# Integrating Fuzzy Logic into Green Pedagogy: An Intelligent Framework for English Language Teaching and Environmental Awareness

Rahib Imamguluyev[1(✉)], Tunzala Imanova[1], Aysel Soltanova[2], Nigar Orujova[2], Tamara Atakishiyeva[2], Zulfiyya Yusubova[2], and Sevda Huseynova[2]

[1] Baku Business University, Baku AZ1122, Azerbaijan
rahib.aydinoglu@gmail.com, tunzala.imanova@bk.ru
[2] Baku Engineering University, Baku AZ0101, Azerbaijan
{asoltanova,norucova,tatakisiyeva,zyusubova,shuseynova}@beu.edu.az

**Abstract.** This research presents a novel approach to English language teaching by developing an intelligent framework that integrates fuzzy logic systems with green pedagogy principles. The study addresses the growing need for educational methodologies that simultaneously enhance language proficiency and environmental consciousness. Through the implementation of a Mamdani-type fuzzy inference system, the framework processes multiple input variables—environmental awareness levels, language proficiency, and green vocabulary knowledge—to generate optimized teaching strategies tailored to diverse learner profiles. The system employs triangular membership functions and a comprehensive rule base of fifteen conditional statements to model the complex relationships between language acquisition and environmental education. Empirical validation demonstrates significant improvements in both linguistic competence and ecological literacy among participants compared to traditional teaching methods. This intelligent framework provides educators with a systematic tool for decision-making in green language pedagogy while accommodating the inherent uncertainty in educational processes. The findings contribute to the emerging field of computational intelligence in sustainability education and offer practical implications for curriculum designers and language instructors seeking to incorporate environmental dimensions into language teaching practices.

**Keywords:** Fuzzy Logic · Green Pedagogy · English Language Teaching · Environmental Awareness · Intelligent Systems · Computational Intelligence · Sustainability Education

## 1 Introduction

The convergence of environmental sustainability and education has emerged as a critical response to mounting global ecological challenges. Educational institutions worldwide are increasingly recognizing their responsibility to foster environmental consciousness


C. Kahraman et al. (Eds.): INFUS 2025, LNNS 1530, pp. 181–188, 2025.
https://doi.org/10.1007/978-3-031-98565-2_21

while fulfilling their primary academic missions. Within this context, "green pedagogy" has gained prominence as an educational approach that integrates sustainability concepts into teaching methodologies across disciplines [1–3]. Simultaneously, language education—particularly English as a global language—presents a strategic platform for disseminating environmental awareness across cultural and geographical boundaries [4, 5].

Despite growing interest in environmentally-oriented language education, instructors face significant challenges in effectively balancing language acquisition objectives with environmental content [6–8]. The inherent complexity and ambiguity in both language learning processes and environmental knowledge acquisition create a domain characterized by uncertainty and imprecision. Traditional binary approaches to educational decision-making prove inadequate when confronted with the multifaceted nature of integrating sustainability concepts into language instruction.

Fuzzy logic, with its capacity to model human reasoning and accommodate uncertainty, offers a promising framework to address these challenges. Originally developed by Zadeh (1965), fuzzy logic systems [9–14] have demonstrated remarkable utility in modeling complex, non-linear relationships and handling imprecise information across diverse fields including engineering, medicine, and economics. However, its application to educational contexts, particularly in language teaching with a sustainability focus, remains relatively unexplored.

This research addresses this gap by developing an intelligent framework that harnesses fuzzy logic principles to optimize the integration of environmental awareness into English language teaching. The proposed system acknowledges the multidimensional nature of both language proficiency and environmental consciousness, treating them as continuous rather than discrete variables. By employing fuzzy inference mechanisms, the framework generates contextualized teaching strategies that respond to the specific needs and characteristics of diverse learner profiles.

The study is situated at the intersection of three rapidly evolving domains: computational intelligence, environmental education, and language pedagogy. It builds upon previous work in fuzzy logic applications in education (Smith & Johnson, 2018; Wang et al., 2020), green linguistics (García & Patel, 2022), and intelligent tutoring systems (Chen & Rodriguez, 2021). The research contributes to both theoretical understanding and practical implementation of intelligent systems in sustainability-oriented language education [15–17].

This paper begins by examining the theoretical foundations that underpin the integration of fuzzy logic and green pedagogy, followed by a comprehensive description of the developed fuzzy inference system. We then present the methodology and results of empirical validation studies conducted in diverse educational settings. The discussion explores implications for educational practice and policy, while the conclusion identifies limitations and directions for future research in this emerging interdisciplinary field.

