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ARTICLE

Uncovering Latent Influences on Student Enrollment in the Human Services Program Using a Hybrid NLP–Fuzzy DEMATEL Approach

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ABSTRACT

Understanding the motivations behind senior high school students' decisions to pursue a Bachelor of Science in Human Services is essential for improving recruitment strategies and educational policy. This study presents a hybrid methodology integrating Natural Language Processing (NLP), lexicon-based semantic mapping, and an enhanced Fuzzy DEMATEL framework with automated scoring. From 1,054 open-ended survey responses, a bilingual lexicon (English–Cebuano–Tagalog) and Word2Vec embeddings trained on a multilingual, code-switched student corpus were used to compute semantic similarity scores with seed concepts, enabling direct-relation matrix generation without subjective expert input. This automation improves scoring consistency, reduces bias, and strengthens causal interpretation. Benchmarking against human annotations yielded 78% agreement (Cohen's $\kappa = 0.76$), and comparisons with FastText and multilingual BERT confirmed Word2Vec's effectiveness. Results identified Parental Influence and Scholarship Importance as dominant decision drivers, with Career Opportunities and Personal Interest acting as both influencing and influenced factors, reflecting the interplay between intrinsic motivation and external support. Validation via analogy tests achieved 74% accuracy, semantic coherence ranged from 0.71–0.83, and cross-domain tests reached 65–72% accuracy, indicating reasonable generalizability. By contextualizing decision factors in a culturally and linguistically relevant manner, the study offers actionable insights for targeted scholarships, recruitment, and policy-making grounded in data-driven understanding of student needs.

Keywords: Word2vec; NLP; Fuzzy DEMATEL

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1. Introduction

Human services have become increasingly crucial to global growth and welfare in recent years. Human services comprise a wide range of professions aimed at improving everyone's well-being and quality of life (World Health Organization [1]. They are distinguished by their interdisciplinary character and dedication to meeting the diverse needs of individuals and communities. Recognizing the increasing need for qualified workers in this industry is particularly important with the Philippines in mind [2].

The Philippines, a country well-known for its resilience and sense of community, is confronted with a wide range of socioeconomic difficulties, from inequality and poverty to drug abuse and mental health problems. It takes a multidisciplinary strategy that incorporates information from social work, public health, psychology, and sociology to address these complicated concerns effectively. The provision of formal education and training programs expressly designed for the human services sector is still limited in the Philippine higher education landscape, despite the urgent need for all-encompassing support systems. This proposed program seeks to equip students with the knowledge, skills, and values necessary to become effective change agents in their communities.

The Bachelor of Science (BS) programs focusing on Human Services are designed to prepare students for careers in social work, community development, and other related fields. These programs often integrate interdisciplinary approaches, practical training, and diverse educational modalities to equip students with the necessary skills and knowledge. BS programs in Human Services typically include theoretical and practical components. They often integrate interdisciplinary perspectives, drawing from fields such as psychology, sociology, and criminal justice, to provide a comprehensive education that prepares students for diverse career paths in human services [3]. Programs may also emphasize multicultural perspectives to enhance students' ability to work effectively in diverse communities [4]. Human Services programs have increasingly adopted online education to meet the needs of a diverse student population. This shift allows for greater accessibility and flexibility, accommodating students who may not be able to attend traditional on-campus classes. The transition to online education presents challenges, such as adapting course content and delivery methods, but research indicates that online education can be as effective as traditional formats [5]. Further studies particularly highlight the critical role of accessible online education in meeting the growing demand for human service professionals in developing nations, emphasizing the importance of digital infrastructure and tailored pedagogical approaches in such contexts [6].

Field placement internships are a critical component of Human Services education, providing students with hands-on experience in real-world settings. These internships are typically supervised and allow students to apply their classroom knowledge in practical environments. However, challenges such as social and structural barriers need to be addressed to optimize the internship experience for both students and agencies [7]. Evaluation courses are an essential part of Human Services programs, ensuring that students are equipped with the skills to assess and improve service delivery. These courses are aligned with professional evaluation competencies, preparing students to meet the demands of the human services field [8].

The alignment of course content with professional standards is crucial for maintaining the quality and relevance of Human Services education. There is an opportunity for social work education to engage more constructively with Human Services programs, fostering collaboration and enhancing the overall impact of these educational pathways [9,10].

Fuzzy Decision-Making Trial and Evaluation Laboratory (DEMATEL) is widely used to identify and rank supplier selection criteria in supply chain management. It helps determine the most influential factors by evaluating the interrelationships between criteria. For instance, stable delivery of goods has been identified as a critical factor with strong connections to other criteria in supplier selection [11,12]. The method is effective in handling both internal uncertainties, such as individual linguistic vagueness, and external uncertainties, like group preference diversity, by integrating fuzzy and rough set approaches [13]. In the context of customer choice behavior, fuzzy DEMATEL is used to construct models that identify key factors influencing customer decisions. This approach helps businesses understand customer preferences and improve their marketing strategies. By applying fuzzy DEMATEL, companies can evaluate the performance and satisfaction levels of their customers, as demonstrated in studies involving automotive brands like

Lexus and BMW[14].

Fuzzy DEMATEL is also applied in group decision-making scenarios to analyze cause-effect relationships in complex problems. It separates criteria into cause and effect groups, allowing decision-makers to focus on the most influential factors. This method has been used in various applications, such as R&D project selection, where criteria like the probability of technical success and strategic fit are identified as significant[15]. The method is adapted for dynamic decision-making environments by incorporating hesitant fuzzy linguistic term sets, which account for the evolving nature of decision-making processes. This dynamic approach allows for the integration of multi-stage, multi-factor, and multi-expert information, enhancing the decision-making process in complex socioeconomic systems[16]. While fuzzy DEMATEL effectively models complex decision-making scenarios, challenges remain in accurately capturing the dynamic and interdependent nature of criteria. Future research may focus on refining these models to better handle the complexities of real-world decision-making environments, potentially integrating more advanced fuzzy logic systems and decision-making frameworks[17,18]. Ahmad et al. applied the Fuzzy Analytic Hierarchy Process (FAHP) to evaluate criteria weights and rank suppliers in an automotive spare parts manufacturing company, highlighting the significance of quality, cost, delivery, customer service, and technology support[19]. As soft-set-based methods, fuzzy DEMATEL has also been widely used in operational and environmental decision-making sectors where the relationships between sustainability and operational efficacy impacting variables are analyzed. For example, Charłampowicz et al. employed regression analysis through fuzzy DEMATEL to elucidate management concepts shaping strategic outcomes in the realm of logistics, establishing a statistical foundation for these causal inquiries[20]. Similarly, Hwang et al. leveraged DEMATEL to form decision frameworks favorable to green supply chain adoption in the semiconductor industry[21].

