Automating the Mapping of Course Learning Outcomes to Program Learning Outcomes using Natural Language Processing for Accurate Educational Program Evaluation

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Automating the Mapping of Course Learning Outcomes to Program Learning Outcomes using Natural Language Processing for Accurate Educational Program Evaluation

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Abstract—**Quality control and assurance plays a fundamental role within higher education contexts. One means by which quality control can be performed is by mapping the course learning outcomes (CLOs) to the program learning outcomes (PLO). This paper describes a system by which this mapping process can be automated and validated. The proposed AI-based system automates the mapping process through the use of natural language processing. The framework underwent testing using two actual datasets from two educational programs, and the findings were promising. A testament to the potential of the suggested framework was the precision of the mapping detected (83.1% and 88.1% for the two programs, respectively) compared to the mapping performed by the domain experts. A web-based tool was created to help teachers and administrators execute automatic mappings (https://bidac-uaeu.github.io/mapper.-html). The data and software used in this research project can be found at the following URL: https://github.com/-nzaki02/CLO-PLO**

Index Terms— **Academic mapping, natural language processing, program learning outcomes, course learning outcomes, quality assurance in higher education, Artificial Intelligence**

I. Introduction

The contemporary educational system is far from ideal. Numerous issues arise that need to be continuously identified and addressed. However, educational outcomes can be enhanced by putting quality assurance into place and adhering to accreditation procedures. The process of ensuring that academic objectives and standards are followed is known as quality assurance (QA). A robust quality assurance system is essential in higher education contexts because it makes sure students are receiving the highest standard of education. Accreditation signifies that a recognized body has certified that a given institution offers a program that meets the required standards and criteria. As such, it is imperative that higher education institutions (HEIs) are structured in a manner that includes quality assurance as a crucial component. In contemporary educational contexts, it is standard practice to establish a department within an HEI that manages and implements quality assurance across all the different areas. This can be seen as a prerequisite that must be met when HEIs apply for program or institutional accreditation from a national or international accrediting body, like the Accreditation Board for Engineering and Technology (ABET) [https://www.abet.org/], which focuses on accrediting STEM programs, or the Southern Association of Colleges and Schools Commission on Colleges (SACSCOC), which accredits HEIs. In addition to the academic programs offered, a HEI implements quality assurance practices within all its departments and the services it offers. Given its extensive scope, quality assurance must be established on a framework that covers all facets of program delivery, research, community services, and all other auxiliary departments like human resources, finance, student services, and others. In order to achieve quality results for any educational program or offered service, quality assurance is designed to ensure consistent interactions between units. A quality assurance manual is often developed by the HEI. This manual typically outlines the procedures that must be followed by all units. The implementation of the processes outlined in the manual is then overseen by a team of QA officers, who may be a part of a larger unit within the university structure or a separate QA unit. The approach employed will typically be determined by the size of the HEI. The ISO 9000 set of standards [https://www.iso.org/iso-9001-quality-management-.html] outlines organizational quality management criteria that can be used, but are not mandated, by HEIs as part of their QA strategy. QA procedures ensure that the objectives of a course, program, or service unit are clearly specified and that these objectives are planned, implemented, and verified before any necessary steps are taken to address any weaknesses or advance the underlying objectives. To ensure its application at all levels, a hierarchal QA infrastructure is typically adopted by an HEI. To guarantee appropriate execution and fair assessment, self-assessments, internal assessments, and external audits are included. A thorough QA procedure is required to verify that high-quality programs are being delivered that satisfy the HEI goal. This implies implementing QA at various levels, including the module level, when defining and evaluating the course learning outcome; the program level when determining and evaluating the program learning outcomes; and the holistic level when delineating suitable program objectives and goals in alignment with the HEI goals, mission, and vision. QA is fundamental in ensuring that the programs on offer are continually updated in line with changing requirements. Additionally, adopting QA as a component of such a process might result in graduates of a program securing better job placements (Immerstein, R., Hasleberg, H., and Eri, G., 2020). Although the idea of quality assurance is not new, it can be improved with innovative techniques. For instance, the authors of (Ujkani, B., Minkovska, D., and Stoyanova, L., 2021) employed natural language processing (NLP) to verify that the program's overall syllabus and its associated learning outcomes were consistent. In many states and countries, governmental authorities frequently have to approve HEIs' operations before they can are permitted to operate. In addition to having a license to operate, offering programs may also require accreditation from local or external bodies. For instance, in the United Arab Emirates (UAE), the Commission for Academic Accreditation (CAA), a division of the UAE Ministry of Education (MOE), is in charge of the initial licensing of HEI and the accreditation of any programs provided. By adhering to its own standards and operational guidelines, the CAA ensures that a minimal standard of quality is upheld at the HEI and program levels. A further example of a group that exclusively accredits programs to verify that they meet specific requirements and standards is the ABET, an independent certification authority. It is frequently necessary to demonstrate that awarded degrees have been accredited by either the local authorities or/and by an outside entity in order for employers or HEIs to accept them as valid. Accreditation aims to establish uniform standards across all programs and guarantee that students can exhibit particular competency levels after completing such programs. To have faith that the program outcomes are founded on global standards and best practices based on a peer-reviewed process of a specific program's criteria. Different accrediting standards may apply depending on the educational level of a given program (bachelor, master, PhD, etc.) and subject matter (arts, engineering, science, etc.). Accreditors develop the specific applied program criteria as part of a set of guidelines and operational manuals. Implementing a worldwide benchmarking methodology promotes legitimacy and greater employability for the graduate of such programs.

The program curricula, faculty qualifications, admission standards, facilities, research, community participation, institutional support, and program-specific outcomes are all examined as part of the accreditation process and as required by the accrediting standards and criteria. Thus, prospective students and faculty interested in joining, as well as companies and other HEI looking for graduates of such programs, view accredited programs as high-quality programs. It is for this reason that HEIs may view accreditation as a key priority (Shafi, A., et al., 2019).

Examining pupils' academic performance is a common method for determining how effective a teacher performs. Curriculum mapping is important in developing the curriculum and measuring performance against objectives. It is a systematic and logical plan for how content will be arranged and presented in a course, program, or curriculum. The goal of curriculum mapping is to guarantee that all learning objectives and outcomes are attained or exceeded by the conclusion of the course.

