Model of the document of the educational business process of a higher education institution

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Abstract

Improving the quality of the educational process (EP) and aligning it with modern requirements is a complex task that requires higher education institutions (HEIs) to adopt a systemic approach and to develop a strategy for enhancing the quality and efficiency of services. When analyzing large data volumes in universities, to effectively address data structuring and the generation of new knowledge, it is proposed to use an ontological approach based on associative rules. This paper investigates the peculiarities of information modeling within an ontological approach to a distributed information environment, as well as the entities considered in the ontological analysis of business processes governing the EP of a HEI, and the management technology that ensures the quality of educational services. An ontological analysis of the modeling of university business processes is carried out, together with an analysis of the structure, functions, and information flows of organizing and managing educational activities, based on a structural approach and recognizing that competence as an integrated characteristic of a graduate's quality is a category of educational outcomes. Using an ontological model of interactions among the system's agents and objects makes it possible to assess system efficiency and to build a management model that supports forecasting the emergence of critical business processes which may reduce decision-making efficiency and disrupt the functioning of HEIs and their units. The proposed models enable mathematical modeling and optimization of business processes without limitations on their complexity and provide a basis for creating software systems for numerical (as opposed to merely descriptive) design.

Keywords

higher education institutions, information environment, ontology, modeling, business process, reengineering

1. Introduction

The definition of a "document" may vary depending on context. The most general definition is as follows: a document is information recorded on a material (or virtual) medium in the form of text, audio, image, or a combination thereof, which has requisites that allow it to be identified and is intended for storage, transmission in time and space, and use for a specific purpose.

Key elements of this definition include:

- Material (or virtual) medium: the information must be recorded on something (paper, electronic file, film, etc.).
- Recorded information: this may be text, audio, video, image, or their combination.
- Presence of requisites: requisites (e.g., signature, date, number, title) allow a document to be identified, confer legal force, or determine ownership.
- Purpose: a document is created to preserve information, transmit it to others, prove facts, manage activities, etc.

Thus, a document is not just information but information with a particular form, structure, and purpose that enables it to be preserved, transmitted, and used.

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Education, as a type of economic activity, comprises the production and provision of higher education services in line with official international and national classifications.

Accordingly, the higher education system is oriented primarily toward improving quality and meeting modern innovation needs, as well as toward aligning the structure and content of education with the real needs of the economy.

In education, the learner is both the consumer and the co-creator of educational services, which makes the process uniquely human-centered. This is the key distinction between the creation of educational services and other services.

Quantitative design of business processes, understood as the numerical, optimization-based synthesis of a business process's structure, factors, and parameters, has, despite its relevance, not yet been adequately developed.

The structural model of the business process considered in this work allows mathematical modeling and optimization of business processes without complexity constraints, including under conditions of future development and uncertainty in the economic situation and funding. It also supports the creation of software systems for numerical design. The relevance of the topic follows from growing interest in data integration across domains that accumulate and use information.

Given the above, the EP in a HEI must be adaptive and anticipatory, ensuring a quick and adequate response of content to new challenges, requests, and needs of education service consumers.

2. Literature review and problem statement

In educational institutions, it is important to organize the management of units that provide educational, methodological, and research services. Relevant issues include studying the peculiarities of information modeling, particularly the creation of an ontological approach to a distributed information environment, and the application of ontological models in various domains [1, 2, 3].

The university education system is the principal mechanism for training highly qualified personnel capable of creatively perceiving rapid changes in economic conditions. Universities actively employ business processes in their activities to preserve pedagogical and scientific achievements, as reflected in the literature. The present study relies on publicly available descriptions of real business processes at functioning universities in Kyiv, Rivne, and other institutions, as well as on materials from KNUCA. The aim was not to create an exhaustive review, as the mere existence of such processes suffices for further research. To further refine and optimize the electronic document management system that was implemented and tested at KNUCA, it is now examined through the lens of an ontological approach grounded in university business processes [4].

The specifics of managing educational business processes (EBPs) remain topical and require additional scholarly inquiry. Foundational ideas include Deming's principles of quality [5], the Kaizen concept [6], and the business process reengineering of Hammer and Champy [7]. Under contemporary conditions characterized by high uncertainty, scenario analysis is among the promising approaches for forecasting [8].

In a market economy, managing business processes becomes crucial to ensure the profitability of HEIs [9]. Universities face the same challenges as commercial organizations: to remain competitive by operating efficiently and preparing high-quality specialists who meet the demands of today's labor market [10, 11].

