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A Rule-Based AI Writing Assistant for Beginner English Learners with Visual Feedback

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Abstract: The increasing adoption of artificial intelligence (AI) in educational technology has created new opportunities to support second language (L2) writing development. Beginner English learners often struggle with grammatical accuracy, limited vocabulary, and unclear sentence construction, while immediate and individualized feedback remains difficult to provide in traditional learning settings. This study proposes a rule-based AI writing assistant designed to deliver automated, transparent, and interpretable feedback for beginner-level English writing without relying on data-intensive machine learning models. The system employs symbolic AI principles through predefined grammatical rules and heuristic textual metrics to evaluate writing quality across three dimensions: grammar accuracy, vocabulary richness, and text clarity. Grammar errors are detected using regular expression-based rules, vocabulary quality is measured via lexical diversity ratios, and clarity is estimated using a length-based heuristic. These metrics are normalized and combined to produce an overall writing quality score. To enhance usability and learner engagement, the system integrates visual feedback elements, including progress bars, graphical score representations, and animated character responses. Functional testing using sample beginner texts demonstrates that the proposed system effectively identifies common writing issues, provides consistent scoring, and delivers immediate, explainable feedback. The results indicate that rule-based AI, when combined with visual feedback mechanisms, can offer a lightweight, efficient, and pedagogically meaningful solution for beginner English writing support. This approach is particularly suitable for educational contexts that prioritize explainability, accessibility, and low computational requirements.

Keywords: Rule-Based Artificial Intelligence; Writing Assistant; Beginner English Learners; Automated Writing Evaluation; Textual Metrics; Visual Feedback; Educational Technology; Explainable AI

I. Introduction

The rapid advancement of artificial intelligence (AI) has increasingly influenced the design of modern software systems, including educational and assistive technologies [1]. AI-driven approaches are widely applied to improve system intelligence, adaptability, and decision-making capabilities, even when implemented through symbolic or rule-based mechanisms rather than complex machine learning models [2], [3]. Such approaches are particularly appropriate for educational applications, where explainability, transparency, and low computational requirements are essential.

Writing in a second language (L2) remains a cognitively demanding process for beginner English learners. Learners frequently encounter difficulties related to grammatical accuracy, limited vocabulary usage, and lack of clarity in expressing ideas. Prior research highlights the importance of structured guidance and continuous feedback in supporting the development of writing skills in both native and second language contexts [4]. However, providing immediate and individualized feedback in conventional learning environments remains a persistent challenge [5].

AI-based writing assistants have emerged as effective tools to support writing instruction by automating text evaluation and feedback generation. While many existing systems rely on data-driven or machine learning-based techniques, such approaches typically require extensive datasets, high computational resources, and complex data integration processes [3], [6]. These limitations may reduce system accessibility and transparency, particularly for beginner-level educational settings. In contrast, rule-based AI systems offer a transparent and interpretable alternative by utilizing predefined linguistic rules and heuristic evaluation functions [7]. These systems align with classical artificial intelligence principles, where explicit knowledge representation and deterministic reasoning are used to simulate expert-level decision-making [2], [6]. In educational software, such systems are well-suited for identifying common learner errors and providing explainable feedback without dependence on external data sources [8].

Visual feedback has been shown to enhance user engagement and comprehension in interactive systems. Graphical elements such as progress indicators and visual summaries enable users to better interpret abstract evaluation results and support reflective learning processes [9]. Integrating textual analysis with visual feedback can therefore improve both usability and pedagogical effectiveness. This study proposes a rule-based AI writing assistant specifically designed to support beginner English learners through automated textual analysis and visual feedback [10]. The proposed method follows a lightweight and deterministic procedure that can be fully executed on the client side, ensuring data privacy and computational efficiency.