Furthermore, evaluation is a crucial component of any educational program since it sheds light on how well a specific program performs in terms of reaching its objectives. Evaluations can be qualitative or quantitative, and each form offers distinct insights into how successfully a specific teaching technique or instructional method achieves its objectives.

Program learning outcomes (PLOs), also known as student learning objectives, are frequently used to assess a program's efficacy (SLOs). The PLOs are the precise outcomes that can be witnessed or measured after a learning session. They are intended to assist mentors and students in comprehending what will be required of them once they have completed a program. They also aid in identifying the abilities, information, and attitudes required to execute a successful program. Depending on the PLOs that have been established, the learner's experience with, and evaluation of, the program will vary. Clear objectives and quantifiable PLOs should be used when designing educational programs. The CLOs are frequently mapped to the PLOs to assess if the PLOs, which serve as the program's overarching results, have been met. The achievement of scores of associated CLOs constitutes a significant performance indicator of the PLOs. The CLOs are a key piece of quantifiable evidence of student learning that results from their attendance on a given course. The CLOs of particular courses are mapped to quantify the PLOs, general education learning outcomes (GELOs), and institutional learning outcomes (ILOs) associated with a given program of study. These metrics are frequently applied in institution-wide reports and program reviews conducted by accreditation agencies.

The process of mapping between PLOs and CLOs is time-consuming and very subjective. A two-dimensional matrix that expresses the correlation between the PLOs and the CLOs is frequently employed. However, this mapping task is difficult, even for program educators and leaders with a lot of expertise. The complexity is derived from the fact that mistakes are likely to occur throughout the mapping process, and program directors need to be aware of the proper techniques for mapping in a manner that is beneficial for the curriculum. In addition, it is difficult to identify inconsistencies in the PLOs-CLOs mappings (Alshanqiti, A., Tanweer A., Mohamed B., Abdallah, N., and Ahmad T., 2020). Since the achievement of all CLOs is taken into account as a significant factor for evaluating PLOs, GELOs, and ILOs, it is necessary to maintain the consistency and accuracy of these crucial mappings.

To the best of our knowledge, no previously published work has aimed to automate or enhance the precision of the -CLOs to PLOs mapping. There are, however, several initiatives regarding curricular mapping in general. By using a curriculum mapping technique, teachers can better understand what has been taught in a class, how it has been taught, and how the PLOs and CLOs are evaluated.

In a previous effort, Plaza et al. (Plaza, C. M. , Draugalis, J. R. , Slack, M. K., Skrepnek, G. H., and Sauer, K. A., 2007) aimed to illustrate the application of curriculum mapping in program evaluation and assessment. The authors of this study adopted a descriptive cross-sectional study approach based on a document outlining learning outcomes and numerous additional student and curriculum data sets that were already available. However, the primary objective of this study was to compare the graphical curriculum maps created by students and professors. Comparing the maps' relative rankings of each domain's emphasis revealed that the intended/delivered and received curricula agreed with one another.

A method for gathering, analyzing, and presenting information on teaching and the evaluation of graduate competencies was introduced by Spencer et al. (Spencer, D., Riddle, M., and Knewstubb, B., 2012). The suggested discursive technique encourages reflection-based practice in curriculum design, and the resulting heat maps offer diagrammatic representations of current practices and pointers as to where the curriculum should be redesigned.

The effects of curriculum ideas in higher education were discussed by Linden et al. (Linden, J., Annala, J., and Coate, K., 2017). The writers of this study concentrated on the intellectual and historical foundations of approaches to curricular theory. In higher education environments, competency-based and outcome-focused contexts are employed to avoid separating the normative and critical roles of curriculum frameworks. They recommended that everyone concentrate on the curriculum's educational value and update it in accordance with higher education norms.

A novel approach to curriculum mapping, known as the web-based learning opportunities, goals, and outcome platform (LOOOP) method, was proposed by Treadwell et al. (Treadwell, I., Ahlers, O., and Botha, G., 2019). The authors conducted a questionnaire survey with a four-point Likert scale to ascertain how the instructors perceived the projected benefits of curricular mapping. The authors concluded that instructors' comments on LOOOP's worth and usability were favorable.

For the objective of creating a four-dimensional typology for curricular maps that outlines features relating to their purpose, product, process, and display, Watson et al. (Watson, S., Steketee, C., Mansfield, K., Moore, M., Dalziel, B., Damodaran, A., Walker, B., Duvivier, RJ., and Hu, W., 2020) undertook a thorough assessment of the higher education literature. They sought to verify the framework by comparing the parameters with six curriculum maps from medical schools around Australia. Educators who specialize in the health profession are anticipated to use the proposed typology to guide crucial choices regarding the available curricular map possibilities.

A rule-based strategy was recently created by Abdullah Alshanqiti et al. (Alshanqiti, A., Tanweer A., Mohamed B., Abdallah, N., and Ahmad T., 2020) that aims to automate the evaluations of academic curriculum mapping. The goal of this method is to make it possible to examine the CLOs-PLOs mappings, identify inconsistencies, and offer recommendations for enhancing the curriculum mapping. The authors recommended a rule-based approach for curricular matrix assessments. The authors also used curriculum mapping specialists to create a web interface tool that leveraged user-based experiments to automate evaluations of their academic programs. However, the CLO to PLO mapping was also manually executed.

Unlike earlier research, our goal here is to use Natural language processing (NLP) to automate, simplify, and remove subjectivity from the CLOs-PLOs mapping process. To the best of our knowledge, this study is the first to use this technique. NLP is a subfield of artificial intelligence (AI) that studies how computers and human (natural) languages interact. It can be viewed as the research and development of tools that enable computers to process linguistic information in a manner comparable to that of humans. NLP has been around for a long time, but due to recent developments in machine learning, big data, data science, and deep learning, it has recently gained popularity as a subject of study. The field spans a wide range of useful applications, including sentiment analyzers, chatbots, search engines, online translators, automatic summarizers, and recommendation systems. The primary objective of this study is to identify the semantic connections between the PLOs and the CLOs to enable more precise mappings and, ultimately, meaningful evaluation of the educational program. A web interface tool is also created to aid administrators and teachers in quickly and automatically performing AI-based mapping.