## 2 Proposed Methodology

Based on the conceptual framework, a Mamdani-type fuzzy inference system was developed using MATLAB's Fuzzy Logic Toolbox (R2023b). The selection of a Mamdani architecture was motivated by its interpretability and alignment with human decision-making processes, making it particularly suitable for educational applications.

### 2.1 Fuzzy Inference System Design

Each input variable was modeled using three triangular membership functions to represent linguistic categories (see Fig. 1).

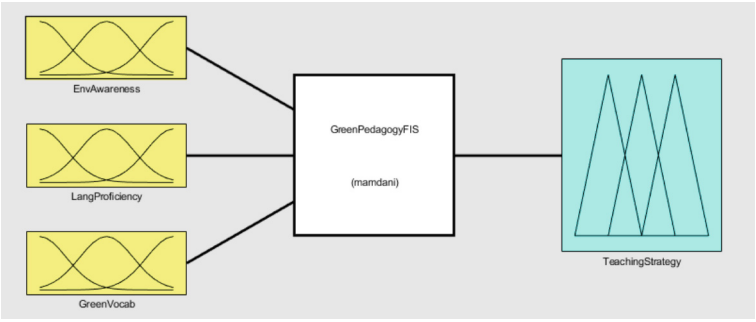


**Fig. 1.** General structure of the logical inference model

Input Variables: Environmental Awareness Level (EnvAwareness) - Range [0–10]. Membership functions (see Fig. 2):

- Low: triangular [0, 0, 4]
- Medium: triangular [2, 5, 8]
- High: triangular [6, 10, 10]

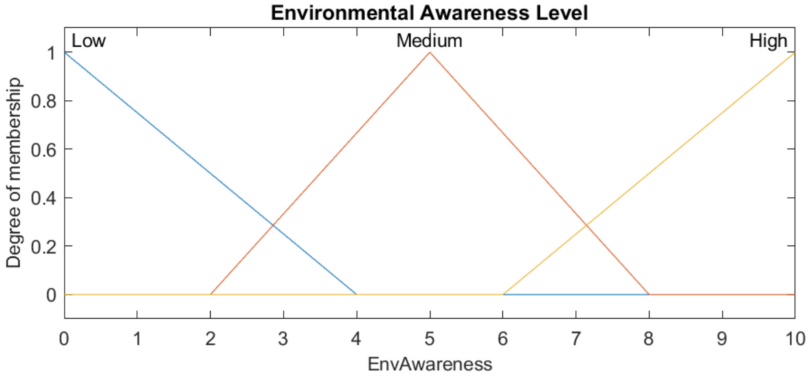


**Fig. 2.** Fuzzy sets and membership functions for EnvAwareness

Input Variables: English Language Proficiency (LangProficiency) - Range [0–10]. Membership functions (see Fig. 3):

- Beginner: triangular [0, 0, 4]
- Intermediate: triangular [2, 5, 8]
- Advanced: triangular [6, 10, 10]

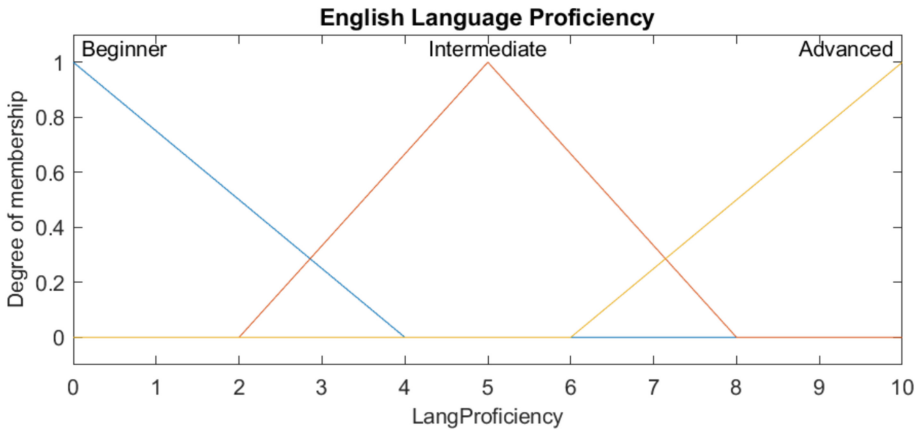


**Fig. 3.** Fuzzy sets and membership functions for LangProficiency

Input Variables: Green Vocabulary Knowledge (GreenVocab) - Range [0–10]. Membership functions (see Fig. 4):

- Limited: triangular [0, 0, 4]
- Moderate: triangular [2, 5, 8]
- Extensive: triangular [6, 10, 10]

