the increasing reliance on AI-assisted grammatical analysis. Automated syntactic analysis enables learners to obtain immediate *i'rāb* and grammatical explanations without necessarily engaging in the cognitive processes of identifying grammatical categories, applying *nahwu* principles, or constructing grammatical arguments independently. As a consequence, excessive dependence on NLP-based applications may gradually weaken learners' grammatical reasoning, analytical thinking, and problem-solving abilities, which constitute the fundamental objectives of *nahwu* instruction. Furthermore, the reviewed studies demonstrate that current research predominantly emphasizes algorithm development, parser accuracy, and AI-based language technologies, whereas relatively limited attention has been devoted to examining their pedagogical implications for Arabic grammar education. Collectively, these findings suggest that the principal challenge of integrating NLP into Arabic syntactic instruction is not merely technological, but pedagogical, emphasizing the importance of employing NLP as a complementary instructional tool that supports—rather than replaces—learners' independent grammatical reasoning.

Table 3. Synthesized Weaknesses of Natural Language Processing (NLP) in Teaching Arabic Syntactic Analysis

No.	Weakness Theme	Supporting Articles	Evidence/Key Findings
1	Limited contextual understanding	2, 5, 10	NLP systems encounter difficulties in interpreting contextual meaning, discourse, and complex Arabic syntactic structures.
2	Reduced grammatical reasoning	3, 4, 6, 9	Excessive reliance on AI-assisted analysis may reduce learners' independent grammatical reasoning and analytical skills.
3	Dependence on technology	3, 4, 6	Frequent use of NLP tools may increase learners' dependence on AI rather than

			manual <i>nahwu</i> analysis.
4	Limited performance on complex sentence structures	2, 5, 10	NLP models perform less accurately when analyzing long, ambiguous, or structurally complex Arabic sentences.
5	Dependence on corpus and training data	1, 5	The quality of syntactic analysis depends heavily on the size, quality, and representativeness of the training corpus.
6	Limited pedagogical orientation	3, 4, 8	Most studies emphasize technological development rather than pedagogical strategies for teaching <i>nahwu</i> .
7	Limited coverage of traditional Arabic grammar	2, 10	Computational models cannot fully accommodate the diversity of classical Arabic grammatical interpretations and schools of thought.

The thematic synthesis demonstrates that the application of Natural Language Processing (NLP) in teaching Arabic syntactic analysis presents a dual perspective. On the one hand, the reviewed studies consistently highlight the substantial contribution of NLP to improving the efficiency, accuracy, and accessibility of grammatical analysis through automated parsing, grammatical error detection, intelligent tutoring systems, and AI-assisted learning environments. These technological capabilities have transformed conventional *nahwu* instruction into a more interactive and digitally supported learning experience. On the other hand, the literature also reveals that these technological advantages are accompanied by important pedagogical challenges. Excessive reliance on automated grammatical analysis may reduce learners' engagement in the analytical processes required to understand Arabic grammatical rules, thereby weakening their grammatical reasoning and independent problem-solving abilities. Furthermore, most existing studies continue to emphasize technological innovation and computational performance, while relatively limited attention has been devoted to investigating how NLP should be pedagogically integrated into Arabic grammar instruction. Therefore, the findings suggest that the educational value of NLP should not be evaluated solely based on its computational accuracy but also on its capacity to facilitate meaningful learning experiences that promote learners' grammatical competence and analytical thinking.

Table 4. Cross-Study Synthesis of the Strengths and Limitations of NLP in Teaching Arabic Syntactic Analysis

Dimension	Strengths Identified	Limitations Identified	Educational Implications
Technological	Automated syntactic analysis, grammatical error detection, high processing speed, AI-assisted language analysis	Performance depends on corpus quality, parser architecture, and computational models	Continuous improvement of Arabic NLP resources and algorithms is required.
Linguistic	Accurate identification of grammatical	Difficulties in interpreting contextual	Human validation remains necessary for

	categories and syntactic structures	meaning, syntactic ambiguity, and complex sentence structures	advanced grammatical analysis.
Pedagogical	Immediate feedback, personalized learning, intelligent tutoring systems, enhanced learning efficiency	Risk of reducing learners' grammatical reasoning and increasing dependence on AI-generated analyses	NLP should function as a learning aid rather than a substitute for manual grammatical analysis.
Cognitive	Facilitates initial understanding of Arabic sentence structures and supports self-directed learning	May weaken analytical thinking, rule application, and independent <i>i'rāb</i> construction	Learning activities should encourage active grammatical reasoning alongside NLP utilization.
Research Trends	Rapid growth of NLP applications in Arabic language education	Existing studies predominantly focus on technological development rather than pedagogical effectiveness	Future studies should investigate instructional models that integrate NLP with <i>nahwu</i> pedagogy.

