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FUZZY LOGIC-BASED PROTOTYPE FOR PEER ASSESSMENT IN HIGHER EDUCATION

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ABSTRACT

Artificial intelligence plays a fundamental role in educational research, especially in the assessment of problems involving uncertainty and imprecision. This article aims to model, within the peer assessment prototype, the integration of a computational model that correlates numerical and sentiment scores using fuzzy logic to generate individual and collective scores through measures of central tendency. The modelling method was applied and tested at the Technical University of Manabí (Ecuador) using the agile Scrum methodology. User testing was conducted to obtain feedback on the prototype's usability. The findings revealed that 80% of students and 90% of teachers did not experience any difficulties using the peer assessment prototype. Based on the recommendations provided by students and teachers, the necessary adjustments were made to the grade reporting interfaces. As future work, simulations are planned in massive scenarios to evaluate the prototype's performance and user satisfaction, as well as the implementation of cloud storage and processing solutions.

KEYWORDS: Student Assessment, Artificial Intelligence, Quantitative and Qualitative Grade Correlation, Student Achievement, Higher Education.

1. INTRODUCTION

In higher education, courses often have a large number of students, and assignment assessment is a common issue. Therefore, peer assessment has become necessary to solve this problem. However, it is a process that has traditionally been established with quantitative methods, recognized for their precision, but which fail to capture details of student performance. While qualitative assessment offers a detailed and contextualized view that can complement quantitative assessment, it sometimes lacks objectivity and consistency. Therefore, to address these limitations, an innovative solution involves correlating quantitative and qualitative assessments using fuzzy logic (Pinargote-Ortega et al., 2021, 2024a). This study is part of several investigations that have demonstrated the effectiveness of artificial intelligence in the educational context. Several authors have proposed innovative approaches to enhancing the validity and reliability of peer assessments. Bowen-Mendoza et al. (2020, 2022, and 2023) analysed the quality of the rubric through a study of content validity, reliability, and internal consistency. Pinargote-Ortega et al. (2020, 2023b, 2023a, 2024b, 2024c) created peer feedback sentiment analysis models as an alternative to analyze subjectivity and improve opportunities for qualitative assessment. Similarly, Head et al. (2019), Capuano et al. (2020), Yang (2025), Dam et al. (2022), Doz et al. (2022), and Glushkova et al. (2024) applied fuzzy logic to improve the subjectivity and inconsistency inherent in traditional assessments. Revathi et al. (2024) developed a mathematical model using fuzzy numbers and Newton’s method to strategically prioritize core engineering activities and reduce the educational gap between urban and rural students. Furthermore, Wang et al. (2020) and Pinargote-Ortega et al. (2021) sought to improve assessment results by using fuzzy logic to model opinions. Likewise, El Alaoui et al. (2019) weighted the opinions according to their validity and then aggregated them to achieve consensus, and obtained a reliable assessment. With this approach, this study aims to model a peer evaluation prototype at the Technical University of Manabí (Ecuador), integrating a fuzzy logic calculation model that correlates numerical and sentiment scores to generate individual and collective scores, using measures of central tendency as published in Pinargote-Ortega et al. (2024a). The article is organized as follows. After describing the related work in Section 2, the third section presents a description of the methodology. The fourth section presents the results, while the fifth section compares them with those obtained from other existing approaches. Finally, the concluding section summarizes the key findings and outlines future work.