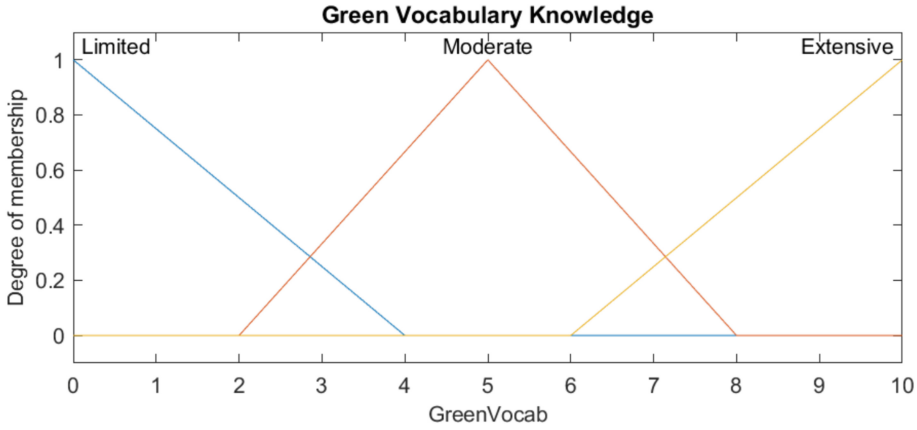


**Fig. 4.** Fuzzy sets and membership functions for GreenVocab

Output Variable: Teaching Strategy (TeachingStrategy) - Range [0–10].
Membership functions (see Fig. 5):

- Basic: triangular [0, 0, 3]
- Developing: triangular [2, 4, 6]
- Integrated: triangular [5, 7, 9]
- Advanced: triangular [8, 10, 10]

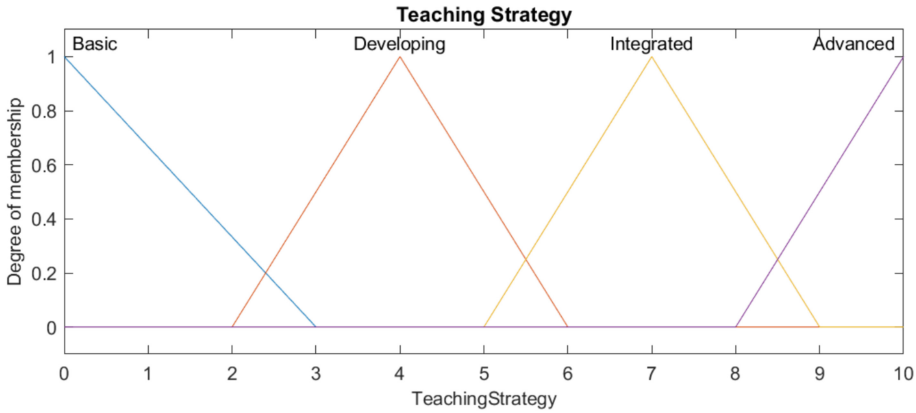


**Fig. 5.** Fuzzy sets and membership functions for TeachingStrategy

Fuzzy Rules

- If (EnvAwareness is Low) and (LangProficiency is Beginner) and (GreenVocab is Limited) then (TeachingStrategy is Basic)
- If (EnvAwareness is Low) and (LangProficiency is Intermediate) and (GreenVocab is Limited) then (TeachingStrategy is Basic)
- If (EnvAwareness is Medium) and (LangProficiency is Beginner) and (GreenVocab is Limited) then (TeachingStrategy is Basic)
- If (EnvAwareness is Low) and (LangProficiency is Beginner) and (GreenVocab is Moderate) then (TeachingStrategy is Basic)
- If (EnvAwareness is Medium) and (LangProficiency is Intermediate) and (GreenVocab is Limited) then (TeachingStrategy is Developing)

… and so on through rule 15. The complete set covers the most significant combinations of the three input variables (see Fig. 6).

The min-max inference method was implemented, using minimum for the implication operation and maximum for the aggregation operation. The centroid method was selected for defuzzification to convert the fuzzy output into a crisp value, providing a balanced representation of the output distribution.