First, the input text is preprocessed through tokenization to extract individual words and determine the total word count and unique vocabulary size. This step enables basic lexical analysis required for subsequent evaluation [6]. Second, a rule-based grammar analysis is performed using a predefined set of common beginner-level grammatical error patterns. Each rule is represented as a regular expression, and detected errors are counted to estimate grammatical accuracy. This approach reflects symbolic AI principles, where expert knowledge is explicitly encoded in the system [2], [11]. Third, vocabulary richness is evaluated using a heuristic metric based on the ratio between unique words and total words. This metric provides an approximate indication of lexical diversity, which is particularly relevant for assessing beginner writing quality [4]. Fourth, text clarity is estimated using a length-based heuristic that penalizes overly long or dense text, under the assumption that concise writing improves readability for beginner learners. The grammar, vocabulary, and clarity scores are then normalized and combined to produce an overall writing quality score. Finally, the evaluation results are presented through interactive visual feedback, including progress bars, graphical score representations, and animated character responses. This visual layer is designed to improve user engagement and facilitate intuitive interpretation of assessment outcomes [9]. The proposed method demonstrates how a rule-based AI approach, combined with heuristic textual metrics and visual feedback, can provide meaningful writing assistance without relying on data-intensive machine learning models. This makes the system suitable for educational environments that prioritize explainability, accessibility, and learner-centered feedback.

2. Research Method

2.1. Research Design

The study follows a system development and evaluation methodology, where the proposed writing assistant is first designed based on theoretical foundations of artificial intelligence, second language writing, and data-driven evaluation principles [2], [6]. The system is then implemented as a fully client-side web application and evaluated using predefined textual metrics.

This approach is suitable for educational technology research, where the effectiveness of an algorithmic system is assessed through its functional behavior and output quality rather than predictive accuracy alone [12]. Then the proposed system consists of four main components:

1. Text Input Module, which allows users to submit English text for analysis.
2. Rule-Based Analysis Engine, responsible for detecting grammatical patterns and calculating textual metrics.
3. Scoring and Evaluation Module, which computes grammar, vocabulary, and clarity scores.
4. Visual Feedback Module, which presents the analysis results using progress bars, graphical indicators, and animated character responses.

This modular architecture ensures transparency, extensibility, and ease of interpretation, which are essential characteristics of AI-assisted educational systems [3].

2.2. Textual Metrics and Rule-Based Analysis

The analysis engine applies a set of predefined linguistic rules targeting common beginner-level errors, such as incorrect tense usage, capitalization errors, and subject verb disagreement. Each detected error contributes to a penalty applied to the grammar score. Vocabulary richness is measured using the lexical diversity ratio, defined as the number of unique words divided by the total number of words. This metric provides an approximate representation of lexical variation in learner writing [4].

Text clarity is estimated using a heuristic function based on text length, assuming that excessively long or dense text reduces readability for beginner learners. These three metrics are normalized and combined to form an overall writing quality assessment. The use of heuristic metrics aligns with data science principles that prioritize interpretability and computational efficiency over model complexity, particularly in low-resource educational contexts [6].

2.3. Visual Feedback Design

To enhance user engagement and comprehension, the system incorporates visual feedback elements, including progress bars and animated character expressions that reflect writing performance. Visual representations are designed to translate abstract numerical scores into intuitive cues that support reflective learning [9]. The integration of visual feedback aims to improve learner motivation and promote self-directed improvement, consistent with interactive learning system design principles [12]. The evaluation of the proposed system is conducted through functional testing using predefined sample texts representing common beginner writing errors. The system's performance is assessed based on its ability to:

- Detect grammatical issues accurately,
- Differentiate vocabulary richness levels,
- Provide consistent clarity scoring,
- Generate meaningful visual feedback.

Rather than focusing on predictive accuracy, the evaluation emphasizes usability, interpretability, and pedagogical relevance, which are critical success factors for educational AI systems [2].