2. RELATED WORK

Fuzzy logic provides a novel solution to persistent educational disparities, offering a path toward more equitable and effective education for all students (Revathi et al., 2024). In the context of student achievement assessment, it has been applied in studies of massive online courses (MOOCs) and in face-to-face and hybrid modalities. Montero et al. (2005) transformed student evaluations into linguistic terms, and used subjective criteria such as student interest or progress to decide whether the student passed or failed the subject. Gokmen et al. (2010) they used a fuzzy logic model to evaluate a laboratory course, reporting that the advantages of the model are automation, flexibility, and a greater number of performance assessment options relative to a classical approach that adheres to static mathematical calculations. Yadav y Singh (2011) they proposed a fuzzy system for academic assessment, reporting on its flexibility and reliability, including suitability not only for laboratory applications, but also in theoretical lectures and in online and distance education. Other authors, such as Hossein et al. (2013) developed a model where they considered three characteristics for an academic course: exam, theoretical exam and practical exam, and then, through the use of fuzzy logic based on the Mamdani technique , they obtained a new approach to student assessment. Voskoglou (2013) developed a model to assess subject knowledge, problem-solving, and analogical reasoning characteristics, represented as fuzzy subsets of a set of linguistic labels that characterized their performance, and calculated the probabilities of all student profiles. Meenakshi and Nagar (2015) proposed a fuzzy logic-based performance evaluation method, where they considered three parameters: attendance, internal and external grades, subsequently tested on a real sample, comparing both results. Chai et al. (2015) used a fuzzy classification algorithm to obtain appropriate performance indices that reflect a student's contribution in a group and subsequently classify the student accordingly. Barlybayev et al. (2016) proposed a fuzzy model of performance evaluation of students through the establishment of performance. In other experiments, Capuano et al. (2017, 2020) presented an approach in which each student randomly ranked some papers from best to worst, and specified, through a set of intuitive labels, how superior each paper is to the next one in the ranking; the rankings provided by the students were transformed into fuzzy preference relationships. Eduardo et al. (2019) used fuzzy logic to determine which of the two types of theoretical or laboratory classes the students performed best in; they concluded that students performed better on laboratory exams. Martínez-Vázquez (2019) addressed the critical evaluation of the graduate profile by collecting, processing, and interpreting numerical information derived from surveys; the data processed through fuzzy logic allowed for a critical evaluation of the correlation between academic practice and graduate attributes. Bello Saleh (2020) applied fuzzy logic and compared it with the simulation evaluation method to a single subject; the simulation assessment method provided students with an exact score, without truncation or approximation in their performance, while the fuzzy logic assessment method truncates the result, which abbreviates their performance. Wang et al. (2020) developed a system to calculate the sentiment score of student reviews and then applied a fuzzy logic module to analyse and quantify student satisfaction at a detailed level. In other studies, Gedela and Bodanki (2021) presented an approach based on fuzzy logic, they considered academic performance parameters and extracurricular activities to analyse student performance. Zatul et al. (2021) designed and tested an expert system with fuzzy logic considering the characteristics of knowledge, problem-solving ability, with a real sample of student grades, subsequently comparing the results of the fuzzy expert system and the conventional method. Dam et al. (2022) presented a system to measure the knowledge and cognitive skills acquired by the student, they adopted the approach of fuzzy set theory to overcome the vagueness present in the assessment process. Doz et al. (2022) analysed methods of assessing students' mathematical knowledge considering their written and oral grades and their achievements in the Italian national assessment of knowledge, the final grade was produced using the fuzzy logic inference system. Esin Ozseven and Cagman (2022) developed a fuzzy logic model with student behavior factors during the semester and the distractor weighting coefficient for multiple-choice exams, and performed a performance evaluation on the student's incorrect answers.