II. Method

A. Data

The Department of Computer Science and Software Engineering at the College of Information Technology, United Arab Emirates University (UAEU), offers a Bachelor of Computer Science approved by ABET and is the basis for the CLOs and PLOs data utilized in this study. To graduate, students must complete 42 courses, which equates to 130 credits. For the purposes of accreditation, 26 college and program-required courses, totaling 121 CLOs, were manually mapped to the six PLOs of the programs. Each course coordinator independently generated the mapping, which was subsequently approved by the department council.

An additional dataset based on its ABET-accredited bachelor's degree program in Information Security delivered by the Department of Information Systems and Security at the same college was also taken into account. Thirty-four courses from the 130 credits hours program were considered (including 173 CLOs). The CLOs were manually mapped to six PLOs, and the department council validated the mapping. The

Supplementary Materials files can be accessed online (https://github.com/nzaki02/CLO-PLO) and contain the course list, related CLOs, PLOs for the two programs, and manual mappings.

B. Proposed framework

This section presents an overview of the proposed framework and the methods employed in this study. **Error! Reference source not found.** presents an overview of the framework's architecture, which consists of an input module, text preprocessing module, text representation module, CLO-to-PLO mapping module, and evaluation module.

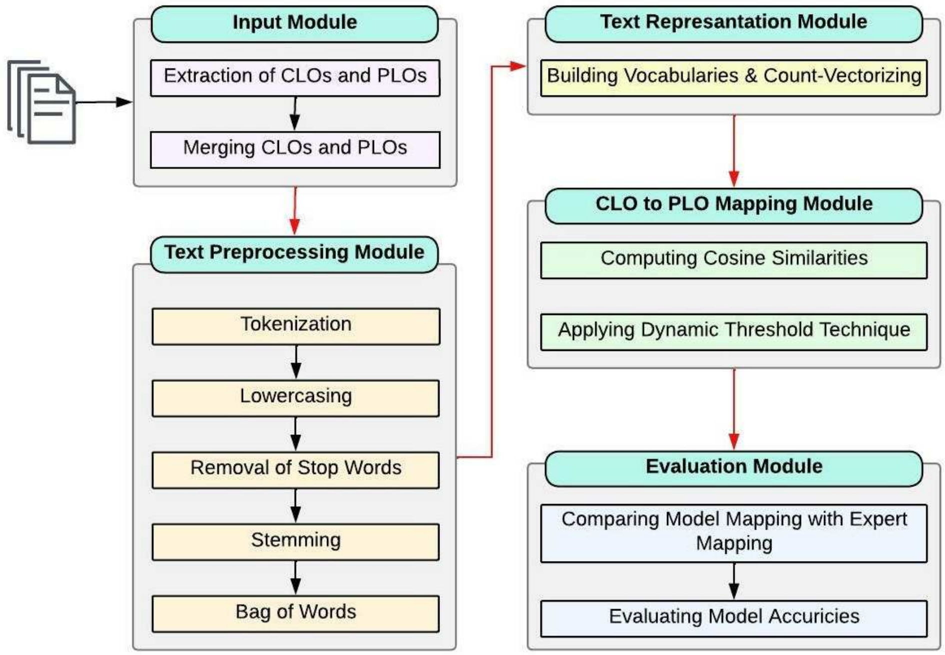

Figure 1: The proposed framework overview

C. Input module

The first step involves presenting the PLOs and CLOs in a table format that can undergo further text preprocessing. The number of the CLO collections (i.e., the number of the courses in the program) is represented by n and the number of the CLOs in each course, i, is j_i where $j_i = 1, 2, \dots, n$. Consequently, each table is $(j_i \times 2)$ with each row containing the ID and corresponding CLO. The final table is developed by combining the PLOs with the CLOs; i.e., every PLO is inserted as the first row of each CLO table. Consequently, if the quantity of PLOs is m, we have $n \times m$ output tables. This is referred to as the "PLO-and-CLOs" tables and is denoted by T_i, $i = 1, 2, \dots, n \times m$ where each T_i is of size $\left((j_i + 1) \times 2\right)$.

D. Text preprocessing module

In the next step, each CLO and PLO were converted into a list of their constituent words (word tokenization). All text was presented in lowercase because there is no distinction between lowercase and uppercase terms. Punctuation and stop words—commonly used English terms like "a," "an," "the," "in," "of," etc.—were eliminated.

The last stage in this module involved stemming, which entails eliminating suffixes and reducing a word to a base form so that all of its variations may be represented by the same form, or lemmatization, which is mapping all of a word's variations to its root word, or lemma (Vajjala, S., Majumder, B., Gupta, A., and Surana H., 2020). For instance, "work" replaces words like "works", "worked", and "working". These procedures were crucial in the current study because they enabled the construction of dense word vectors, known as bag of words (BOW), which is a collection (list) of words that disregard context and order. These also supported the accurate counting of the number of words sharing the same base or stem.

Finally, we constructed the multiset of words (i.e., set of words that may have multiple occurrences) for each CLO and PLO in every table T_i. The set of words corresponding to the kth (where $k = 1$ refers to the PLO in the current table) learning outcome in table T_i was represented by $t_{i,k}$, where $i = 1, 2, \dots, n \times m$ and $k = 1, 2, \dots, q_i$ denote the set of words.

E. Text representation module

The local vocabularies were defined as V_i, $i = 1, 2, \dots, n \times m$. The words obtained from the table T_i (see the input module) was represented by vocabulary, V_i. We mapped each word, w, in vocabulary, V_i, to a unique integer ID between 1 and $|V_i|$, where $|V_i|$ denotes the number of words in V_i. This mapping resulted in the generation of a list of unique words $[w_1, w_2, \dots, w_{p_i}]$ where $p_i = |V_i|$. Following that, each multiset, $t_{i,k}$, was converted into a vector of $|V_i|$ dimensions, called count-vector of words, where the jth component was the frequency of the word, w_j, occurring in $t_{i,k}$. Consequently, we obtained the matrix (2D array) B_i for each T_i, $i = 1, 2, \ldots, n \times m$, where the size of each B_i is $\left((j_i + 1) \times p_i\right)$.