3. Results and Discussion

3.1. Result

This study use grammar scoring formula to evaluate the performance of the proposed rule-based AI writing assistant through automated analysis of beginner-level English texts. After the system is executed, users receive real-time feedback consisting of numerical scores, corrective suggestions, animated visual responses, and graphical representations of writing quality metrics. The system assesses writing quality using three primary metrics: Grammar, Vocabulary, and Clarity. Grammar evaluation is conducted using a rule-based error detection mechanism, where common beginner grammatical mistakes are identified using predefined patterns. Each detected error contributes to a penalty applied to the grammar score, which is computed as:

$$G = \max\,(0{,}100 - \alpha \times E)$$

where Erepresents the total number of detected grammatical errors and $\alpha$is a penalty factor set between 15 and 20. Experimental results show that texts containing frequent tense misuse, missing capitalization, or incorrect sentence structure produce significantly lower grammar scores, effectively highlighting areas requiring improvement. Vocabulary quality is measured using a lexical diversity approach, calculated as the ratio of unique words to the total number of words in the text. The vocabulary score is defined as:

$$V = \min\left(100, \frac{U}{W} \times \beta\right)$$

where Udenotes the number of unique words, $W$is the total word count, and $\beta$is a normalization constant set to 180. The results indicate that repetitive word usage, commonly observed in beginner writing, results in lower vocabulary scores, whereas varied word selection improves the evaluation outcome. Clarity assessment is approximated using a length-based heuristic, assuming that excessively long or unfocused beginner texts tend to reduce readability. The clarity score is computed as:

$$C = \max\left(0{,}100 - \frac{L}{\gamma}\right)$$

where Lrepresents the total number of characters and $\gamma$is a scaling parameter set to 8. The findings show that concise texts generally achieve higher clarity scores, encouraging learners to write more focused sentences. To determine overall writing quality, the system calculates the average score:

$$A = \frac{G + V + C}{3}$$

The main writing panel is positioned on the left side, featuring a large text input area labeled *"Write something (English)"*. This component encourages free-form text entry and serves as the primary interaction point between the user and the system. Below the text area, two control buttons *Analyze* and *Random Sample* are provided. The *Analyze* button initiates the automated evaluation process, while the *Random Sample* button supplies predefined beginner-level texts to assist users who may struggle to start writing independently. Beneath the control buttons, three horizontal progress indicators are displayed, corresponding to Grammar, Vocabulary, and Clarity. In the initial interface state, these bars remain empty, indicating that no analysis has been performed. This visual design communicates system readiness while avoiding premature feedback that could confuse first-time users.

The right panel presents an animated character avatar in an idle state, accompanied by the status label *"Idle"*. This character functions as a visual feedback agent, representing the system's evaluative state. Prior to analysis, the neutral facial expression reinforces that the system is awaiting user input. Such visual cues are intended to increase user engagement and reduce anxiety, particularly for novice learners.

Following text submission, the writing area displays the analyzed input, while the three evaluation indicators Grammar, Vocabulary, and Clarity are dynamically updated in the form of horizontal progress bars. Each progress bar visually represents the numerical score computed from the predefined textual metrics described in the previous section. The use of color variations, such as warning tones for moderate scores and success tones for higher scores, provides immediate visual cues that help users quickly identify strengths and weaknesses in their writing without requiring detailed interpretation of numerical values. This visual encoding reduces cognitive load and supports beginner learners in understanding assessment outcomes more intuitively.

Below the metric indicators, a dedicated *Suggestions for Improvement* section becomes active once the analysis is completed. This section delivers explicit, rule-based corrective feedback derived directly from detected grammatical and stylistic patterns. Examples include reminders to capitalize the pronoun "I," apply consistent verb tense usage, avoid informal constructions, and use appropriate punctuation such as apostrophes in contractions. Because these suggestions are generated from transparent, predefined rules, learners can easily trace feedback to specific writing issues, reinforcing explainability and trust in the system's AI-driven decision process. This aligns with educational AI principles that emphasize interpretability and learner awareness rather than opaque automated judgments.