Similarly, Jaju et al. (2023) used a fuzzy inference system to analyse student performance based on scores and other environmental factors. Jan et al. (2023) used fuzzy logic to monitor student academic performance by considering three factors: direct assessment, indirect assessment, and stress; the system output shows the comfort zone, which is a satisfactory assessment; the average zone, which shows an average or acceptable assessment; and the high-pressure zone, which reflects areas of concern where work is needed to improve student assessment. Kumar and Singh (2023) applied a fuzzy inference system based on input variables and found that the fuzzy method 2 is much better than the fuzzy method 1. Elfakki et al. (2023) they used fuzzy logic to analyse the academic performance of students with disabilities with characteristics of experience, understanding, problem-solving ability, according to the findings, based on 20 students with disabilities, the fuzzy logic technique used in 3D virtual learning environments produces different results than traditional assessments. Moe (2023) employed fuzzy logic to calculate student performance in online classes, he concluded that fuzzy set theory helped teachers easily understand the student in a specific course. Yang et al. (2023) combined student input on student opinion on teaching into an overall output using fuzzy logic to create a defuzzy output that simulates a reduced score on an exam. In other research, Sapuguh et al. (2024) they developed a fuzzy logic-based system to accurately and efficiently predict student performance. It integrated various input factors, such as test scores, class participation, and other variables, into the decision-making process. Nabiel Algshat (2024) compared the performance, attendance, and self-reported satisfaction of students assessed using fuzzy logic with those assessed using traditional methods; the results showed that students assessed using fuzzy logic obtained higher average scores and expressed greater satisfaction with the assessment process. Vora and Tulshyan (2024) evaluated student performance using a fuzzy inference system, which analyses input variables, data processing, and implementation. Mathew et al. (2024) focused on academic performance, evaluating theoretical and practical qualifications using the fuzzy logic technique. The simulation results provided strong evidence of the technique’s effectiveness. Singh and Sharma (2024) conducted a fuzzy logic performance evaluation model, considering four attributes: leadership, communication, discipline, and GPA. The results obtained show that the proposed model can improve in fairly selecting the best candidate. Loan et al. (2024) employed a combination of fuzzy logic and hierarchical linear regression to analyse student performance, showing that the hybrid approach assessed student performance with greater nuance and adaptability compared to the traditional method. Similarly, Glushkova et al. (2024) modelled the assessment process in a cyber-physical educational environment using the formal semantics of context-aware fuzzy environment computation. Kamel and ElGhool (2024) developed a fuzzy logic-based self-learning system using data representing students' knowledge, skills, and educational needs. Barlybayev et al. (2025) they proposed a fuzzy logic model for assessing student achievement and compared the model's effectiveness with traditional grading systems, such as national standards, arithmetic mean, and institutional systems. Pathak (2025) used fuzzy logic to classify each student's performance based on various factors: stress, motivation, confidence, parental support and availability, hours of independent study, punctuality, and circle of friends, and generated more accurate and measurable results. And Azmin et al. (2025) created a fuzzy logic model that integrates three main input variables: attendance, study hours, and exam results, selected for their significant impact on academic performance, as established in previous studies.

3. METHODOLOGY

3.1. Study Context

Modelling was performed to evaluate a calculation model in the peer assessment prototype.

3.2. Participants

The study involved 712 students from various subjects, including software engineering fundamentals, software engineering, office automation fundamentals, business process management, enterprise systems, and programming fundamentals. These subjects were taught in face-to-face, asynchronous, and synchronous virtual learning environments as part of the Computer Systems Engineering, Information Technology, and Chemical Pedagogy programs at the Technical University of Manabí in Ecuador.

3.3. Procedure

Figure 1 illustrates the implementation procedure for the calculation model in the peer assessment prototype. The steps are described below:

Step 1. Process Modelling. The numerical and sentiment score correlation calculation model using fuzzy logic, and the generation of individual and collective scores using central tendency adjustment measures, from this research published by Pinargote-Ortega et al. (2024a) were considered to develop the API (Figure 2).

Step 2. Implementation Methodology. The agile Scrum methodology was used to implement the calculation model in the prototype previously published in Pinargote-Ortega et al. (2023a). The activities were organized into two iterations, with the following priorities:

First Iteration:

- Extension of the prototype architecture.
- Database expansion.
- Design of the grading interfaces.

Second Iteration:

- Implementing the calculation model in an API.
- Integrating the API into the peer assessment prototype.
- End-user testing.

Step 3. Implementation of the Calculation Model. The architecture and databases were expanded, and the grading interfaces were designed. The calculation model was then integrated into an API and implemented in the peer assessment prototype (Figure 3).

Step 4. End-User Testing. End-user testing was conducted, where students and teachers interacted with the prototype and provided feedback on the interfaces through a survey. Participants were trained through the Google Meet platform. During the session, they were explained the objective of the research, the importance of their participation, and the procedure for completing an informed consent form. They were also informed about the processing of the collected data, with an emphasis on the use of an anonymization procedure to ensure confidentiality and compliance with the study's ethical standards.