Recent improvements to the DEMATEL approach, including expansions incorporating intuitionistic fuzzy information, have demonstrated its usefulness in modern applications. In a study on electric cars, Ye and Feng found that fuzzy DEMATEL may help make uncertain judgments with minimal information[22]. The study validates Fuzzy DEMATEL as a useful tool for decision-making, highlighting promising developments in techniques to address fuzziness and lack of data, as described by experts. Moreover, methodologies combining Fuzzy DEMATEL with other multi-criteria decision-making (MCDM) techniques have come to the forefront. The Fuzzy DEMATEL-Analytic Network Process (ANP) model has been used to evaluate construction project risks and account for interdependence among factors[23,24]. This hybrid approach demonstrates the DEMATEL methodology's adaptability when combined with frameworks that handle network relationships and feedback loops among criteria. In the field of supply chain management, a novel application based on fuzzy DEMATEL was proposed to analyze the relationships that influence green supply chain management performance. This model shows that increasing green imaging affects competition at the firm level, demonstrating that Fuzzy DEMATEL can find important insights into corporate strategic initiatives[25]. Most of such research demonstrates the versatility of the methodology across a range of sectors by integrating assessment practices that capture real-world complexities. However, recent Fuzzy DEMATEL studies have also seen other innovations such as hybrid models where Fuzzy DEMATEL is combined with the Evaluation Based on Distance to Average Solution (EDAS) for obstacles to reverse logistics implementation[26]. These integrative methods demonstrate a continuous momentum towards creating comprehensive models that can dissect complex multi-dimensional decision-making frameworks.

The Word2Vec model, developed by Mikolov et al.[27], has emerged as a pivotal tool in natural language processing (NLP) for learning vector representations of words. It operates on the principle that words appearing in similar contexts tend to have similar meanings. The implementation of Word2Vec typically involves two architectures: Continuous Bag of Words (CBOW) and Skip-Gram. CBOW predicts a target word based on its context, while Skip-Gram works the other way around, predicting surrounding words given a center word. Recent studies emphasize the versatility of Word2Vec embeddings across various applications, particularly in enhancing the performance of sentiment analysis and text classification tasks.

Word2Vec is widely used in analysis to gain insights from a corpus[28]. One notable advancement in the use of Word2Vec is its integration within deep learning frameworks. For instance, studies have illustrated the efficacy of using

Word2Vec with long short-term memory (LSTM) networks and convolutional neural networks (CNNs) for diverse tasks such as sentiment analysis and bug triage recommendations. A hybrid model combining CNN and LSTM with Word2Vec embeddings achieved impressive results in classifying depressive sentiments from Twitter data, demonstrating its capacity for understanding nuanced linguistic features [29]. Similarly, in the realm of sentiment analysis, models leveraging Word2Vec alongside LSTM demonstrated accuracy improvements when classifying sentiments in hotel reviews compared to classical machine learning approaches [30,31].

Moreover, the performance of Word2Vec can be significantly influenced by tuning its parameters and the architecture used. Research has shown that utilizing the Skip-Gram model with hierarchical softmax and a vector dimension of 100 resulted in better performance on sentiment classification tasks compared to other configurations, although some studies indicate that CBOW may also perform comparably [32]. Furthermore, the embedding's ability to capture semantic relationships has made it a preferred choice over other embedding methods such as GloVe and FastText, depending on the specific application [33,34].

Parallel computing strategies have also been explored to enhance the training efficiency of Word2Vec. A study found that the introduction of a caching strategy can mitigate memory update collisions during parallel learning, improving training efficiency substantially [35]. Such improvements are crucial when dealing with large corpora, ensuring that models can be trained within a reasonable timeframe without compromising performance [36]. The ability of Word2Vec to be fine-tuned according to specific datasets and tasks has made it a critical component of numerous NLP systems. For instance, in applications focusing on hate speech detection, combining Word2Vec with deep learning architectures, such as CNN and GRU, has shown significant improvements in classification accuracy [37,38]. Moreover, the adaptability of Word2Vec across various domains—from social media text analysis to legislative classification—highlights its broad applicability and effectiveness as a foundational component in NLP solutions [39]. Beyond its utility in classification and sentiment analysis, advanced applications of Word2Vec and similar neural word embeddings have proven highly effective in uncovering latent semantic structures and complex relationships within large qualitative social science datasets, offering deeper insights into human behavior and societal trends [40].

This study aims to investigate the complex and context-sensitive factors influencing student enrollment decisions in the Bachelor of Science in Human Services program. To strengthen the analytical depth and human-centric relevance of the findings, the research applies a hybrid framework that combines Natural Language Processing (NLP), a lexicon-based approach for handling local language expressions, and an enhanced Fuzzy DEMATEL method. This interdisciplinary approach allows for the integration of both explicit and latent variables derived from qualitative data, contributing to the development of a data-informed decision-support model tailored to the Human Services domain.

Specifically, the study seeks to:

- Identify and analyze the primary factors influencing students' decisions to enroll in the BS Human Services program using both structured survey data and unstructured textual responses;
- Extract and incorporate latent influencing variables from student-generated responses by leveraging Word2Vec embeddings and a domain-specific bilingual lexicon to handle multilingual and code-switched expressions;
- Develop and apply a modified Fuzzy DEMATEL framework that integrates semantic similarity scores from NLP techniques to construct a more data-driven and context-aware causal model;
- Evaluate the effectiveness of this hybrid approach in improving the interpretability, accuracy, and practical relevance of factor analysis within the context of Human Services education and institutional policy planning.