On the right side of the interface, an animated character avatar provides affective visual feedback by dynamically adjusting its facial expression and status label based on the aggregated writing score. In the post-analysis state illustrated in Fig. 1, the character displays a positive facial expression accompanied by the status label "Excellent," indicating satisfactory overall writing performance. This affective computing element plays an important motivational role by translating abstract evaluation results into emotionally resonant feedback. Such non-verbal cues are particularly beneficial for beginner learners, as they can reduce anxiety and foster a more supportive learning environment. Figure 2 presents the post-analysis interface of the proposed rule-based AI writing assistant after a user submits a text for evaluation. This interface represents the core analytical functionality of the system, where automated assessment results, corrective textual feedback, and visual responses are delivered simultaneously. The synchronized presentation of multiple feedback modalities ensures that learners receive comprehensive yet coherent information about their writing performance.

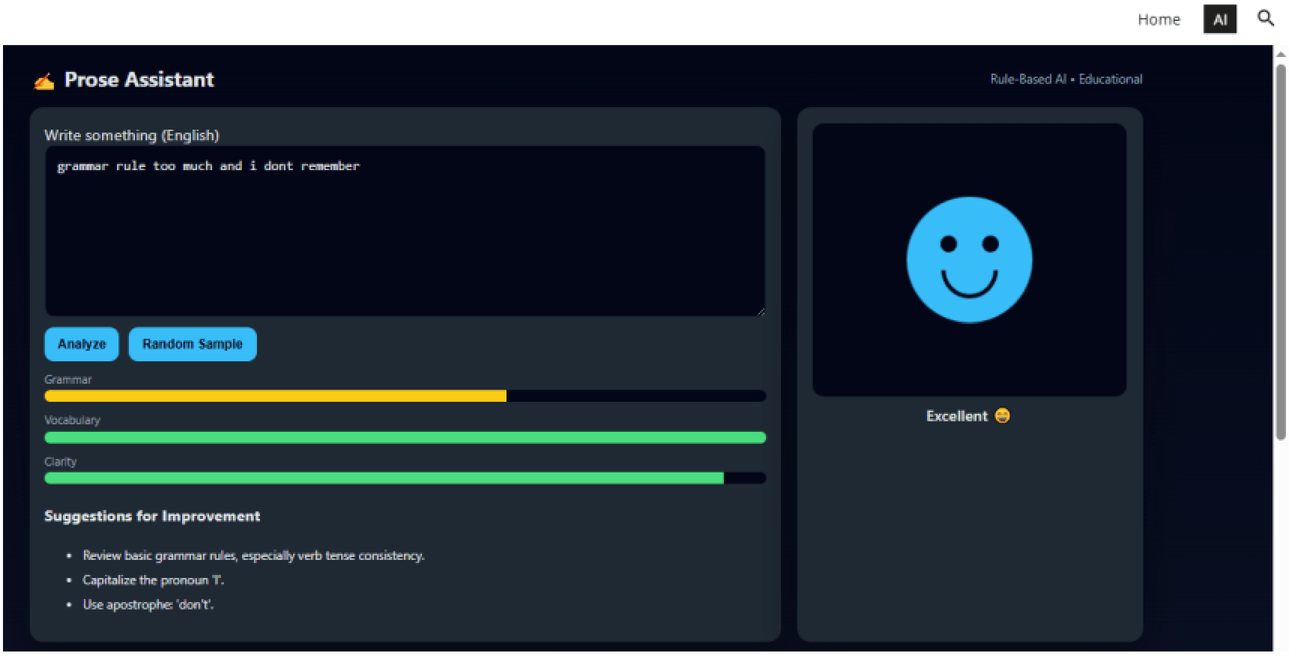

Fig.1. Post-Analysis Interface.

On the right side of the interface, an animated character avatar provides affective visual feedback by dynamically adjusting its facial expression and status label based on the aggregated writing score. In the post-analysis state illustrated in Fig. 2, the character displays a positive facial expression accompanied by the status label "Excellent," indicating satisfactory overall writing performance. This affective computing element plays an important motivational role by translating abstract evaluation results into emotionally resonant feedback. Such non-verbal cues are particularly beneficial for beginner learners, as they can reduce anxiety and foster a more supportive learning environment. Figure 2 presents the post-analysis interface of the proposed rule-based AI writing assistant after a user submits a text for evaluation. This interface represents the core analytical functionality of the system, where automated assessment results, corrective textual feedback, and visual responses are delivered simultaneously. The synchronized presentation of multiple feedback modalities ensures that learners receive comprehensive yet coherent information about their writing performance.