Overall, the synthesized findings indicate that Natural Language Processing (NLP) should be viewed not merely as a technological innovation but as a pedagogical instrument whose educational effectiveness depends on how it is integrated into the teaching and learning process. While NLP substantially enhances the efficiency and accessibility of Arabic syntactic analysis, its implementation should remain aligned with the fundamental objectives of *nahwu* instruction, namely fostering learners' grammatical reasoning, critical analysis, and independent interpretation of Arabic sentence structures. Consequently, the successful integration of NLP into Arabic language education requires a balanced instructional approach in which technological assistance complements, rather than replaces, learners' active engagement with grammatical principles.

DISCUSSION

The synthesis of the reviewed literature indicates that Natural Language Processing (NLP) is increasingly becoming an important component of technology-mediated Arabic syntactic instruction. Across the studies included in this review, NLP is primarily represented through automated syntactic parsing, grammatical error detection, *i'rāb* analysis, and immediate feedback, which collectively expand learners' access to grammatical information and analytical support. These functions indicate that the educational significance of NLP is not limited to its computational capacity to process Arabic linguistic structures but also concerns its potential to reshape how learners interact with grammatical knowledge. Computer-assisted *i'rāb*, for example, has been developed not only to generate appropriate case endings but also to provide logical justification for syntactic analyses, demonstrating that computational systems can potentially support both the identification and explanation of Arabic grammatical structures (Alhawiti et al., 2022). From the perspective of Artificial Intelligence in Education (AIED), such developments represent a movement toward learning environments in which intelligent technologies provide learners with more immediate, responsive, and individualized forms of

instructional assistance (Luckin et al., 2016; Holmes et al., 2022). Nevertheless, the pedagogical value of NLP cannot be determined solely by its speed, accuracy, or ability to generate grammatical answers. The central issue emerging from the literature is the relationship between automated syntactic assistance and learners' development of grammatical reasoning. NLP can make syntactic information more accessible, but accessibility does not necessarily constitute learning. In Arabic *nahwu* instruction, meaningful learning is also concerned with learners' capacity to identify syntactic relationships, apply grammatical principles, explain the basis of an *i'rāb* decision, and evaluate alternative analyses. The findings therefore reveal a fundamental pedagogical tension between computational efficiency and cognitive engagement. NLP represents a valuable form of instructional support when it reduces unnecessary procedural difficulty while preserving the intellectual work through which learners construct grammatical understanding.

From an AIED perspective, this development is better understood as a reconfiguration of instructional support rather than a complete transformation of Arabic grammar education. Artificial intelligence is increasingly capable of functioning as an adaptive source of feedback, information, and contextual assistance, thereby extending the forms of support available to learners beyond the immediate presence of the teacher (Luckin et al., 2016; Holmes et al., 2022). The reviewed literature indicates that NLP can perform several functions that are particularly relevant to Arabic syntactic learning, including identifying grammatical categories, detecting syntactic relations, recognizing grammatical errors, and generating *i'rāb*-related information. These capabilities are pedagogically significant because Arabic syntactic analysis is often characterized by multiple interrelated grammatical decisions whose interpretation depends on lexical, morphological, syntactic, and contextual information. A computational system can therefore provide learners with rapid access to analytical feedback that would otherwise require considerable teacher time. Such support may increase opportunities for practice, allow learners to receive feedback beyond scheduled classroom interaction, and facilitate repeated engagement with grammatical structures. However, describing this development simply as a shift from teacher-centered to learner-centered learning would be insufficient. The presence of AI does not automatically make learning learner-centered. Learner-centeredness depends on how technological assistance is incorporated into the cognitive and pedagogical structure of learning activities. AI becomes educationally meaningful when learners remain responsible for interpreting information, making decisions, evaluating alternatives, and constructing explanations. Thus, NLP should be understood as extending the instructional environment rather than replacing the pedagogical relationship between teacher, learner, and grammatical knowledge.