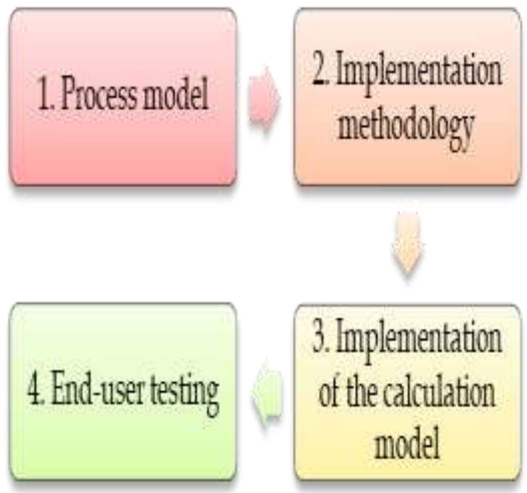

Figure 1: Procedure for Implementing the Calculation Model in the Peer Assessment Prototype.

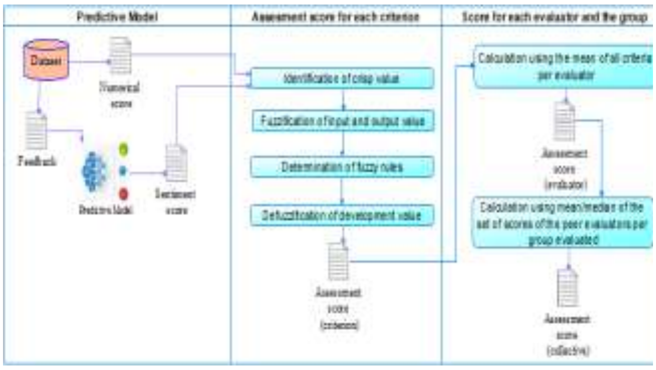

Figure 2: Calculation Model based in Pinargote-Ortega et al. (2024a).

4. RESULTS

4.1. Implementation of the Calculation Model

The peer assessment prototype (Figure 3) is linked to the Academic Management System (SGA) of the Technical University of Manabí through various APIs, allowing access to relevant information such as the assignment of departments to teachers, academic periods of students and teaching loads, as well as the subjects taught. Furthermore, the support vector machine model with a 1-g and 2-g+TFIDF representation, which achieved an F- Measure of 0.879 to classify sentiments as positive or negative, published in Pinargote-Ortega et al. (2021), was implemented in a textual feedback sentiment analysis API (qualitative assessment) published in Pinargote-Ortega et al. (2023a). Next, a calculation model published in Pinargote-Ortega et al. (2024a) was integrated using an API, as illustrated in Figure 4. This API receives as input the activity ID, the numerical score, and the sentiment score generated by the predictive model. The processes associated with this end point include generating the task evaluation score for each criterion, using fuzzy logic. Subsequently, the average of all the criteria is calculated, and finally, the mean or median of all the individual scores is determined to obtain the collective score. The prototype's new features include grade generation, where teachers can view the final grades in the "Grades" section, selecting the parallel, the activity, the type of report and the type of measure to calculate, as shown in Figure 5. In addition, they have the option to download an Excel file with the same data displayed, as seen in Figure 6. Students can also access their scores in the "Grades" section by selecting the desired activity, as shown in Figure 7.

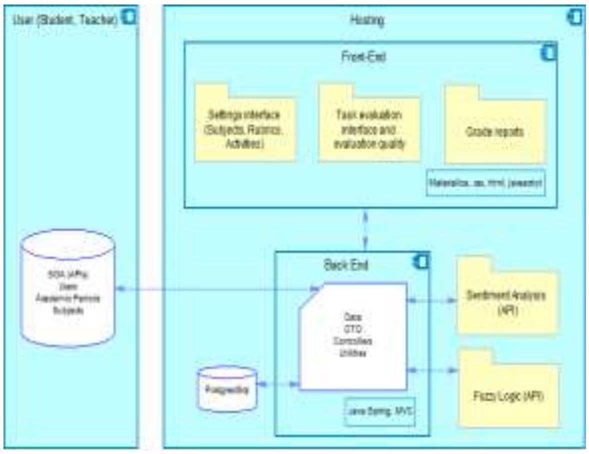

Figure 3. Architecture of the Peer Assessment Prototype.