To demonstrate the effectiveness of the proposed rule-based AI writing assistant, this section presents a sample evaluation of a beginner-level English sentence using the system's scoring formulas beneath.

Grammar (G)

$G = \max(0, 100 - \alpha \cdot E)$ with $E = 3, \alpha = 20$

$G = 40$

Vocabulary (V)

$V = \min(100, \frac{U}{W} \cdot \beta)$ with $U = 7, W = 7, \beta = 180$

$V = 100$

Clarity (C)

$C = \max(0, 100 - \frac{L}{\gamma})$ with $L = 43, \gamma = 8$

$C \approx 94.63$

Average (A)

$$A = \frac{G + V + C}{3}$$

$A \approx 78.21$

The rule-based writing assistant evaluates beginner-level English texts using three core formulas such as Grammar score $G = \max(0, 100 - \alpha \cdot E)$, where E is the number of detected grammar errors and α is a penalty factor; Vocabulary score $V = \min(100, \frac{U}{W} \cdot \beta)$, based on the ratio of unique words U to total words W, scaled by β; and Clarity score $C = \max(0, 100 - \frac{L}{\gamma})$, which penalizes excessive text length L using a scaling factor γ. These metrics are averaged to produce an overall score that drives visual and textual feedback. Suggestions for improvement are generated when grammar issues are detected, such as failing to capitalize the pronoun "I," omitting the apostrophe in "don't," or misusing verb tenses common beginner mistakes that reduce clarity and correctness. By linking each suggestion to a specific rule violation, the system promotes transparent, actionable learning.

The algorithmic workflow shown on figure 2 and decision logic by pseudocode of the *RuleBasedWritingAssistant* algorithm beneath illustrates the structured reasoning process underlying the proposed AI-driven writing assistant. The algorithm follows a deterministic and interpretable workflow that reflects symbolic artificial intelligence principles, where explicit linguistic rules and heuristic evaluation functions are used instead of data-driven learning models. The process begins with a preprocessing stage that verifies the presence of user input. If no text is provided, the system remains in an idle state, preventing unnecessary computation and ensuring a clear interaction flow. Once valid input is detected, the text is tokenized to extract individual words, enabling the calculation of total word count and unique vocabulary size. These fundamental linguistic features serve as the basis for subsequent metric computation and support lightweight lexical analysis suitable for beginner-level writing assessment.

```
Algorithm RuleBasedWritingAssistant
Input  : Text T entered by user
Output : Grammar score G, Vocabulary score V, Clarity score C,
         Suggestions S, Visual Feedback VF
Begin
   // Step 1: Preprocessing
   if T is empty then
      return Idle State
   end if
   Tokenize T into word list W
   Count total words → totalWords = |W|
   Extract unique words → uniqueWords = Set(W)
   Count unique vocabulary → uniqueCount = |uniqueWords|
   // Step 2: Rule-Based Grammar Analysis
   errorCount ← 0
   suggestionList ← empty list
   for each grammarRule R in RULE_SET do
      if R.pattern matches T then
         errorCount ← errorCount + 1
```

```
        Add R.suggestion to suggestionList
      end if
    end for
    // Step 3: Grammar Scoring
    G ← max(0, 100 − α × errorCount)
    // Step 4: Vocabulary Scoring
    V ← min(100, (uniqueCount / max(1, totalWords)) × β)
    // Step 5: Clarity Scoring
    textLength ← number of characters in T
    C ← max(0, 100 − (textLength / γ))
    // Step 6: Overall Score Calculation
    A ← (G + V + C) / 3
    // Step 7: Generate Suggestions
    if G < thresholdGrammar then
      Add general grammar advice to suggestionList
    end if
    if V < thresholdVocabulary then
      Add vocabulary improvement advice to suggestionList
    end if
    if C < thresholdClarity then
      Add clarity improvement advice to suggestionList
    end if
    if suggestionList is empty then
      Add "Good job! Minor or no revisions needed." to suggestionList
    end if
    // Step 8: Visual Feedback Mapping
    if A ≥ 70 then
      VF.characterMood ← "Happy"
      VF.statusLabel ← "Excellent"
    else if A ≥ 40 then
      VF.characterMood ← "Neutral"
      VF.statusLabel ← "Needs Improvement"
    else
      VF.characterMood ← "Sad"
      VF.statusLabel ← "Poor"
    end if
    // Step 9: Visualization
    Display progress bars for G, V, C
    Render score distribution graph
    Render text statistics graph (word count, unique words, errors)
    Display animated character with corresponding mood
    return G, V, C, suggestionList, VF
  End
```