The distinction between computational assistance and grammatical learning becomes particularly important when the object of learning is *nahwu*. Arabic syntactic competence is not adequately represented by the ability to obtain a correct grammatical label or an automatically generated *i'rāb*. Rather, syntactic competence involves the ability to establish relationships among linguistic elements and to justify grammatical interpretations according to relevant rules. This distinction is supported by developments in computer-assisted Arabic *i'rāb*, where syntactic analysis has been conceptualized as involving both the assignment of appropriate case endings and the provision of logical justification for those assignments (Alhawiti et al., 2022). Consequently, the educational objective of NLP-supported grammar instruction should not be restricted to improving the correctness of the final answer. It should also concern the cognitive processes through which learners arrive at, evaluate, and justify that answer. In this respect, the contribution of NLP becomes more meaningful when it creates opportunities for learners to

compare their own analyses with machine-generated analyses and subsequently determine whether the generated output is linguistically defensible. The analytical process therefore becomes more important than the automated answer itself. This perspective also provides a more precise interpretation of the benefits of NLP identified in the reviewed literature. Efficiency is pedagogically valuable when it creates additional opportunities for reasoning and practice; it becomes problematic when it eliminates the reasoning that learners are expected to acquire.

This issue introduces the second major finding of the synthesis, namely the possibility of cognitive dependency when automated grammatical analysis becomes a substitute for learners' own analytical activity. From a constructivist perspective, learning represents an active process in which learners construct and reorganize knowledge through interaction, reflection, problem-solving, and interpretation rather than merely receiving completed information. When NLP applications immediately provide syntactic classifications or *i'rāb* without requiring learners to formulate their own analyses, part of the cognitive activity associated with grammar learning may be delegated to the technological system. Contemporary scholarship on AI-supported learning has similarly identified a tension between AI as a scaffold and AI as a substitute for learner cognition. The educational value of AI is therefore highly dependent on whether learners are required to interrogate, evaluate, and reflect upon AI-generated outputs rather than simply accept them. This concern is particularly relevant to syntactic analysis because the production of a correct answer and the development of the ability to derive that answer are not equivalent learning outcomes. A learner who repeatedly obtains an accurate *i'rāb* from an NLP system may perform well on immediate tasks while having limited opportunities to develop the underlying reasoning required to reproduce the analysis independently. Accordingly, the findings suggest that computational accuracy should not be interpreted automatically as evidence of pedagogical effectiveness. The critical pedagogical question is whether computational accuracy becomes a resource for learning or a substitute for learning.

The concept of cognitive offloading provides a useful theoretical lens for understanding this tension. Cognitive offloading refers broadly to the delegation of cognitive activity to external tools in order to reduce the demands placed on internal cognitive processes. Such delegation is not inherently detrimental because external tools can help learners manage complex information and allocate cognitive resources more efficiently. The problem arises when offloading removes the very cognitive activity that the instructional task is intended to develop. Recent literature on AI in education has consequently distinguished between productive forms of cognitive support and excessive reliance that may weaken independent reasoning, metacognitive monitoring, and learner agency. A similar distinction is relevant to Arabic syntactic instruction. Delegating repetitive or computationally demanding aspects of grammatical analysis to NLP may allow learners to devote greater attention to interpretation and explanation. Conversely, delegating the entire analytical process may prevent learners from developing the procedural and conceptual knowledge necessary for independent *nahwu* reasoning. The issue, therefore, is not whether learners should use NLP, but which components of syntactic reasoning should remain cognitively active during NLP-supported learning. This distinction shifts the discussion from a simplistic opposition between technology and traditional instruction toward a more productive question concerning the distribution of cognitive responsibility between learner and AI.

On this basis, the pedagogical integration of NLP should be organized around a sequence in which learners initially engage in independent grammatical analysis before consulting automated systems. Such an approach positions NLP as a cognitive scaffold rather than an answer-generating mechanism. In practice, learners may first identify the grammatical

categories and syntactic relationships within a sentence, formulate an initial *i'rāb*, and provide a preliminary justification based on the relevant *nahwu* rules. NLP can then be employed to generate an alternative analysis or provide diagnostic feedback. The learner subsequently compares the two analyses, identifies similarities and discrepancies, examines the grammatical principles underlying those differences, and revises the original analysis when necessary. The final stage involves articulating the reasons for accepting, modifying, or rejecting the machine-generated output. Such a sequence preserves the learner's responsibility for grammatical reasoning while exploiting the efficiency and accessibility of NLP. It is also consistent with emerging research arguing that AI-supported learning is most productive when technological assistance is accompanied by structured evaluation, verification, reflection, and metacognitive engagement. Thus, the pedagogical role of NLP is more appropriately conceptualized as supporting a cycle of analysis, comparison, justification, and revision than as simply providing immediate grammatical answers.