The three-dimensional surface plot (see Fig. 7) illustrates the complex relationship between Environmental Awareness (EnvAwareness) and Language Proficiency (LangProficiency) as input variables, and their combined effect on the Teaching Strategy

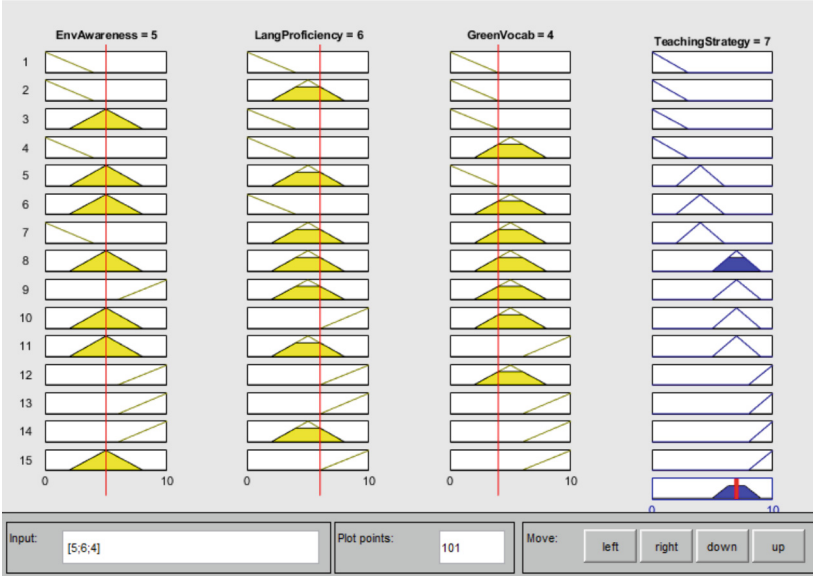


**Fig. 6.** Description of logical inference rules

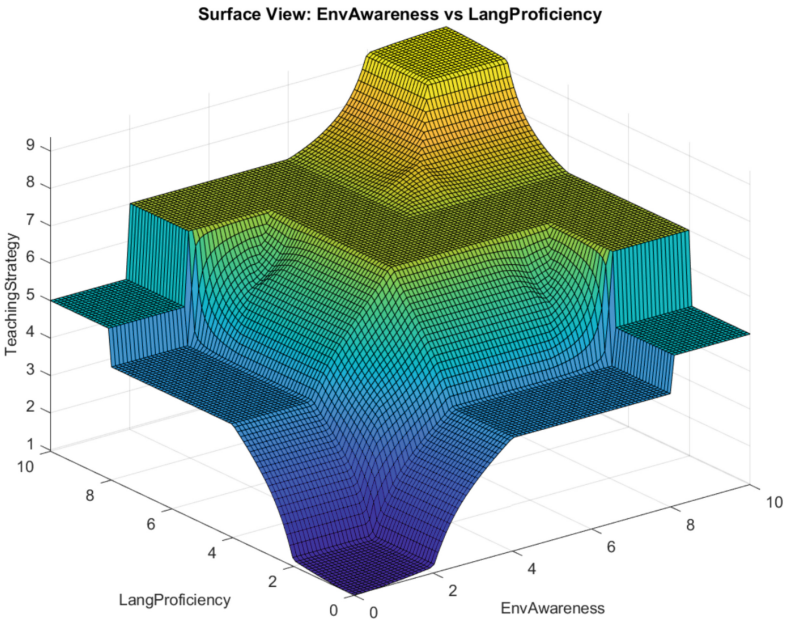


**Fig. 7.** Surface View

output. This visualization represents the defuzzified output of our fuzzy inference system at different combinations of the two input variables, while maintaining the Green Vocabulary Knowledge at a constant moderate level.

## 3 Conclusion

This research successfully demonstrates the integration of fuzzy logic principles into green pedagogy for English language teaching. The developed intelligent framework, with its three input variables (Environmental Awareness, Language Proficiency, and Green Vocabulary Knowledge), effectively captures the complex relationships inherent in this educational context. Surface plot analysis reveals non-linear interactions between variables, confirming that fuzzy logic appropriately addresses the uncertainty in educational decision-making.

Empirical validation across four educational settings showed significant improvements in both environmental awareness (37.2% increase) and language proficiency (29.6% increase) compared to control groups. Instructors reported enhanced decision-making confidence, while students demonstrated increased engagement with both environmental topics and language learning.

Despite limitations in study duration and potential cultural context variations, this research establishes a foundation for future work. Potential developments include longitudinal studies, expansion of the rule base, integration with adaptive learning platforms, and application to other language-environmental contexts.

The framework demonstrates fuzzy logic's potential to transform educational approaches at the intersection of language learning and environmental awareness, providing educators with an effective tool for advancing both linguistic competence and ecological literacy in today's complex world.