Grammar evaluation is conducted through a rule-based analysis mechanism. A predefined set of grammar rules, represented as pattern suggestion pairs, is applied to the input text. Each rule corresponds to common beginner-level grammatical errors, such as incorrect tense usage or capitalization mistakes. When a rule pattern matches the input text, the system increments an error counter and records an associated corrective suggestion. This explicit rule-matching process ensures transparency and explainability, allowing learners to understand how evaluation decisions are derived.

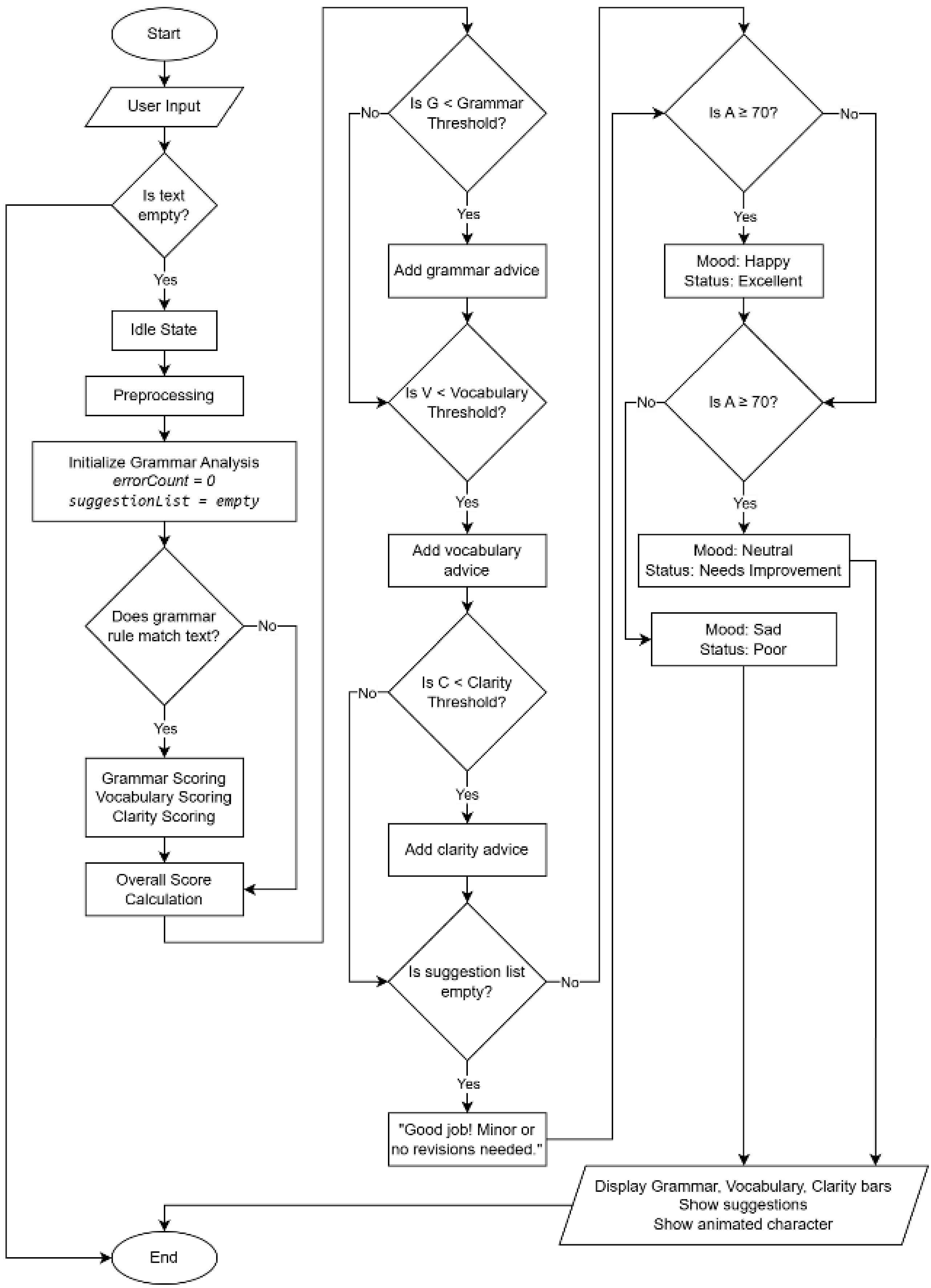

Fig.2. Algorithmic Workflow and Decision Logic.

3.2. Discussion

Based on this value, the system classifies writing performance into qualitative categories (*Good*, *Needs Improvement*, or *Poor*), which directly influence the animated character's expressions and feedback messages. This adaptive visual response enhances user engagement and reinforces the evaluation results. Additionally, graphical visualizations are generated to support interpretability. The score distribution graph illustrates the relative performance of grammar, vocabulary, and clarity, while the word count graph provides insight into text length. These visual components assist users in understanding their writing strengths and weaknesses more intuitively. The results demonstrate that the proposed rule-based AI writing assistant effectively delivers immediate, transparent, and interpretable feedback for beginner English learners. Despite not employing complex machine learning models, the system fulfills essential AI characteristics such as automated reasoning, rule-based decision-making, and interactive feedback. The simplicity of the evaluation formulas ensures low computational overhead, making the system suitable for educational contexts with limited resources. However, future enhancements may integrate semantic analysis or learning-based methods to improve contextual understanding and feedback accuracy.