F. CLO-to-PLO mapping module

In this module, the obtained matrices B_i, $i = 1, 2, \ldots, n \times m$, were used to accurately map each CLO to PLO(s). For this purpose, we employed the cosine similarity, which facilitates the measurement of the similarity of vectors $b_{i,k}$ and $b_{i,1}$ in matrix B_i representing a CLO, $t_{i,k}$, $k = 2, 3, \ldots, j_i$, and a PLO, $t_{i,1}$ where $i = 1, 2, \ldots, n \times m$:

$$(\cos\theta)_{i,k,1} = \frac{b_{i,k} \times b_{i,1}}{\left\|b_{i,k}\right\|_2 \times \left\|b_{i,1}\right\|} = \frac{\sum_{l=1}^{p_i}\left(b_{i,k}\right)_l \times \sum_{l=1}^{p_i}\left(b_{i,1}\right)_l}{\sqrt{\sum_{l=1}^{p_i}\left(b_{i,k}\right)_l^2} \times \sqrt{\sum_{l=1}^{p_i}\left(b_{i,1}\right)_l^2}}$$

where $\left(b_{i,k}\right)_l$ and $\left(b_{i,1}\right)_l$ are the lth components of vectors $b_{i,k}$ and $b_{i,1}$, respectively. If the cosine value of the vectors $b_{i,k}$ and $b_{i,1}$ is close to 1, they are deemed to be similar. The possibility of mapping CLO i_k, $k = 2, 3, \ldots, j_i + 1$, in each CLOs group i, $i = 1, 2, \ldots, n \times m$, into the PLO j, $j = 1, 2, \ldots, m$, for which the cosine similarity is computed, is delineated by establishing a specific dynamic threshold ϕ_i for each group of CLOs and PLO based on the minimum and maximum values of the cosine similarities computed:

$$\phi_i = \frac{h_i + s_i}{2}$$

where $h_i = \max\left\{(\cos\theta)_{i,k,1} : k = 1, 2, \ldots, j_i + 1\right\}$ and $s_i = \min\left\{(\cos\theta)_{i,k,1} : k = 1, 2, \ldots, j_i + 1\right\}$ with $i = 1, 2, \ldots, n$.

Further, we constructed the n "CLOs-to-PLOs" mapping tables. These tables took the form of Boolean matrices (i.e., matrices with 0 and 1 entries), $M_i = \left\{m_{kp}\right\}_i$, $i = 1, 2, \ldots, n$, of sizes $(j_i \times m)$, $j = 1, 2, \ldots, n$. We defined $m_{kl} = 1$, $k = 1, 2, \ldots, j_i$, $l = 1, 2, \ldots, m$, in matrix M_i if the cosine similarity of the corresponding vectors $\left(b_{i,k}\right)_l$ and $\left(b_{i,1}\right)_l$ was greater than or equal to the established threshold ϕ,

$$m_{kl} = \begin{cases} 1 & if\ (\cos\theta)_{i,k,1} \geq \phi \\ 0 & if\ (\cos\theta)_{i,k,1} < \phi \end{cases}$$

In its turn, $m_{kl} = 1$ in matrix M_i entailed that CLO i_k was positively mapped to PLO l, otherwise, i.e., $m_{kl} = 0$, it was not mapped

G. Evaluation module

The purpose of this module is to analyze the accuracy of the CLO-to- PLO mappings produced by the model. This was achieved by comparing the model's CLO-to-PLO mappings to those presented by the human expert(s), as described in Section 2.1. The aggregated Boolean matrices, H_i, of sizes $(j_i \times m)$Were based on the table of expert mappings we constructed, where each entry is defined by selecting the maximum of the numbers of 0s and 1s in the corresponding entries of the expert tables. We then defined the evaluation matrix, $S_i = \left\{s_{kp}\right\}_i$, for each pair of matrices M_i and H_i. An entry was recorded as 1 if the corresponding entries of M_i and H_i were of the same value, and 0 otherwise.

We defined the model accuracies with respect to each PLO, each CLO, each course CLOs, and the total accuracy using the evaluation matrices S_i as follows:

"PLO" accuracy was defined for each PLO, p, in the program as the ratio of the sum of the sums of the values of the column p in all matrices S_i by the total number of CLOs in the program; i.e.,

$$Accuracy\left(PLO_p\right) = \frac{\sum_{i=1}^{n}\sum_{k=1}^{j_i}\left(s_{kp}\right)_i}{\sum_{i=1}^{n} j_i}$$

"CLO" accuracy was defined for each CLO, k, in the course, i, as the ratio of the sum of values of the row representing the CLO by the total number of PLOs in the program, i.e.,

$$Accuracy\left(CLO_k\right) = \frac{\sum_{p=1}^{m}\left(s_{kp}\right)_i}{m}$$

"CLOs-to-PLOs" (course) accuracy was defined for all CLOs in the course, i, as the division of the sum of all entries of matrix S_i by the total number of the entries in the matrix; i.e.,

$$Accuracy\left(course_i\right) = \frac{\sum_{k=1}^{j_i}\sum_{p=1}^{m}\left(s_{kp}\right)_i}{j_i \times m}$$

The model (program) accuracy was defined for all CLOs and PLOs in the program as the ratio of the sum of the sums of the entries of all matrices, S_i, by the total number of all entries in the matrices S_i; i.e.,

$$Accuracy(program) = \frac{\sum_{i=1}^{n}\sum_{k=1}^{j_i}\sum_{p=1}^{m}\left(s_{kp}\right)_i}{n \times j_i \times m}$$

To illustrate the process, assume we have the following lists of four PLOs and four CLOs along with the corresponding expert(s) mapping presented in **Error! Reference source not found.**. A value of "1" denotes positive mapping; otherwise, a value of "0" is recorded.

TABLE 1
HYPOTHETICAL PLOs AND CLOs MANUAL MAPPINGS

		PLO 1	PLO 2	PLO 3	PLO 4
		Analyze a computing problem	Apply, and evaluate a computing system	Communicate effectively	Recognize professional responsibilities
CLO1	Explain AI	0	0	0	0
CLO2	Apply AI methods	0	1	0	0
CLO3	Analyze a simple AI system	1	0	0	0
CLO4	Evaluate AI system	0	1	0	0

The stop words are removed, lowercased, and then tokenized during the preprocessing stage. Tokenization in this context refers to the division of a phrase or sentence (PLO, CLO) into tokens. The retrieved tokens were extracted and mapped to each CLO based on the data displayed in **Error! Reference source not found.**, as shown in **Error! Reference source not found.**.