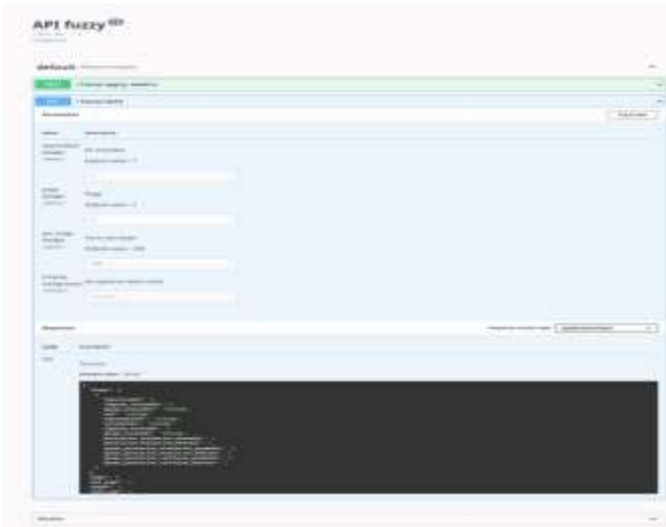

Figure 4: Fuzzy API Interface, Data post/fuzzy/apply-Models.

Figure 5: Student Grades with Mean/Median by Activity.

	Student	Group	Peer Rating	Teacher Rating
2	MENENDEZ ESPINOZA MARCO ANTONIO	Grupo-2	3.52	3.25
3	PICO LOOR ADONIS ALEXANDER	Grupo-3	3.25	3.00
4	VELEZ MARCILLO ANGEL RICARDO	Grupo-1	3.56	2.75
5	ZAMBRANO DEMERA XAVIER ALEJANDRO	Grupo-3	3.25	3.00
6	MENDOZA GARCIA JORDY UBALDO	Grupo-1	3.56	2.75
7	MACIAS MERO ANGELO STEEVEN	Grupo-1	3.56	2.75
8	LOOR URETA JHOAN SEBASTIAN	Grupo-3	3.25	3.00
9	MENDOZA MEJIA GABRIEL EDUARDO	Grupo-3	3.25	3.00
10	SANTANA FAUBLA SANDRO JAVIER	Grupo-1	3.56	2.75
11	ALVAREZ BRAVO MERY LAURA	Grupo-1	3.56	2.75
12	IBARRA ALCIVAR ELVIA ELIANA	Grupo-2	3.52	3.25
13	NARANJO SANTOS KATHYA CHANEL	Grupo-3	3.25	3.00
14	PEÑAFIEL ARTEAGA NATALY NAYELI	Grupo-2	3.52	3.25
15	VELEZ SAN ANDRES FERNANDO JOSE	Grupo-3	3.25	3.00
16	SANCHEZ LOOR JOAN PATRICIO	Grupo-2	3.52	3.25
17	BRIONES RIOS SHARIFF STEPHEN	Grupo-2	3.52	3.25
18	MENENDEZ MACIAS MAURO MANUEL	Grupo-2	3.52	3.25

Figure 6: Excel File with Data Calculated with Mean/Median by Activity.

Figure 7: Student Assessment Scores Display Interface.