The synthesis consequently supports a conceptual shift from AI as an Answer Provider to AI as a Cognitive Partner in Arabic syntactic instruction. In the Answer Provider model, the learner formulates a question, submits a sentence to an AI system, receives an automated syntactic analysis, and accepts the generated output as the endpoint of the learning process. Such a configuration places the technological system at the center of the analytical process and potentially reduces the learner's cognitive responsibility. In the Cognitive Partner model, by contrast, AI becomes one component of a dialogic analytical process. The learner produces an initial interpretation, the AI provides an alternative analysis or feedback, and the learner evaluates the output in relation to established *nahwu* principles. The resulting process can be represented as initial analysis , AI-generated feedback , comparison , grammatical justification, revision, reflection. The distinction is important because it relocates the educational objective from obtaining an answer to developing the capacity to reason about an answer. Within Arabic grammar education, this conceptualization extends the broader discussion of AI-supported learning by specifying the particular form of reasoning that should remain under learner control: the identification, interpretation, justification, and revision of syntactic relationships.

The distinction between these two models can be summarized in Table X. Rather than presenting another classification of NLP applications, the table synthesizes the pedagogical implications of the reviewed literature and clarifies the conceptual contribution proposed by this study.

Table 2. Conceptual Shift in NLP-Supported Arabic Syntactic Instruction

Dimension	AI as an Answer Provider	AI as a Cognitive Partner
Primary function	Provides immediate syntactic answers	Supports learners' grammatical reasoning
Learner position	Recipient of automated analysis	Active evaluator and co-constructor of analysis
Learning process	Question → AI answer	Initial analysis → AI feedback → comparison → justification → revision
Role of NLP	Answer generation and correction	Cognitive scaffolding and analytical support
Grammatical reasoning	Potentially delegated to AI	Remains primarily under learner responsibility
Learner activity	Receiving and accepting output	Analyzing, comparing, questioning, evaluating, and revising

Feedback	Primarily corrective	Dialogic, comparative, and reflective
Teacher role	Provider of explanations and correct answers	Designer, mediator, and evaluator of AI-supported learning
Main pedagogical risk	Passive reliance and cognitive offloading	Requires appropriate scaffolding to prevent overreliance
Expected learning outcome	Accurate immediate answers	Independent ability to analyze, explain, and justify <i>i'rāb</i>
Evaluation focus	Computational accuracy	Grammatical competence, reasoning, transfer, and learner autonomy

Source: Developed from the synthesis of the reviewed literature and the theoretical interpretation presented in this study.

The comparison presented in Table X indicates that the distinction between the two models is not primarily technological but pedagogical. The same NLP system may function as an Answer Provider or a Cognitive Partner depending on how the learning activity is structured. When learners are encouraged to submit sentences and accept the resulting analysis without further interrogation, NLP primarily performs an answer-generating function. When learners are required to formulate their own analysis, compare it with the system's output, investigate discrepancies, and justify their final interpretation, the same technology assumes a cognitively supportive role. This distinction is important because it locates educational responsibility within instructional design rather than within the technological system itself. The pedagogical effectiveness of NLP is therefore constituted by the interaction among technological affordances, learner activity, teacher mediation, and the nature of the grammatical task.

The proposed conceptual shift also provides a more specific interpretation of the relationship between NLP and learner autonomy. Learner autonomy in AI-supported education does not necessarily mean learning without technological assistance; rather, it concerns the learner's capacity to make informed decisions about when, why, and how technological assistance should be used. In Arabic syntactic learning, an autonomous learner should therefore be capable of questioning an automated analysis, identifying a possible inconsistency, consulting grammatical principles, and providing a reasoned justification for accepting or rejecting the output. Such autonomy requires more than access to AI. It requires sufficient grammatical knowledge and AI literacy to evaluate the reliability and relevance of generated information. Accordingly, the integration of NLP into Arabic grammar instruction should be accompanied by explicit development of students' AI literacy, particularly their ability to verify syntactic outputs, recognize uncertainty, compare alternative analyses, and distinguish computational plausibility from grammatical justification.

This perspective also redefines the role of the Arabic grammar teacher. The increasing availability of NLP does not eliminate the need for teachers; rather, it shifts part of their pedagogical responsibility from providing every grammatical answer toward designing and supervising analytical learning processes. Teachers remain important in determining which grammatical problems require independent reasoning, which forms of AI assistance are pedagogically appropriate, how students should evaluate machine-generated analyses, and how disagreements between human and machine analyses should be discussed. In this configuration, the teacher functions as a designer of cognitive activity, a mediator of grammatical interpretation, and an evaluator of learners' reasoning. Such a role is particularly important because automated NLP systems may produce outputs that are computationally plausible but pedagogically inadequate or contextually inappropriate. Consequently, AI-supported Arabic grammar instruction should not be organized around the assumption that machine-generated

analyses are inherently authoritative. Instead, AI outputs should constitute objects of inquiry that learners are expected to examine in relation to established linguistic knowledge.