TABLE 2
TOKENS EXTRACTED FROM THE HYPOTHETICAL PLOS AND CLOS

						PLO1			PLO2			PLO3		PLO4		
		ai	explain	methods	simple	analyze	computing	problem	apply	evaluate	system	Communicate	effectively	Recognize	professional	responsibilities
CLO1	Explain AI	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
CLO2	Apply AI methods	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0
CLO3	Analyze a simple AI system	1	0	0	1	1	0	0	0	0	1	0	0	0	0	0
CLO4	Evaluate AI system	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0

The cosine similarity is then used to calculate how similar the vectors are, after which the appropriate threshold values are applied. In this instance, the threshold values were computed as 0.0833, 0.1854, 0., and 0. PLO1 and CLO3 were both considered to represent favorable maps when the similarity score was at least 0.0833 for PLO1 (PLO2 and CLO2). No mapping was performed for PLO3 and PLO4.

displays the overall mappings that were produced.

TABLE 3
COMPARISON BETWEEN THE MANUAL AND CALCULATED MAPPINGS

	PLO1	PLO2	PLO3	PLO4			PLO1	PLO2	PLO3	PLO4		Accuracy
CLO1	0	0	0	0	→	**CLO1**	0	0	0	0		100
CLO2	0	0.3333	0	0	→	**CLO2**	0	1	0	0		100
CLO3	0.3333	0	0	0	→	**CLO3**	1	0	0	0		100
CLO4	0	0.4082	0	0	→	**CLO4**	0	1	0	0		100

A comparison of the obtained mapping to the original mapping revealed an accuracy of 100%.

III. EXPERIMENTAL WORK AND RESULTS

The 121 CLOs and all 6 PLOs were stored in a single file representing the input file. The input was next transformed into distinct DataFrame tables using pandas, a Python data analysis tool (pandas.DataFrame — pandas 1.4.3 documentation). Each table contained all 121 CLOs and a single PLO. Word tokenization was performed after the PLO-CLOs tables were built using the “CountVectorizer,” a quick and effective method of counting features in a dataset. The Scikit-learn Python library's (scikit-learn Machine Learning in Python) CountVectorizer was imported. This counts how frequently each feature appears in the supplied data. The vectorization process was performed by breaking the input into distinct words and subsequently counting the word frequency. Additionally, preprocessing operations, like lowercasing, removing stop words, and lemmatization, were carried out.

After performing the text representation phase, we determined how similar the vectors were by importing “cosine similarity” modules from the Scikit-learn Python library. A 6121 matrix, consisting of 6 PLOs by 121 CLOs, was created as a result of this process. Each member of the matrix represented the cosine similarity score between a CLO and the related PLO. Dynamic thresholds were calculated for each PLO to produce the final mapping (for example, 0.1961, 0.221, 0.3162, 0.1667, 0.2236, and 0.2697, respectively). Each cosine similarity greater than or equal to the appropriate threshold value was denoted by “1” (positive mapping). Cosine similarity below the threshold was denoted as “0” (no mapping). **Error! Reference source not found.** presents an overview of the mappings based on the data from three courses—CSBP421 Smart Computer Graphics, CSBP320 Data Mining, and CSBP499 Special Topics in Computer Science.

The data presented in **Error! Reference source not found.** reveals that all the mappings between the CSBP421 and the corresponding PLOs were detected correctly, apart from the C3-P2, and C4-P2 mappings. The overall accuracy of the course mapping, in this case, was 91.67%. Similarly, the accuracy of the mapping of CSBP320 to the corresponding PLO was 90%, and 88.89% for CSBP499.

Additionally, we evaluated the proposed framework's performance in

with several well-known, commonly used NLP models, including Bidirectional Encoder Representations from Transformers (BERT) (Devlin, J., Chang, M., Lee, K., and

Toutanova, K., 2018), SpaCy (Industrial-Strength Natural Language Processing, n.d.), Levenshtein distance (Levenshtein, V.I., 1966), and Jaro-Winkler distance (Winkler, W. E., 1990).

		P1			P2			P3			P4			P5			P6			
		CS*	OM*	CM*	CS	OM	CM	CS	OM	CM	CS	OM	CM	CS	OM	CM	CS	OM	CM	Accuracy
CSBP421	C1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.21	0	0	100
	C2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.45	1	1	100
	C3	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0.21	0	0	83.33
	C4	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0.21	0	0	83.33
																	Average Accuracy			91.67
CSBP320	C1	0.16	0	0	0	0	0	0	0	0	0.17	0	1	0	0	0	0	0	0	83.33
	C2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	83.33
	C3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	83.33
	C4	0	0	0	0.3	1	1	0	0	0	0	0	0	0	0	0	0	0	0	100
	C5	0	0	0	0	0	0	0.52	1	1	0	0	0	0.37	1	1	0	0	0	100
																	Average Accuracy			90
CSBP499	C1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100
	C2	0	1	0	0	0	0	0	0	0	0.29	0	1	0	0	0	0	0	0	66.6667
	C3	0.16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.52	1	1	100
																	Average Accuracy			88.89
Threshold		0.1961			0.2210			0.2582			0.1443			0.2236			0.2697			

** "CS" represents the "Cosine Similarity" score, the "OM" represents the original mapping (1 positive mapping) and the "CM" represents the calculated mapping. The idle case is when the "CMs" are similar to the "OMs"*

Fig. 2. Demonstration of detected mappings based on three courses namely CSBP421 Smart Computer Graphics, CSBP320 Data Mining, and CSBP499 Special Topics in Computer Science.

The outcomes revealed that the proposed framework outperformed these models. The overall accuracy obtained was 83.06% compared to the results obtained using BERT, SpaCy, Levenshtein distance, and Jaro-Winkler distance, which were 45.9%, 52.8, 33.8, and 55.4%, respectively.