The grammar score is calculated by applying a linear penalty function, where each detected error reduces the score by a fixed factor. This approach emphasizes error frequency while maintaining computational simplicity. Vocabulary quality is assessed using a lexical diversity ratio, calculated as the proportion of unique words relative to the total number of words, normalized to a maximum score. This metric effectively captures repetitive word usage, which is commonly observed in beginner writing. Clarity is estimated using a length-based heuristic that penalizes overly long or dense texts, under the assumption that concise writing enhances readability for novice learners. After computing the individual scores, the algorithm calculates an overall writing quality score by averaging the grammar, vocabulary, and clarity values. This aggregated score is then used to generate targeted feedback. Threshold-based conditions determine whether additional general advice should be provided for grammar, vocabulary, or clarity. If no significant issues are detected, the system generates a positive reinforcement message, supporting learner motivation.

The final stage of the algorithm maps the overall score to visual feedback elements. Based on predefined score ranges, the system assigns a character mood and status label that reflect the writing quality. These visual cues are presented alongside progress bars and graphical summaries of textual statistics, translating abstract numerical evaluations into intuitive and engaging feedback. This integration of rule-based reasoning with visual feedback supports human-centered AI design by improving interpretability and user engagement. The pseudocode demonstrates that the proposed system fulfills essential AI characteristics, including automated reasoning, rule-based decision-making, and adaptive feedback generation. Despite its simplicity, the algorithm effectively supports beginner English learners by providing immediate, explainable, and pedagogically relevant feedback, making it well-suited for educational environments that prioritize transparency and low computational overhead.