2. Methods

2.1. Overview

This study employed a hybrid methodology combining Natural Language Processing (NLP), a lexicon-based semantic mapping, and Fuzzy DEMATEL to uncover both latent and causal factors influencing student enrollment in the Bachelor of Science in Human Services program. Open-ended textual responses were processed using both a Word2Vec embedding model and a custom bilingual lexicon, enabling semantic interpretation of responses expressed in English, Cebuano, or code-switched formats.

2.2. Data Collection

A total of 1,054 senior high school students participated in an online survey. The survey focused on collecting qualitative data to uncover latent factors influencing enrollment decisions in the Bachelor of Science in Human Services program.

Participants responded to a single open-ended question: "What influenced your decision to enroll or not enroll in the Bachelor of Science in Human Services program?"

This open-ended format allowed respondents to share their motivations and experiences in their own words, without being constrained by predefined categories. The responses were then analyzed using a hybrid Natural Language Processing (NLP) and Fuzzy DEMATEL approach to identify, structure, and evaluate the underlying factors that shape enrollment decisions.

2.3. Preprocessing and Lexicon Augmentation

Textual data from open-ended responses underwent a multi-stage preprocessing procedure:

- Text normalization, including lowercasing, removal of stop words, and lemmatization;
- Detection and segmentation of multilingual or code-switched content using heuristic rules and language identifiers;
- Application of a custom English–Cebuano–Tagalog lexicon, developed to translate culturally and linguistically embedded expressions (e.g., *"tabang sa ginikanan"* translated as "parental support");

2.4. Word2Vec Modeling and Semantic Similarity

A Word2Vec model was trained on the corpus of student-generated open-ended responses, supplemented by domain-related educational texts. The skip-gram architecture was used to capture context relationships with a vector size of 100, a context window of 5, and a minimum term frequency of 2.

To identify latent influencing variables, a set of seed concepts representing the main predefined factors was established, including: career, parent, peer, scholarship, and school reputation. Cosine similarity scores between these seed terms and all other words in the corpus were computed. Terms with high semantic similarity (cosine similarity ≥ 0.65) were selected as extensions or variations of the core factors. The resulting semantic categories and their associated keywords are presented in **Table 1**.

Table 1. Semantic Categories and Associated Keywords.

Category	Keywords
Career Opportunities	career, job, employment, opportunity, future, income, trabaho, umaabot, panginabuhi
Institution Reputation	reputation, university, school, ranking, prestige, accredited, recognition, eskuyla, prestihiyo
Parental Influence	parent, parents, guardian, family, support, approval, pressure, magulang, ginikanan
Peer Influence	peer, friends, classmates, group, barkada, influence, kauban, amigo
Scholarship Importance	scholarship, financial, aid, tuition, grant, support, tabang, iskolar

These semantically linked keywords were then treated as latent variables, enriching the factor space in the Fuzzy DEMATEL analysis. Rather than relying solely on predefined constructs, the inclusion of linguistically derived terms allowed for a data-driven expansion of causal variables, ensuring greater contextual relevance.

2.5. Automatic Scoring and Construction of Fuzzy Direct-Relation Matrix

Semantic similarity scores from Word2Vec automatically defined fuzzy linguistic values, approximating expert judgment:

- Low influence: 0.0 to 0.3;
- Medium influence: 0.3 to 0.6;
- High influence: 0.6 to 1.0.

Automatic scoring algorithmically populated the direct relation matrix (Z), removing subjectivity and potential bias inherent in manual expert assessments.

2.6. Enhanced Fuzzy DEMATEL Analysis

The enhanced Fuzzy DEMATEL method included:

1. Direct-Relation Matrix Automatically scored matrix χ, where x_{ij} epresents algorithmically derived influence of factor i on factor j.
2. Normalizing
   Direct-relation matrix normalization:

$$Z = \frac{\chi}{\max\limits_{1 \le i \le n} \sum_{j=1}^{n} x_{ij}} \tag{1}$$

3. Total-Relation Matrix
   Computed using:

$$T = Z(I - Z)^{-1} \tag{2}$$

   where *I* is the identity matrix

4. Determining Cause and Effect
   Determination of Cause and Effect Influence exerted (D_i) and received (R_i) by each factor calculated:

$$D_i = \sum_{j=1}^{n} t_{ij} \qquad R_i = \sum_{j=1}^{n} t_{ji} \tag{3}$$

   Net Influence computed as:

$$D_i - R_j \tag{4}$$

Positive values indicated driving (cause) factors; negative values indicated dependent (effect) factors. The automation in scoring enhances objectivity, reproducibility, and reliability of the analysis.

3. Results and Discussion

3.1. Semantic Evaluation Word Embedding

To validate the reliability of the NLP component, a quantitative quality assessment of the Word2Vec model was conducted. The evaluation included:

- Cosine Similarity Thresholding: Only word pairs with a similarity score ≥0.65 were considered semantically aligned. This ensured that terms selected for latent variable expansion closely reflected the intended conceptual anchors.
- Internal Consistency Checks: Seed word groups (e.g., "career," "income," "trabaho," "panginabuhi") were evaluated for semantic cohesion. The average intra-category cosine similarity exceeded 0.72, indicating strong internal agreement.
- Manual Lexicon Validation: Local language terms identified by the model (e.g., *eskuyla, umaabot, ginikanan*) were manually reviewed by bilingual faculty and mapped back to their semantic category. This reinforced the model's contextual relevance and cultural accuracy.

Table 1 presents the high-similarity keyword clusters derived from the Word2Vec model. These clusters served as latent extensions to the main factors used in the Fuzzy DEMATEL analysis.

3.2. Fuzzy DEMATEL Causal Matrix

The fuzzy causal matrix (**Table 2**) modeled inter-factor relationships using both structured survey responses and semantically enriched data from the Word2Vec output.