TABLE 4
PERFORMANCE COMPARISONS OF THE PROPOSED FRAMEWORK IN DETECTING CORRECT MAPPINGS WITH OTHER STATE-OF-THE-ART NLP MODELS

#	Course	Proposed Framework	SpaCy (Industrial-Strength Natural Language Processing, n.d.)	BERT (Devlin, J., Chang, M., Lee, K., and Toutanova, K., 2018)	Levenshtein (Levenshtein, V.I., 1966)	Jaro–Winkler (Winkler, W. E., 1990)
1	CSBP301	**0.875**	0.5417	0.5833	0.125	0.7917
2	CSBP320	**0.9**	0.3667	0.5333	0.3667	0.3667
3	CSBP400	**0.8667**	0.3	0.5	0.1667	0.6667
4	CSBP411	**0.75**	0.25	0.4167	0.375	0.2917
5	CSBP412	**0.875**	0.7917	0.375	0.4167	0.5417
6	CSBP421	**0.9167**	0.4583	0.625	0.2917	0.6667
7	CSBP431	**0.8333**	0.4167	0.7917	0.3333	0.4167
8	CSBP461	**0.7**	0.6333	0.6333	0.4333	0.4667
9	CSBP476	**0.7917**	0.375	0.4583	0.1667	0.7083
10	CSBP483	**0.7083**	0.5	0.5	0.4583	0.4583
11	CSBP487	**0.9583**	0.4167	0.625	0.375	0.3333
12	CSBP491	**0.8667**	0.4333	0.3	0.3333	0.5333
13	CSBP499	**0.8889**	0.5556	0.3333	0.5	0.4444
14	CSBP119	**0.875**	0.5	0.4583	0.3333	0.5833
15	CSBP121	**0.8**	0.4667	0.4667	0.3667	0.5667
16	CSBP219	**0.8**	0.4667	0.7333	0.2333	**0.8**
17	CSBP221	**0.8333**	0.4667	0.6333	0.2667	0.7
18	CSBP315	**0.9167**	0.2778	0.3333	0.3611	0.4722
19	CSBP316	**0.7333**	0.4667	0.2333	0.3333	0.5333
20	CSBP319	**0.8333**	0.4667	0.6667	0.3	**0.8333**
21	SWEB300	**0.8889**	0.3333	0.3056	0.25	0.8611
22	SWEB450	**0.75**	**0.5**	**0.75**	0.3333	0.4167
23	SWEB451	**0.9**	0.5667	0.7667	0.3	0.7
24	CSBP340	**0.8333**	0.3889	0.4444	0.3056	0.5278
25	ITBP370	**0.7778**	0.3056	0.75	0.5	0.3611
26	CSBP492	**0.8333**	0.3333	0.5	0.5	0.4167
	Overall accuracy	**0.8306**	**0.4593**	**0.5276**	**0.3376**	**0.5543**

compares the proposed framework's overall accuracy to the aforementioned NLP models by mapping each PLO against the 121 CLOs. All PLOs performed better under the suggested framework.

TABLE 5
PERFORMANCE ACCURACY ACHIEVED BASED ON EACH PLO USING THE PROPOSED FRAMEWORK IN COMPARISON WITH THE PREVIOUSLY MENTIONED NLP MODELS

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
Proposed Framework	**0.7769**	**0.7107**	**0.9587**	**0.876**	**0.9835**	**0.6777**
SpaCy (Industrial-Strength Natural Language Processing, n.d.)	0.3106	0.3864	0.4545	0.5000	0.5985	0.4773
BERT (Devlin, J., Chang, M., Lee, K., and Toutanova, K., 2018)	0.4697	0.4318	0.5985	0.4545	0.6667	0.5379
Levenshtein (Levenshtein, V.I., 1966)	0.3636	0.5303	0.0758	0.5606	0.1288	0.3561
Jaro–Winkler (Winkler, W. E., 1990)	0.3939	0.4924	0.7576	0.5758	0.6667	0.4697

Moreover, given that the positive mapping (as denoted by a "1" value) only makes up 16.8% of the 6x121 matrix, it is crucial to use metrics like precision (PR), recall (RE), and F score (F) (Classification: Precision and Recall, n.d.) to ensure an in-depth examination of the detections of the positive and negative mappings:

$$PR = \frac{tp}{tp+fp},\ RE = \frac{tp}{tp+fn},\ \text{and PR} = 2 \cdot \frac{(PR \cdot RE)}{(PR+RE)}$$

compares the performance of the suggested framework with the aforementioned NLP models. In this instance, the suggested framework was able to accurately map three PLOs (PLO3, PLO4 and PLO5), outperforming the available approaches. SpaCy achieved the best performance for PLO6, BERT performed best for PLO6, and Jaro-Winkler performed best for PLO2.

TABLE 6
PERFORMANCE COMPARISONS OF THE PROPOSED FRAMEWORK WITH STATE-OF-THE-ART NLP MODELS IN TERMS OF PRECISION, RECALL, AND F SCORE

		PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
Proposed Framework	PR	0.1765	0.7368	0.5	0.1429	0.875	0.6667
	RE	0.1875	0.3182	0.4	0.4	0.875	0.2273
	F	0.1818	0.4444	**0.4444**	**0.2105**	**0.875**	0.339
SpaCy (Industrial-Strength Natural Language Processing, n.d.)	PR	0.1386	0.2967	0.0779	0.0704	0.1228	0.4018
	RE	0.7778	0.6136	0.8571	1	0.7	0.9574
	F	0.2353	0.4	0.1429	0.1316	0.209	**0.566**
BERT (Devlin, J., Chang, M., Lee, K., and Toutanova, K., 2018)	PR	0.1579	0.2933	0.0893	0.0533	0.1731	0.4054
	RE	0.6667	0.5	0.7143	0.8	0.9	0.6383
	F	**0.2553**	0.3697	0.1587	0.1	0.2903	0.4959
Levenshtein (Levenshtein, V.I., 1966)	PR	0.1333	0.2955	0.0168	0.0351	0.0093	0.3273
	RE	0.6667	0.2955	0.2857	0.4	0.1	0.766
	F	0.2222	0.2955	0.0317	0.0645	0.0171	0.4586
Jaro–Winkler (Winkler, W. E., 1990)	PR	0.1395	0.3544	0.1429	0.082	0.16	0.3506
	RE	0.6667	0.6364	0.7143	1	0.8	0.5745
	F	0.2308	**0.4553**	0.2381	0.1515	0.2667	0.4355

We evaluated the framework using data from the Bachelor of Information Security curriculum to ensure the proposed approach was reliable and universal. We obtained an overall accuracy of 88.1%. The mapping detection accuracy values for PLO1 to PLO6 were 81.5%, 78.6%, 94.8%, 91.33%, 97.11%, and 84.97%. **Error! Reference source not found.** presents the mapping accuracy based on the 34 courses from the Bachelor of Information Security degree. The mapping of courses like CSBP119, CSBP219, and CSBP221 was 100% accurate. In this instance, every course was mapped with an accuracy of at least 75%. This demonstrates unequivocally that the performance of the suggested framework is reliable and consistent.