The findings further suggest that the effectiveness of NLP should be evaluated through learning processes and outcomes rather than computational performance alone. Existing research on AI-supported education indicates that the benefits of AI are conditional on task design, learner characteristics, prior knowledge, and the degree of pedagogical scaffolding provided during AI use. This principle is particularly relevant to Arabic syntactic instruction because different grammatical tasks may require different levels of AI involvement. Tasks involving repetitive identification or preliminary parsing may benefit from relatively direct computational assistance, whereas tasks requiring syntactic explanation, rule application, ambiguity resolution, and grammatical argumentation may require greater learner participation. Consequently, future empirical studies should distinguish between different forms of NLP use rather than treating AI-assisted grammar learning as a homogeneous intervention. Research should examine not only whether learners produce more accurate answers with NLP but also whether they can explain those answers without AI assistance, transfer grammatical principles to unfamiliar sentences, detect erroneous machine outputs, and maintain analytical performance when technological support is removed. Such measures would provide stronger evidence concerning whether NLP contributes to durable grammatical competence rather than merely improving immediate task performance.

Taken together, the systematic synthesis demonstrates that the educational potential of NLP in Arabic syntactic instruction is fundamentally conditional. NLP represents a significant technological resource because it can increase access to syntactic analysis, provide immediate feedback, support repeated practice, and reduce the procedural burden associated with complex grammatical analysis. However, these advantages do not automatically translate into deeper learning. The pedagogical value of NLP depends on whether its computational capabilities are embedded within learning activities that preserve learners' responsibility for analysis, interpretation, justification, and reflection. The central contribution of this review is therefore not simply the identification of the benefits and limitations of NLP, but the articulation of a pedagogical principle for its integration: the more a grammatical task is intended to develop reasoning, the more carefully AI assistance should be structured so that it supports rather than substitutes that reasoning. Within this framework, the movement from AI as an Answer Provider toward AI as a Cognitive Partner represents a conceptual orientation in which technological intelligence and human grammatical reasoning are complementary rather than competing forms of cognition.

The findings position NLP as an important emerging resource for Arabic grammar education while simultaneously emphasizing the need for pedagogical conditions that preserve learner agency and grammatical reasoning. The future development of NLP for Arabic education should therefore proceed in two interconnected directions. The first concerns the computational dimension, including improvements in Arabic parsing, syntactic disambiguation, *i'rāb* generation, error detection, and contextual interpretation. The second concerns the pedagogical dimension, particularly the development and empirical validation of instructional models that determine how, when, and for what purposes learners interact with NLP systems. Future studies should consequently move beyond the question of whether NLP can analyze Arabic sentences accurately and examine whether learners become better able to analyze, explain, evaluate, and justify Arabic syntactic structures independently. Such a research orientation would place technological innovation within its proper educational context: NLP is not the endpoint of Arabic grammar learning, but a potentially powerful cognitive resource whose educational value is

determined by how it is positioned within the learner's process of constructing grammatical knowledge.

CONCLUSION

The synthesized findings demonstrate that NLP offers substantial educational potential by enhancing the efficiency, accuracy, and accessibility of Arabic grammar instruction through automated syntactic analysis, grammatical error detection, immediate feedback, and integration with AI-powered learning environments. Nevertheless, the review also reveals important pedagogical challenges, particularly the possibility that excessive reliance on automated grammatical analysis may reduce learners' opportunities to develop grammatical reasoning, independent analytical skills, and deeper engagement with nahwu principles. Accordingly, the findings indicate that the educational impact of NLP is inherently dual in nature: while it significantly improves instructional effectiveness, it may also diminish meaningful learning processes when employed as a substitute for learners' own grammatical analysis.

The principal contribution of this study lies in proposing that the educational effectiveness of NLP should be understood not in terms of technological sophistication alone but in terms of its pedagogical positioning as AI as a Cognitive Partner that supports rather than replaces learners' grammatical reasoning. This conceptual perspective provides practical implications for educators, curriculum developers, and educational technology designers by emphasizing the importance of integrating manual grammatical analysis with AI-assisted verification to foster analytical thinking and grammatical competence. Since this review was limited to studies published in nationally accredited SINTA journals, future research is encouraged to incorporate international publications, conduct meta-analyses, and empirically examine the effectiveness of NLP-based instructional models in enhancing learners' grammatical reasoning and Arabic syntactic competence.

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