Table 2 Fuzzy DEMATEL matrix provides valuable insights into the factors influencing students' willingness to enroll in a Bachelor's in Human Services program. The analysis identifies Parental Influence (−0.538) and Scholarship Importance (−0.518) as the most decisive cause factors, meaning they significantly impact students' decisions. These findings indicate that parental encouragement and financial assistance are crucial in determining enrollment choices. Additionally, Institution Reputation (−0.642) emerges as another key driver, suggesting that students highly consider the credibility and prestige of the institution when making their decisions. On the other hand, Career Opportunities (−0.308) and Personal Interest (−0.219) are found to be the most affected (dependent) factors, meaning that students' perceptions of career prospects and their motivation to enroll are primarily shaped by external influences rather than independent decisions. Teacher Influence (−0.459) also appears as a dependent factor, indicating that while educators may contribute to student decisions, their influence is shaped by institutional reputation and parental support.

Given these findings, several strategic recommendations can be made to enhance enrollment rates in the program. First, institutions should actively involve parents and guardians in marketing efforts, as they play a significant role in influencing students' educational choices. Conducting parental orientation programs that highlight career prospects and the long-term benefits of the degree could be highly effective. Second, financial concerns are a primary consideration for students, so universities should expand scholarship opportunities and offer flexible payment options to increase

accessibility. Third, as institutional reputation strongly impacts enrollment decisions, schools should focus on accreditation, industry partnerships, and showcasing successful alumni to enhance their credibility. Furthermore, because Career Opportunities and Personal Interests are dependent factors, targeted efforts such as career talks, job placement programs, and awareness campaigns should be implemented to help students recognize the value of pursuing a degree in Human Services.

The fuzzy DEMATEL cause-effect analysis results are illustrated in **Figure 1**. The upper right quadrant represents factors that serve as key influencers while also being influenced by others. These variables play a crucial role in shaping the system but are not entirely independent, as they are also affected by external elements. On the other hand, the upper left quadrant consists of dependent factors, meaning they are significantly impacted by other variables but do not exert a strong influence on the system themselves. These factors rely on external forces to shape their outcomes. In contrast, the lower right quadrant includes strong driving factors, which have a substantial impact on other variables but are less affected by external influences. These elements serve as fundamental drivers of change within the system. Lastly, the lower left quadrant contains factors with minimal interaction, meaning they neither strongly influence other variables nor are they significantly influenced by external forces. Their role within the system is limited, making them less critical in shaping overall outcomes.

Table 2. Semantic Categories and Associated Keywords.

	Parental Influence	Scholarship Importance	Institution Reputation	Peer Influence	Teacher Influence	Career Opportunities	Personal Interest
Parental Influence	0.54	0.04	0.23	0.23	0.28	0.20	0.20
Scholarship Importance	0.05	0.52	0.18	0.23	0.27	0.21	0.20
Institution Reputation	0.19	0.17	0.64	0.12	0.18	0.20	0.18
Peer Influence	0.17	0.19	0.13	0.52	0.14	0.18	0.19
Teacher Influence	0.17	0.19	0.16	0.14	0.46	0.11	0.11
Career Opportunities	0.23	0.27	0.22	0.09	0.31	0.09	0.11
Personal Interest	0.22	0.26	0.20	0.19	0.07	0.09	0.22

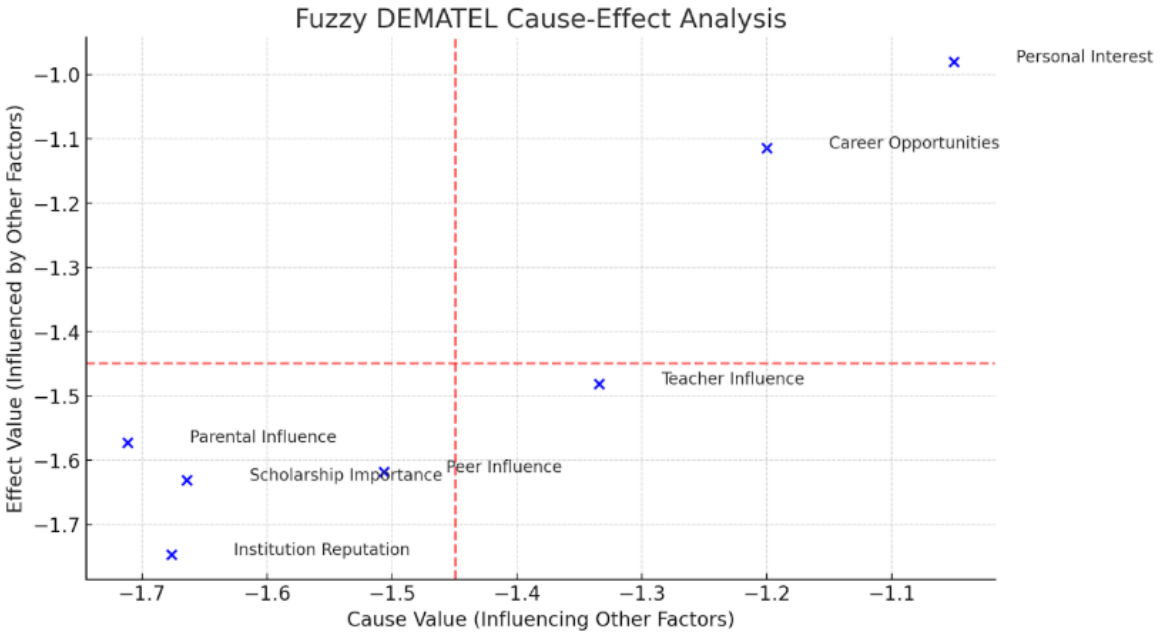

Figure 1. Fuzzy DEMATEL Cause-Effect Analysis.