TABLE 7
MAPPING ACCURACY BASED ON THE 34 COURSES FROM THE BACHELOR DEGREE IN INFORMATION SECURITY PROGRAM

Course	Accuracy	Course	Accuracy	Course	Accuracy	Course	Accuracy
ITBP103	0.75	ITBP301	0.8889	ISEC311	0.9167	ISEC421	0.7917
CSBP119	1	CSBP315	0.9444	ISEC322	0.8667	ISEC412	0.8611
CSBP121	0.9333	CSBP319	0.9	ISEC323	0.8667	ISEC416	0.8889
CENG202	0.9	CSBP340	0.9	ISEC413	0.8333	ISEC424	0.8
CENG205	0.9722	ITBP370	0.75	ISEC414	0.8667	ISEC417	0.8667
CENG210	0.9167	ITBP418	0.9	ISEC423	0.8333	ISEC428	0.8333
CSBP219	1	ITBP495	0.8611	ISEC422	0.9	CSBP320	0.9333
CSBP221	1	ISEC312	0.9	ISEC321	0.8667		
ITBP280	0.8667	ISEC324	0.8333	ISEC411	0.75		

The following link will take you to a web-based application that was created to help teachers and administrators execute automatic mappings: https://bidac-uaeu.github.io/mapper.htm. This tool is depicted in Figure 1. The tool also features a function that enables users to connect through API, allowing it to be used by members of the general public. Users can construct programs, courses, and the associated CLOs, PLOs, and CLOs. Additionally, the user can use and export the mappings.

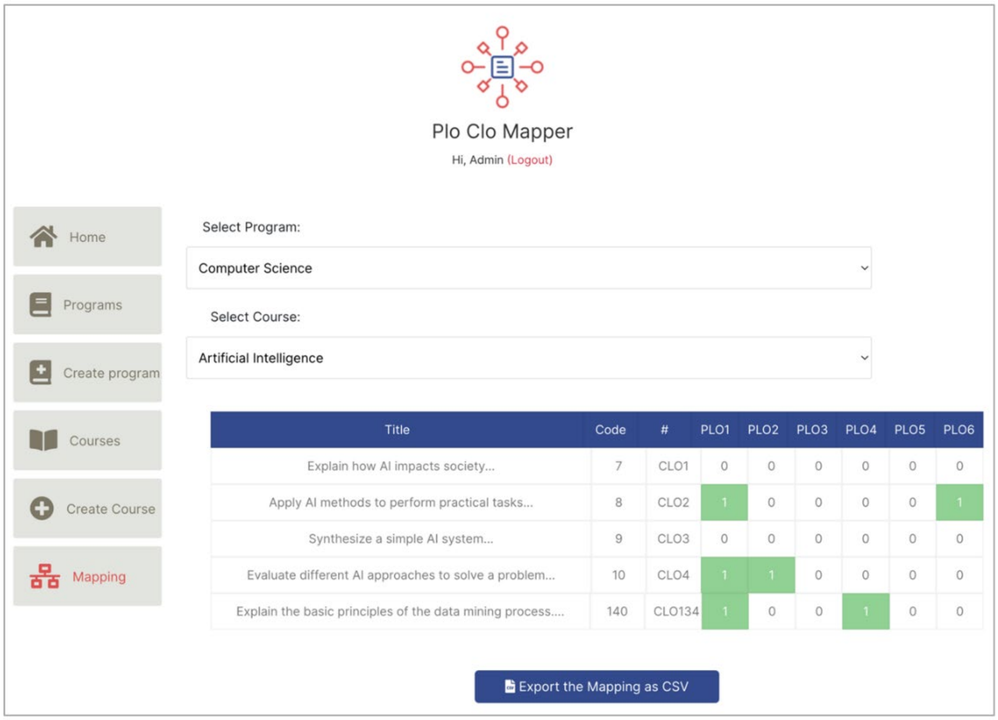

Figure 1: The web-based mapping tool in action

IV. Discussion

The development of accurate evaluation results for the CLOs, which are utilized as a direct measure for assessing the PLOs, depends on effective CLOs-PLOs mapping. Therefore, it is important to choose action verbs carefully so that they are a good match for the PLOs' more general prospects. Subjectivity in determining how to map certain CLOs to PLOs cannot be avoided because educators typically manually map between CLOs and PLOs. However, consistency can be expected when mapping is performed automatically using NLP and AI,

, we note that the results generated by the framework proposed in this paper, while generally yielding better accuracy than previous methods, have less than 75% accuracy for t CSBP316, CSBP483, and CSBP461 courses. The results for every other course were at least 75%.

As can be observed in Figure 2, we examined the CLOs of these courses and how they were mapped to the related PLOs. Wrongly identified mappings are highlighted in red cells in Figure 4, which also presents the original manual mappings. The cell is marked in red, for instance, if the manual mapping is "1" and the framework mapping is "0" or if the manual mapping is "0" and the framework mapping is "1". For the CSBP316 course, for instance, the mapping between CLO2 and assuming that the right action verbs are selected when defining the CLOs. As various techniques can be employed for diversification and a more precise measurement, a PLO is typically measured using more than only the outcomes of an assessment of CLOs. Results from surveys and other indirect assessment tools might be used as examples. Additionally, other direct evaluation procedures, including pre- and post-course examinations or projects, are frequently utilized to supplement the results of the CLO assessment.

Based on the outputs for the Computer Science program provided in

PLO5 was detected as "1" due to the use of the keyword "suitable," but the mapping between the same CLO and PLO6 was overlooked because there is no word-vector matching. Similarly, the framework's decision to map CLO3 to PLO4 was based on the word "principles." In general, CLO2 and CLO4 that are transferred to PLO6 use indirect verbs, such as "select and build," which results in a lower level of matching given what the underlying intention of PLO6.

On the contrary, the output of the mapping performed by the framework may occasionally be more accurate than the manual mapping. For instance, the CLO3 in the course CSBP316 should be mapped to the PLO1. This was missed during the human mapping process; however, it was detected by the proposed framework. As a result, the proposed framework can be effectively used by accreditation/program assessors to ensure that the findings of the quality assurance are correct and meaningful. It can also be used to validate the manual mapping.