4.2. End-User Testing

End-user testing was conducted with the participation of 712 students and five teachers from various subjects. These tests took place in virtual and in-person environments, and detailed training on each prototype interface provided via Google Meet. Subsequently, a questionnaire was administered to assess students' perceptions of the prototype's usability with the calculation model. A total of 630 students and 5 teachers participated in this phase. The results revealed that 1% of teachers encountered significant difficulties with the grading interface, while 9% experienced some difficulties, and 90% had no difficulties at all. Regarding the grading reporting interface, 5% of students faced significant difficulties, 15% had some difficulties, and 80% had no difficulties at all. Overall, a few difficulties were observed with either interface. Based on the feedback provided by teachers and students, the necessary adjustments were made to the prototype.

5. DISCUSSION

Comparing our work with previous studies, we found that all the research explores the uncertainty and imprecision inherent in educational assessment processes, achieving a more equitable assessment through the use of soft computing techniques. In this sense, several authors such as Hossein et al. (2013), Voskoglou (2013), Meenakshi and Nagar (2015), Martínez-Vázquez (2019), Gedela and Bodanki (2021), Zatul et al. (2021), Dam et al. (2022), Doz et al. (2022), Jan et al. (2023), Elfakki et al. (2023), Sapuguh et al. (2024), Algshat (2024), Mathew et al. (2024), Sharma (2024)¸ Pathak (2025), and Azmin et al. (2025) considered multiple criteria to calculate the final grade more accurately, reflecting a more holistic view of student performance. However, our study expands the scope by integrating sentiment analysis of textual feedback with numerical ratings, allowing for a more accurate and fairer final score. On the one hand, researchers such as Capuano et al. (2017, 2020), Voskoglou (2013) and Barlybayev et al. (2016) have worked on models to evaluate distance education platforms, our research was modelled in a face-to-face, virtual synchronous and asynchronous context, which contributes to our approach being more adaptable to institutions in hybrid contexts, however, it requires adjustments to scale to massive platforms. Furthermore, the results of the end-user tests, where both students and teachers had no difficulties using the calculation and reporting interfaces, are consistent with the findings of Bowen-Mendoza et al. (2023), who achieved high satisfaction and perceived validity of the prototype. An important aspect of our work is the prototype architecture, which aims for scalability for adaptation to other educational environments; in contrast to studies focused on theoretical models such as those of Voskoglou (2013) and Barlybayev et al. (2025). Another significant contribution is that the approach adopts a more practical perspective for its implementation in real educational institutions, because it connects directly with the university's academic management system through APIs, facilitating access to relevant academic data ; differing from other previous studies that focus on experimental models such as those by Glushkova et al. (2024) and Yang (2025). Furthermore, our study stands out for its flexibility, adapting to the specific needs of teachers and students, given that the prototype has the functionality to generate customized reports with mean or median and download data in Excel format. This perspective coincides with Gokmen et al. (2010) and Singh (2011), who emphasized the advantage of fuzzy logic over traditional assessment methods.

6. CONCLUSIONS

The implementation of the prototype based on a fuzzy logic computational model proved to be an effective tool for correlating numerical and sentiment scores and generating accurate and equitable individual and collective scores using measures of central tendency, offering a more holistic view of student performance. Furthermore, the prototype demonstrated adaptability to diverse educational contexts, including in-person, synchronous, and asynchronous virtual learning, contributing to its adaptability to institutions in hybrid contexts. End-user testing of the prototype showed that 80% of students and 90% of faculty members did not experience significant difficulties using the grade generation and reporting interfaces, reflecting the effectiveness of the architecture design and the APIs integrated with the university's academic management system for accessing relevant academic data. Despite the achievements, certain inaccuracies in the sentiment analysis were identified due to linguistic ambiguity, errors in commenting, and differences in cultural feedback norms. Furthermore, the study presents limitations in its scalability to massive educational environments, such as open online course platforms (MOOCs), due to the lack of testing with large volumes of data and concurrent users, which could cause delays in processing the sentiment analysis and in calculating scores using fuzzy logic. Therefore, as future work, we propose expanding the dataset and exploring algorithms that can more accurately capture the contextual nuances and regional characteristics of the Spanish language. We also propose conducting simulations in massive scenarios to evaluate prototype performance and user satisfaction, as well as the implementation of cloud storage and processing solutions that overcome these scalability barriers.

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