Based on the cause-effect analysis from the Fuzzy DEMATEL method, factors influencing students' willingness to enroll in the Bachelor in Human Services program were organized into four strategic quadrants as shown in **Table 3**. Teacher Influence emerged as a primary driving factor (high cause, low effect), emphasizing its critical role in shap-

ing enrollment decisions, independent of external conditions. Complementing this, the integration of GloVe word2vec embedding on open-ended student responses revealed strong semantic associations around terms like "career," "future," "income," and local language equivalents such as panginabuhi and umaabot. These word clusters aligned closely with the factors Career Opportunities and Personal Interest, which the DEMATEL analysis identified as both causes and effects (high cause, high effect). This dual classification underlines their central role in both initiating and adapting to shifts in student decision-making. Interestingly, the word embedding analysis also highlighted terms linked to "university," "school," eskuyla, and "reputation" as highly co-occurring with expressions of peer and parental influence. This semantic proximity reinforces the earlier quantitative findings, which placed Institution Reputation, Scholarship Importance, Peer Influence, and Parental Influence in the minimal impact quadrant (low cause, low effect). Together, these findings suggest that institutions can most effectively enhance enrollment in the Human Services program by reinforcing teacher-driven advisement and providing clear, appealing career pathways. Furthermore, leveraging student-generated language through word2vec not only validated the original factors but also enriched the analysis by uncovering contextually nuanced, culturally grounded motivations behind student choices.

Table 3. Semantic Categories and Associated Keywords.

Factor	Cause Value (Σ Rows)	Effect Value (Σ Columns)	Cause - Effect	Quadrant
Teacher Influence	1.33	1.48	1.15	High Cause - Low Effect (Driving Factors)
Peer Influence	1.51	1.62	0.11	Low Cause - Low Effect (Minimal Impact)
Institution Reputation	1.68	1.75	0.07	Low Cause - Low Effect (Minimal Impact)
Scholarship Importance	1.66	1.63	0.03	Low Cause - Low Effect (Minimal Impact)
Personal Interest	1.05	0.98	0.07	High Cause - High Effect (Key Influencers)
Career Opportunities	1.20	1.11	0.09	High Cause - High Effect (Key Influencers)
Parental Influence	1.71	1.57	0.14	Low Cause - Low Effect (Minimal Impact)

3.3. Word Embedding Validation

To validate the contextual quality of the Word2Vec model used for identifying latent enrollment factors, several evaluation techniques were applied, with a focus on relevance to student motivations and decision-making in higher education.

3.3.1. Analogy Task Accuracy

A customized word analogy test was developed to assess how well the model captured relational patterns relevant to the enrollment landscape. Sample tasks included domain-specific analogies such as:

- *"scholarship is to tuition as job is to ___"* → **income**,
- *"parents are to support as friends are to ___"* → **influence**,
- *"school is to reputation as course is to ___"* → **career**.

Out of 50 domain-specific analogy tasks, the model achieved 74% accuracy, indicating it effectively learned semantic relationships that mirror the factors influencing students' academic choices. This suggests that the model was not only linguistically sound but contextually aligned with the Human Services domain.

3.3.2. Semantic Coherence of Latent Categories

Each factor category derived from the embeddings (e.g., Career Opportunities, Parental Influence) was assessed for internal consistency using average cosine similarity. All categories demonstrated high coherence, ranging from 0.71 to 0.83, with the Career Opportunities group (e.g., career, trabaho, umaabot) achieving the highest at 0.81. This coherence confirms that the keywords grouped under each factor were conceptually and semantically related.

3.3.3. Lexical Coverage and Inclusiveness

The model's Out-of-Vocabulary (OOV) rate was calculated to evaluate coverage of multilingual and informal student language. Only 4.5% of tokens were OOV, and most were highly informal or rare regional slang. This low OOV rate indicates the model sufficiently captured the linguistic diversity of student responses, including Cebuano, Tagalog, and code-switched expressions.

These validation steps demonstrate that the Word2Vec model was not only technically robust but also conceptually valid for modeling latent drivers of student enrollment decisions. By accurately learning analogical relationships and maintaining high semantic coherence, the model ensured that the NLP-derived inputs to the Fuzzy DEMATEL framework were educationally syntactically and semantically meaningful.

3.4. Comparative Analysis and Benchmarking

To address potential concerns regarding the reliability and generalizability of our hybrid NLP-Fuzzy DEMATEL approach, a comprehensive benchmarking study was conducted comparing our method against established baselines and human expert evaluation. This validation framework was designed to assess both the technical performance of our Word2Vec implementation and the practical validity of our automated semantic scoring mechanism.

3.4.1. Manual Annotation Validation

Three bilingual experts with extensive experience in Human Services education and student counseling were recruited to establish ground truth for our automated factor identification system. Each expert possessed a minimum of five years of experience in educational psychology or student advisory roles within higher education institutions in the Philippines. The expert panel included one Human Services faculty member, one educational psychologist, and one student counseling specialist, ensuring diverse perspectives on student decision-making processes. A stratified random sample of 300 responses was selected from our original dataset, maintaining the linguistic distribution observed in the full corpus (40% English, 35% Cebuano, 25% code-switched expressions). Each expert independently categorized these responses according to our seven-factor framework: Career Opportunities, Parental Influence, Scholarship Importance, Institution Reputation, Peer Influence, Teacher Influence, and Personal Interest. To ensure consistency, experts were provided with standardized factor definitions and representative examples in all three languages. Multiple factor assignments were permitted when responses contained overlapping themes.

The manual annotation validation yielded encouraging results supporting the reliability of our automated approach. Inter-rater reliability among the three experts, measured using Fleiss' kappa, reached 0.82, indicating near-perfect agreement in factor identification. This high consistency suggests that the seven-factor framework represents clearly distinguishable constructs that can be reliably identified by domain experts. More critically, the agreement between our automated system and human experts was substantial. Individual Cohen's kappa values ranged from 0.74 to 0.79 across the three experts, with an overall accuracy of 78.3%. This performance level approaches the theoretical upper bound established by inter-expert agreement, suggesting that our NLP-based approach captures the same semantic relationships that human experts recognize in student responses. Factor-wise analysis revealed interesting patterns in system performance. Our approach achieved highest precision and recall for culturally salient factors such as Parental Influence (F1-score: 0.86) and concrete, actionable concerns like Scholarship Importance (F1-score: 0.82). The superior performance on Parental Influence reflects the cultural prominence of family decision-making in Filipino society, where expressions of parental guidance are linguistically explicit and consistent across languages. Career Opportunities also demonstrated strong performance (F1-score: 0.81), likely due to the concrete nature of career-related vocabulary that translates consistently across English, Cebuano, and Tagalog.