The two verbs "design" and "use," which are employed in CLO 1, are mapped to PLO6 via CSBP483. These verbs contribute to the low matching accuracy since they do not exactly correspond to the acts that PLO6 intends. If the best threshold value is found, certain situations, such as the mappings of the CLO2 to PLO6 and CLO4 to PLO6, for example, could be discovered. In these two examples, the proposed framework did detect similarity scores; however, they were missed because they fell just shy of the cutoff point.

By comparing the action verbs used in each mapped CLO in CSBP461 to PLO6, it is possible to understand why the accuracy score was so low. For instance, the action verb "develop" employed by CLO2 does not quite match the action verbs utilized by PLO2 and PLO6. CLO3 and CLO4 mappings can be compared in the same way. The accuracy of automated procedures can be undermined if the wrong definitions (rules) are utilized or the wrong action verbs are used to correspond to those PLOs.

		PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	
		Analyze a complex computing problem and to apply principles of computing and other relevant disciplines to identify solutions.	Design, implement, and evaluate a computing-based solution to meet a given set of computing requirements in the context of the program's discipline.	Communicate effectively in a variety of professional contexts.	Recognize professional responsibilities and make informed judgments in computing practice based on legal and ethical principles.	Function effectively as a member or leader of a team engaged in activities appropriate to the program's discipline.	Apply computer science theory and software development fundamentals to produce computing-based solutions.	Accuracy
CSBP316: Human User Interface								
CLO1	Discuss issues related to the process of user-centered design.	0	0	0	0	0	0	100
CLO2	Select appropriate interaction styles.	0	0	0	0	0	1	66.6667
CLO3	Apply usability principles and guidelines.	0	0	0	0	0	1	50
CLO4	Build effective prototypes of user interfaces.	1	1	0	0	0	1	50
CLO5	Evaluate user interfaces given design goals, user goals, and usability principles.	0	1	0	0	0	0	100
								73.33
CSBP483: Mobile Content and Development								
CLO1	Design mobile User Interface (views, layout, controls, etc.)	0	1	0	0	0	1	66.6667
CLO2	Explain the key technological principles and methods for delivering and maintaining mobile applications	0	0	0	0	0	0	66.6667
CLO3	Apply Model-View-View-Model (MVVM) design principle	0	1	0	0	0	1	66.6667
CLO4	Use MVVM to develop a complete project/application for smart-phones and tablets.	0	0	0	0	0	1	83.3333
								70.83
CSBP461: Internet Computing								
CLO1	Explain the evolution of Internet technologies and Web applications concepts and architectures.	0	0	0	0	0	0	100
CLO2	Develop Internet-based applications using client-side and server-side programming.	0	1	0	0	0	1	50
CLO3	Write and parse XML documents	0	0	0	0	0	1	83.3333
CLO4	Develop Internet-based applications using Web Services technology.	0	1	0	0	0	1	50
CLO5	Work on a team to build Internet-based applications	0	0	1	0	1	0	66.6667
								70.00

Figure 2: The 3 courses with poorly detected mappings. The wrongly detected mappings are highlighted in red cells

When looking at the performance results for the PLOs measurement accuracy, the results for PLO2 and PLO6 for the Computer Science program were lower than 75%, as indicated in

. These PLOs are as follows:

- PLO2: Design, implement, and evaluate a computing-based solution to meet a given set of computing requirements in the context of the program's discipline.
- PLO6: Apply computer science theory and software development fundamentals to produce computing-based solutions.

In contrast to the CS PLO6 previously described, the PLO6 for the Information Security program reads, "Apply security principles and practices to maintain operations in the presence of risks and threats." PLO6 of the Information Security program's coverage is more specific.

To better understand why these results are so low, we can see that PLO2 and PLO6 are made up of a variety of requirements described by more than one action verb or a wide range of necessary skills, which suggests that CLOs from a good number of courses must be mapped to cover the wide range of requirements characterized by these PLOs, which is, in fact, the case (PLO2 - 86 out of the possible 121 mappings were detected correctly, similarly for PLO6 – 82 were detected accurately). However, the lower level of accuracy may be caused by the usage of "implied" CLOs-based action verbs that are either wholly incorrect or not an exact match to those used in the PLOs. For instance, multiple CLOs map to PLO2, which employs design, implement, and evaluate, and these CLOs use action verbs like "compare", "develop", and "apply". A similar analysis can be presented for PLO6. For instance, PLO6-mapped CLOs utilize verbs like "use," "write," and "translate," even though they don't quite fulfill the demands of this PLO as stated by its action verbs and context.

While the overall accuracy for the information security program is 88.05%, compared to 83.06% for the computer science program, none of the measured PLOs for that program were below 75% (the minimum was 81.5% - PLO1); thus, the latter program has a marginally better F score. The Information Security program has a total F score of 0.37 compared to the Computer Science program's 0.41.

V. Conclusion

This paper introduced an AI-based framework (NLP) for automatic and precise mapping of CLOs to PLOs. As educational program evaluations are based on these mapping processes, it is important they are accurate and reliable. To the best of our knowledge, this is the first time NLP has been used to solve an issue of this magnitude. Although NLP has demonstrated excellent results in several disciplines, it has yet to be fully embraced within the educational sector. The proposed framework was evaluated against two actual datasets, yielding positive results. The outcomes of the current study could inform future research in this area. The suggested framework performed noticeably better than several well-known NLP methods, like BERT (Devlin, J., Chang, M., Lee, K., and Toutanova, K., 2018) and SpaCy (Industrial-Strength Natural Language Processing, n.d.).

Nevertheless, despite its strong performance, the framework has two significant limitations. The first is the threshold optimization, and the second is the absence of semantic connections between verbs like "implement," "build," "develop," "apply," etc. We discovered that certain incorrect mappings were caused by word similarity rather than the overall semantic meaning. As a result, we intend to emphasize the bloom taxonomy in the future by finding the connections between the verbs using a rule-based technique and giving them more weight. Additionally, methods like generic algorithms can be used to enhance the dynamic threshold values applied in the study.

VI. Declarations

- Availability of data and materials: The datasets used during the current study are available in the GitHub repository, [https://github.com/nzaki02/CLO-PLO
- Competing interests: The authors declare that they have no competing interests.
- Funding: This work was done based on self-funding
- Authors' contributions: NZ, ST, KS, and EA contributed to the conceptual idea of the paper and the research idea. NZ, AK performed the experimental work. NZ, KS collected the data and performed the analysis and validation of the results. All authors are major contributors to the writing of the manuscript. All authors read and approved the final manuscript.
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