The interface design results demonstrate that the proposed rule-based AI writing assistant successfully translates computational evaluation into learner-centered visual feedback. The clear separation between input space, evaluation indicators, and affective feedback elements supports usability and transparency, which are critical for beginner English learners. The initial idle state effectively prepares users for interaction by avoiding premature evaluative signals, thereby reducing potential confusion and anxiety. Once analysis is performed, the dynamic progress bars for Grammar, Vocabulary, and Clarity provide an intuitive representation of system output, allowing users to quickly interpret their writing performance without relying solely on numerical scores. This finding suggests that visual encoding of evaluation metrics can enhance interpretability and aligns well with human-centered AI and educational usability principles.

The integration of explicit rule-based suggestions and affective avatar feedback reinforces learner engagement and trust in the system's decision-making process. Because the corrective feedback is derived from transparent grammatical and stylistic rules, users can easily associate suggestions with specific writing errors, promoting reflective learning rather than passive score consumption. The animated character's adaptive facial expressions and status labels function as motivational cues that humanize the evaluation process and reduce the perceived rigidity of automated assessment. This multimodal feedback strategy indicates that combining cognitive (scores and suggestions) and affective (visual expressions) responses can create a supportive learning environment, particularly for novice learners who may experience apprehension toward automated language evaluation systems. Overall, the discussion highlights that the interface design not only delivers analytical results effectively but also contributes positively to learner motivation and explainability in AI-assisted writing evaluation.

The discussion highlights that the integrated scoring framework of the rule-based writing assistant successfully demonstrates its capacity to provide transparent and actionable feedback for beginner-level English learners. In the sample evaluation, the grammar score of 40 reflects the presence of three common errors, while the vocabulary score of 100 indicates strong lexical diversity, and the clarity score of approximately 94.63 shows concise sentence construction. The resulting average score of 78.21 triggers the "Excellent" status, supported by synchronized visual cues such as progress bars and animated character feedback. Importantly, the system not only quantifies performance but also generates explicit suggestions capitalizing the pronoun "I," using the apostrophe in "don't," and reinforcing verb tense consistency that directly link detected errors to corrective actions. This combination of numerical assessment, visual reinforcement, and rule-based guidance ensures that learners receive comprehensive yet coherent information, fostering both motivation and understanding in the writing improvement process.

4. Conclusion

This study presented a rule-based AI writing assistant designed to support beginner English learners through automated textual analysis and visual feedback. Unlike data-intensive machine learning approaches, the proposed system adopts a symbolic AI paradigm, utilizing predefined linguistic rules and heuristic textual metrics to evaluate writing quality in terms of grammar, vocabulary richness, and clarity. This design choice prioritizes transparency, explainability, and computational efficiency, making the system suitable for educational environments with limited resources. The results demonstrate that the proposed assistant is capable of delivering immediate, interpretable, and actionable feedback. The grammar evaluation mechanism effectively identifies common beginner-level errors through explicit rule matching, while the vocabulary and clarity metrics provide meaningful approximations of lexical diversity and readability. The combination of these metrics into an overall writing score enables consistent performance classification, which is further reinforced through adaptive visual feedback.

The integration of visual feedback elements, including progress bars, graphical score representations, and animated character responses, significantly enhances user engagement and comprehension. The clear distinction between the initial interface and the post-analysis interface supports a smooth human AI interaction flow, guiding learners from text input to reflection and revision. This interaction design aligns with human-centered AI principles, ensuring that users can easily understand both the system's functionality and its evaluation outcomes. Although the system does not employ advanced machine learning or semantic modeling, it fulfills essential characteristics of artificial intelligence, such as automated reasoning, rule-based decision-making, and adaptive feedback generation. The deterministic nature of the evaluation process also ensures consistent behavior and explainable results, which are particularly valuable in educational contexts where learner trust and understanding are critical.

The proposed rule-based AI writing assistant demonstrates that effective AI-supported writing instruction does not necessarily require complex learning models. By combining symbolic AI techniques, heuristic textual metrics, and intuitive visual feedback, the system provides a lightweight yet pedagogically meaningful solution for beginner English writing support. Future work may extend this approach by incorporating semantic analysis, adaptive rule weighting, or hybrid learning-based components to enhance contextual understanding while maintaining interpretability and accessibility.

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