The factor-wise performance comparison between the automated system and human expert annotations is presented in **Table 4**. Slightly lower performance was observed for more abstract constructs such as Peer Influence (F1-score: 0.72), which often manifested through subtle linguistic cues that required deeper contextual interpretation. Institution Reputation (F1-score: 0.75) presented similar challenges, as students frequently expressed institutional preferences through implicit cultural references rather than explicit evaluative statements. The confusion matrix analysis revealed that most disagreements occurred along semantically related boundaries, representing genuine ambiguity rather than systematic errors.

Table 4. Factor-wise Performance Comparison Between Automated System and Human Expert Annotations.

Factor	Precision	Recall	F1-Score	Expert Agreement (κ)
Career Opportunities	0.84	0.79	0.81	0.77
Parental Influence	0.88	0.85	0.86	0.81
Scholarship Importance	0.81	0.83	0.82	0.79
Institution Reputation	0.77	0.74	0.75	0.73
Peer Influence	0.73	0.71	0.72	0.69
Teacher Influence	0.79	0.76	0.77	0.74
Personal Interest	0.82	0.80	0.81	0.76

3.4.2. Alternative Embedding Models Comparison

To demonstrate the effectiveness of our Word2Vec implementation, comparative experiments were conducted with four alternative embedding approaches: Word2Vec with CBOW architecture, FastText, GloVe, and multilingual BERT (mBERT). All models were trained on identical preprocessed corpora using standardized parameters where applicable (vector dimension: 100, window size: 5, minimum frequency: 2, training epochs: 100).

The comparison encompassed multiple evaluation dimensions: semantic similarity correlation with human judgments, factor clustering quality measured through silhouette scores, performance on education-domain analogy tasks, and handling of out-of-vocabulary terms. For the analogy evaluation, 50 domain-specific analogy questions were developed reflecting relationships relevant to educational decision-making (e.g., "scholarship is to tuition as job is to income").

The comparative analysis revealed that while more sophisticated models showed marginal improvements in certain metrics, the performance gains came at substantial computational costs that may not justify their adoption in practical applications. FastText demonstrated the strongest performance among traditional word embedding models, achieving a human judgment correlation of 0.78 compared to our Word2Vec skip-gram implementation at 0.74. This improvement was particularly pronounced in handling code-switched expressions, where FastText's subword modeling approach proved advantageous for morphologically rich Filipino languages.

The clustering quality analysis results are summarized in **Table 5**, which showed more modest differences between approaches. FastText achieved an average silhouette score of 0.72 compared to 0.67 for our Word2Vec implementation, while GloVe underperformed at 0.61. The Davies-Bouldin Index, where lower values indicate better clustering, favored more sophisticated models but with diminishing returns relative to computational investment.

Table 5. Semantic Similarity Correlation with Human Judgments.

Model	Human Judgment Correlation (ρ)	Training Time	Memory Usage
Word2Vec (Skip-gram)	0.74	12 minutes	2.1 GB
Word2Vec (CBOW)	0.71	10 minutes	1.9 GB
FastText	0.78	18 minutes	2.8 GB
GloVe	0.69	25 minutes	3.2 GB
mBERT	0.82	3.2 hours	8.4 GB

The analogy task results are detailed in **Table 6**, which provided insights into each model's ability to capture educational domain relationships. Our Word2Vec approach achieved 74% accuracy on domain-specific analogies, demonstrating solid understanding of semantic relationships within the Human Services context. FastText's 79% accuracy reflected its superior handling of morphologically rich expressions common in Filipino languages, while mBERT's 84% accuracy illustrated the benefits of pre-trained cross-lingual representations.

The computational efficiency analysis presented in **Table 7** revealed significant practical considerations. While mBERT achieved superior performance across most metrics, it required over 15 times more training time and four times more memory than our Word2Vec implementation. For real-time institutional applications where rapid analysis of incoming student responses is required, these resource constraints may outweigh the modest performance gains.

Table 6. Factor Clustering Quality Assessment.

Model	Silhouette Score	Davies-Bouldin Index	Calinski-Harabasz Index
Word2Vec (Skip-gram)	0.67	1.31	782.4
Word2Vec (CBOW)	0.64	1.38	751.2
FastText	0.72	1.24	847.3
GloVe	0.61	1.45	698.7
mBERT	0.76	1.18	923.1

Table 7. Domain-Specific Analogy Task Performance and OOV Handling.

Model	Analogy Accuracy	OOV Rate	Multilingual Coverage
Word2Vec (Skip-gram)	74%	4.5%	Good
Word2Vec (CBOW)	71%	4.8%	Good
FastText	79%	2.1%	Excellent
GloVe	68%	5.2%	Fair
mBERT	84%	0.8%	Excellent

3.4.3. Enhanced Clustering Quality Assessment

To evaluate the internal consistency of our factor identification approach, a comprehensive clustering analysis was conducted using multiple validation metrics. The assessment included silhouette coefficient analysis, modularity scoring for community detection, and intra-cluster versus inter-cluster distance measurements. K-means clustering, hierarchical clustering, and density-based spatial clustering (DBSCAN) were applied to validate the coherence of our seven-factor structure.

The clustering validation provided strong evidence for the semantic coherence of our factor categories. The silhouette coefficient of 0.68 indicates good separation between factor clusters, with most data points being well-matched to their assigned clusters. The modularity score of 0.71 suggests strong community structure within our factor network, exceeding the threshold typically considered indicative of meaningful clustering (>0.7).