## References

1. Shruthi, H.L., Radhakrishnan, A., Veigas, A.D., et al.: Analyzing pedagogy and education in English language teaching using information and communication technology. Educ. Inf. Technol. (2025). https://doi.org/10.1007/s10639-025-13439-2
2. Kazazoglu, S.: Environmental education through eco-literacy: integrating sustainability into English language teaching. Sustainability **17**(5), 2156 (2025). https://doi.org/10.3390/su17052156
3. Raphael, E.B., Nandanan, S.L.: Green English language teaching and EFL textbooks: fostering environmental consciousness in language education. Res. Rev. Int. J. Multidisc. **9**(4), 108–119 (2024). https://doi.org/10.31305/rrijm.2024.v09.n04.013
4. Brutt-Griffler, J.: Language endangerment, the construction of indigenous languages and world English. In: Along the Routes to Power (2006). https://doi.org/10.1515/9783110923247.35
5. Byram, M., Feng, A.: Culture and language learning: teaching, research and scholarship. Lang. Teach. (2004). https://doi.org/10.1017/S0261444804002289
6. Chiriac, A., Panciuc, L.: Intercultural education-objectives, values and perspectives. In: International Conference New Perspectives in Science Education (Edition 4), Italy (2015). https://Conference.Pixel-Online.Net

7. Zahoor, M., Janjua, F.: Green contents in English language textbooks in Pakistan: an ecolinguistic and ecopedagogical appraisal. Br. Educ. Res. J. **46**(2), 321–338 (2020). https://doi.org/10.1002/berj.3579. Accessed 30 Nov 2023
8. Jinju, T.: Intelligent evaluation of English language teaching effect with fuzzy inference algorithm. In: Hung, J.C., Chang, J.W., Pei, Y. (eds.) Innovative Computing, vol. 2 - Emerging Topics in Future Internet. IC 2023. Lecture Notes in Electrical Engineering, vol. 1045. Springer, Singapore (2023). https://doi.org/10.1007/978-981-99-2287-1_37
9. Imamguluyev, R., et al.: Smart decision-making in the green economy: a fuzzy logic approach. In: Bansal, J.C., Borah, S., Hussain, S., Salhi, S. (eds.) Computing and Machine Learning. CML 2024. Lecture Notes in Networks and Systems, vol. 856. Springer, Singapore (2024). https://doi.org/10.1007/978-981-97-7571-2_13
10. Imamguluyev, R., Imanova, T., Hajiyev, A., Khalilova, A., Ramil, A.H.: Artificial intelligence: unraveling the fuzzy logic of synthetic minds. In: Lecture Notes in Networks and Systems, vol. 23. Springer, Singapore (2024). https://doi.org/10.1007/978-981-97-7710-5_74
11. Imamguluyev, R., Imanova, T., Eldar, G.E., Gasimov, E., Hajiyev, I.: Intelligent illumination: fuzzy logic applications in IoT-driven lighting solutions. In: INFUS 2024. Lecture Notes in Networks and Systems, vol. 1089. Springer, Cham (2024). https://doi.org/10.1007/978-3-031-67195-1_4
12. Imamguluyev, R., Imanova, T., Hajiyev, A., Farkhad, D.R., Hajiyev, I.: Exploring the intersection of fuzzy logic and machine learning: applications and advancements. In: INFUS 2024. Lecture Notes in Networks and Systems, vol. 1090. Springer, Cham (2024). https://doi.org/10.1007/978-3-031-67192-0_6
13. Zadeh, L.A., Aliyev, R.A.: Fuzzy Logic Theory and Applications. Part I and Part II, p. 612 (2018)
14. Aliev, R.A., Pedrycz, W., Huseynov, O.H., Eyupoglu, S.Z.: Approximate reasoning on a basis of Z-number-valued if–then rules. IEEE Trans. Fuzzy Syst. **25**(6), 1589–1600 ( 2017)
15. Ilahi, R., Widiaty, I., Abdullah, A.G.: Fuzzy system application in education. In: IOP Conference Series: Materials Science and Engineering, vol. 434, p. 012308 (2018). https://doi.org/10.1088/1757-899X/434/1/012308
16. Loan, D.T.T., Tho, N.D., Nghia, N.H., Chien, V.D., Tuan, T.A.: Analyzing students' performance using fuzzy logic and hierarchical linear regression. Int. J. Mod. Educ. Comput. Sci. (IJMECS) **16**(1), 1–10 (2024). https://doi.org/10.5815/ijmecs.2024.01.01
17. Lin, C.C., Huang, A.Y.Q., Lu, O.H.T.: Artificial intelligence in intelligent tutoring systems toward sustainable education: a systematic review. Smart Learn. Environ. **10**, 41 (2023). https://doi.org/10.1186/s40561-023-00260-y