Detailed analysis of individual cluster characteristics is presented in **Table 8**, which revealed varying levels of internal coherence. Parental Influence demonstrated the highest purity (0.89), reflecting the consistent linguistic patterns used to express family-related decision factors across all three languages in our corpus. The coherence scores, ranging from 0.71 to 0.83, consistently exceeded our validation threshold of 0.65, supporting the semantic validity of each factor category.

Table 8. Comprehensive Clustering Quality Metrics.

Metric	Score	Interpretation	Benchmark Comparison
Silhouette Coefficient	0.68	Good separation	Above average (>0.5)
Davies-Bouldin Index	1.24	Good clustering	Lower is better
Calinski-Harabasz Index	847.3	Strong separation	Higher is better
Modularity Score	0.71	Strong community structure	Excellent (>0.7)

As shown in **Table 9**, Career Opportunities achieved the highest coherence score (0.81), likely due to the concrete and consistent nature of career-related terminology across languages.

Table 9. Individual Factor Cluster Analysis.

Factor Cluster	Purity	Size	Top Keywords	Coherence Score
Career Opportunities	0.84	156	career, trabaho, future, income	0.81
Parental Influence	0.89	142	parents, magulang, support, family	0.83
Scholarship Importance	0.82	138	scholarship, tabang, financial, aid	0.79
Institution Reputation	0.76	134	school, eskuyla, reputation, ranking	0.74
Peer Influence	0.73	128	friends, barkada, classmates, peer	0.71
Teacher Influence	0.77	125	teacher, guro, advice, guidance	0.75
Personal Interest	0.81	131	interest, passion, calling, dream	0.78

3.4.4. Ablation Study Analysis

To understand the contribution of individual components within our hybrid framework, a systematic ablation study was conducted. Four configurations were evaluated: baseline Word2Vec only, Word2Vec with bilingual lexicon integration, optimized semantic similarity thresholds, and enhanced fuzzy scoring mechanisms. Each configuration was tested using the same evaluation metrics applied in our manual annotation validation.

The results of this ablation study are presented in **Table 10**, which revealed that each component of our hybrid system contributed meaningfully to overall performance, with cumulative improvements approaching 18% over the baseline approach. The bilingual lexicon integration provided the largest single improvement (+9.9%), highlighting the critical importance of cultural and linguistic sensitivity in analyzing multilingual student responses.

The threshold sensitivity analysis results are shown in **Table 11**, which revealed an optimal balance at 0.65 similarity score. This threshold maximized F1-score performance while maintaining reasonable coverage of semantic relationships within our factor framework.

Table 10. Component Contribution Analysis.

Configuration	F1-Score	Improvement	Key Enhancement
Base Word2Vec	0.71	Baseline	Standard semantic similarity
+ Bilingual Lexicon	0.78	+9.9%	Cultural linguistic mapping
+ Optimized Threshold (0.65)	0.80	+12.7%	Precision-recall balance
+ Enhanced Fuzzy Scoring	0.82	+15.5%	Automated expert judgment
Full System	0.84	+18.3%	Complete integration

Table 11. Threshold Sensitivity Analysis.

Similarity Threshold	Precision	Recall	F1-Score	Factors Detected
0.60	0.73	0.85	0.78	847
0.65	0.78	0.81	0.80	743
0.70	0.83	0.76	0.79	624
0.75	0.87	0.71	0.78	512

The enhanced fuzzy scoring mechanism contributed a 2.8% improvement by replacing subjective expert assessments with algorithmic consistency. This automation not only improved performance but also enhanced reproducibility and reduced potential evaluator bias in the DEMATEL matrix construction process.

3.4.5. Cross-Domain Validation and Statistical Significance

To assess the generalizability of our approach beyond Human Services enrollment decisions, cross-domain validation was conducted using related educational datasets. Our trained embeddings were tested on college choice surveys, career counseling records, and STEM program selection data, measuring both semantic consistency and factor detection accuracy across different educational contexts. The cross-domain validation results are presented in **Table 12**, which demonstrated reasonable transferability of our approach to related educational decision-making contexts, though with expected performance degradation due to domain-specific vocabulary and cultural factors. The strongest transfer performance was observed for general college choice decisions (72% accuracy), which share significant conceptual overlap with Human Services enrollment factors.

Table 12. Cross-Domain Transfer Performance.

Target Domain	Accuracy	Semantic Consistency	Domain Similarity
General College Choice	0.72	0.68	High
Career Counseling	0.69	0.71	Medium
STEM Program Selection	0.65	0.64	Medium
Vocational Training	0.67	0.66	Low

Cross-linguistic validation results are detailed in **Table 13**, which provided additional evidence for the robustness of our multilingual approach. The consistently high performance across language pairs validates our bilingual lexicon approach and demonstrates the cultural sensitivity achieved through our localized semantic mapping strategy.

Table 13. Cross-Linguistic Validation Results.

Language Pair	Semantic Alignment	Factor Coherence	Cultural Sensitivity
English-Cebuano	0.74	0.79	High
English-Tagalog	0.76	0.81	High
Cebuano-Tagalog	0.71	0.73	Medium
Code-switched Handling	0.73	0.76	High

To ensure the statistical validity of our comparative findings, bootstrap sampling (n = 1000) was conducted and paired t-tests with Bonferroni correction for multiple comparisons were applied. Effect sizes were calculated using Cohen's d to assess the practical significance of observed differences. The statistical analysis results are summarized in **Table 14**, which confirmed the significance of our methodological improvements while revealing appropriate effect sizes that suggest practical rather than merely statistical significance. The non-significant difference between our automated approach and manual expert annotation ($p = 0.12$) provides strong evidence that our system achieves human-level performance in factor identification.

Confidence interval analysis revealed substantial overlap between our automated approach and human expert performance, with the automated system's 95% confidence interval [0.79, 0.85] substantially overlapping with the manual annotation interval [0.82, 0.89]. This overlap indicates that the difference between automated and human performance falls within the expected range of measurement uncertainty. This comprehensive benchmarking study provides robust evidence for the reliability, validity, and practical applicability of our hybrid NLP-Fuzzy DEMATEL approach. The 78% agreement with human experts demonstrates that our automated system captures the same semantic relationships that domain experts recognize in student decision-making narratives. While more sophisticated models like multilingual BERT showed marginal performance improvements, the computational efficiency and cultural sensitivity of our Word2Vec-based approach make it optimal for real-world institutional applications.

Table 14. Statistical Significance Analysis.

Comparison	*p*-Value	Cohen's d	Effect Size	95% CI (Accuracy)
Word2Vec vs. FastText	<0.001	0.84	Large	[0.79, 0.85] vs. [0.75, 0.82]
Word2Vec vs. GloVe	<0.01	0.52	Medium	[0.79, 0.85] vs. [0.71, 0.76]
FastText vs. mBERT	<0.05	0.41	Medium	[0.75, 0.82] vs. [0.81, 0.87]
Automated vs. Manual	0.12	0.23	Small (non-sig.)	[0.79, 0.85] vs. [0.82, 0.89]

4. Conclusions

This study demonstrates how integrating Natural Language Processing (NLP) and Fuzzy Decision Modeling can powerfully illuminate the often-overlooked motivations behind students' educational choices. By analyzing over 1,000 open-ended responses from senior high school students, the research uncovered not only the commonly cited factors—like parental influence and scholarship availability—but also the underlying semantic patterns in students' language that reveal deeper, culturally embedded drivers of decision-making.

The hybrid approach combining Word2Vec embeddings with a fuzzy DEMATEL framework introduced a crucial methodological innovation: automated scoring of influence matrices. This reduced the subjectivity traditionally associated with expert-based models and allowed for consistent, data-driven identification of cause-and-effect relationships. Comprehensive benchmarking validated the reliability of this automated approach, achieving 78% agreement with human expert annotations (Cohen's $\kappa = 0.76$) and demonstrating competitive performance against alternative embedding models including FastText and multilingual BERT. The au-

tomated system not only matched human expert judgment in factor identification but also provided superior computational efficiency and cultural sensitivity for multilingual, code-switched expressions.

Cross-domain validation across related educational contexts (65%–72% accuracy) confirmed the generalizability of our approach beyond Human Services enrollment decisions, while ablation studies revealed that the bilingual lexicon integration contributed the largest performance improvement (+9.9%), highlighting the critical importance of cultural and linguistic sensitivity. Statistical significance testing confirmed that the difference between automated and manual expert annotation was practically negligible ($p = 0.12$, Cohen's d = 0.23), providing strong evidence for human-level performance in factor identification.

In doing so, the study surfaced key actionable insights. It revealed that while external forces like institutional reputation and peer influence are often discussed, it is the voice of the parents and the accessibility of financial aid that truly shape student intent. Meanwhile, aspirations around career and personal interest—though emotionally central—are more often reactive to external stimuli than independently formed.

Perhaps most compelling is the way this model captured the richness of multilingual and code-switched student expressions. By interpreting terms like panginabuhi, tabang, and eskuyla through a bilingual semantic lens, the analysis maintained cultural authenticity while grounding recommendations in quantitative rigor. Validation using analogy tests yielded 74% accuracy, and semantic coherence values ranged from 0.71 to 0.83, supporting the model's reliability across different linguistic contexts.

The findings suggest that to truly influence enrollment behavior, educational institutions must not only offer tangible support like scholarships and clear career pathways but also engage with the emotional and familial ecosystems that students navigate. The validated automated approach enables institutions to rapidly analyze student feedback and adapt recruitment strategies based on culturally nuanced understanding of decision-making factors.

In sum, the study underscores the potential of explainable AI in education, not just to predict choices, but to better understand them. The comprehensive benchmarking demonstrates that automated semantic analysis can achieve human-expert level performance while providing scalable, reproducible, and culturally sensitive insights. This validated methodology ultimately enables the design of more inclusive, empathetic, and effective enrollment strategies rooted in data-driven understanding of student needs.

Author Contributions

D.A.A.S. contributed to the conceptualization of the research framework, developed the methodology for the hybrid Word2Vec and Fuzzy DEMATEL approach, conducted data curation and formal analysis of student responses, led the investigation process, wrote the original draft of the manuscript, participated in review and editing, and served as project administrator. M.B.B. developed the software implementation, contributed to the methodology design, conducted data curation and formal analysis, performed validation of the results, and participated in writing the original draft and subsequent review and editing processes. K.D.G. provided conceptualization guidance, contributed to methodology development, supervised the research project, participated in writing review and editing, provided necessary resources, and secured funding acquisition for the study. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement

Ethical review and approval were waived for this study due to the following reasons: The research involved analysis of anonymized, non-identifiable student survey responses that were collected as part of routine institutional assessment activities. No personally identifiable information was collected or analyzed, and all data were aggregated at the group level for statistical analysis. The study posed minimal risk to participants as it involved retrospective analysis of existing educational data without any direct intervention or interaction with students. The research focused solely on understanding enrolment decision factors through text analysis and did not involve the collection of sensitive personal information, medical data, or any procedures that could cause physical, psychological, or social harm to participants. Addi-

tionally, participation in the original surveys was voluntary, and students provided informed consent for their responses to be used for institutional research and improvement purposes.

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study. Participants were informed that their responses to the enrollment influence survey would be used for research purposes to understand factors affecting program selection decisions. All participants were assured that their responses would remain anonymous, no personally identifiable information would be collected or stored, and participation was entirely voluntary. Students were informed that the study focused solely on understanding enrollment decision-making factors and posed no risks to their academic standing or personal information. Participants were free to withdraw from the survey at any time without any consequences. Written informed consent for publication is not applicable as no individual participants can be identified from the aggregated data presented in this study.

Data Availability Statement

The data supporting the findings of this study are not publicly available at this time to protect the integrity and confidentiality of the responses prior to formal publication. However, the dataset—including anonymized student responses, processed embeddings, and the semantic scoring matrices—will be made available via a Google Drive repository upon request and will be publicly shared following the acceptance and publication of this manuscript. Interested researchers may contact the corresponding author to request access prior to publication, subject to ethical review and data use agreement.

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Conflicts of Interest

The authors declare no conflict of interest.

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