To improve the efficiency of HEIs, it is necessary to study and model all business processes and to build a strategy that promotes growth in all indicators, with a clear assessment of the knowledge acquired and the overall effectiveness of the institution [12].

Managing an active university system entails building a model of system behavior over time under given external and internal conditions, depending on the control inputs applied. A university can influence internal factors by implementing a management system. The aggregate of managerial influences on the core and supporting activities (primary and supporting business processes) forms a university's system of management.

A critical factor is the intensification of information exchange within the university, given that a single unit may participate in multiple business processes. This task becomes increasingly urgent as information volumes grow and as the need for rational processing increases.

The essential characteristic of a business model is the system of relationships among the organization (its resources, capabilities, competencies), the consumption market (volumes, segments, value needs), and partners (potential participants in creating the product: designers, distributors, marketers, public organizations).

3. Problem definition

Based on the ontological analysis of business processes that manage the EP of a HEI and on management technologies, we investigate the entity "document of the EBP of a university" as a key instrument for ensuring the quality of educational services. We take into account the formation of general and specific managerial competencies for governing the institution, grounded in information modeling of business processes for an electronic document management system.

4. Research methods

Ontological modeling is the process of constructing, developing, maintaining, and using an ontology of a subject area. When developing a knowledge-based system, one typically uses a domain ontology consisting of definitions of concepts and the relationships among them.

Mathematical models in ontology are formal descriptions of a subject area using mathematical notions and methods. They enable knowledge to be represented as formal structures that can be used to analyze, compare, and forecast various aspects of the domain. Ontologies describe concepts, the links among them, and the inference rules that determine the logical associations and laws that operate in the subject area.

When modeling university business processes, a key problem is the analysis of large data volumes, tied to the continuous growth of information to be handled. Therefore, improving the efficiency of big data analysis based on ontologies and associative rules is a promising solution for interacting with unstructured data. Data integration is essential in universities where information is scattered across specialized systems developed at different times and for different purposes; integration enhances efficiency and provides higher-quality knowledge from multiple structured data sources.

Because ontology construction encompasses all stages of data structuring, the ontological approach is proposed as an instrument for solving the structuring task itself, so that the resulting data can be directly used for practical tasks in accordance with a formal model.

5. Results

A HEI is an open, integrated, resource-based socio-pedagogical system characterized by integrity and structure, and by adaptability grounded in information and communication. Its chief purpose is to implement the EP to provide high-quality educational services that ensure individual development and self-realization needed to form competitive human capital.

Information sources of a HEI include: students at all levels of study; textbooks; lecture notes; methodological recommendations; administrative orders and directives; internal regulations; orders and regulations of the Ministry of Education and Science; and the laws of Ukraine.

Universities typically employ a three-level management structure:

1. Rectorate headed by the rector.
2. Faculties (institutes) headed by deans (directors), or departments headed by department heads.

3. Chairs (academic departments) headed by department chairs, or units headed by unit managers.

The process approach treats an organization's activities as an interconnected system of business processes, each flowing in relation to others or to the environment (Figure 1).

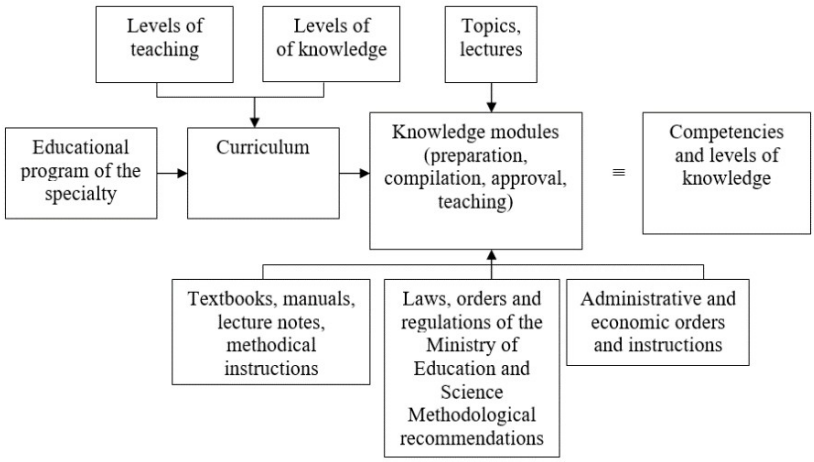

Figure 1: Knowledge modules in the business processes of learning in HEIs.

Based on a classification of a university's business processes by their contribution to added value – namely the production of a "high-quality, competitive graduate" – we distinguish primary, supporting, and managerial processes and derive typical business processes for a HEI (Figure 2).

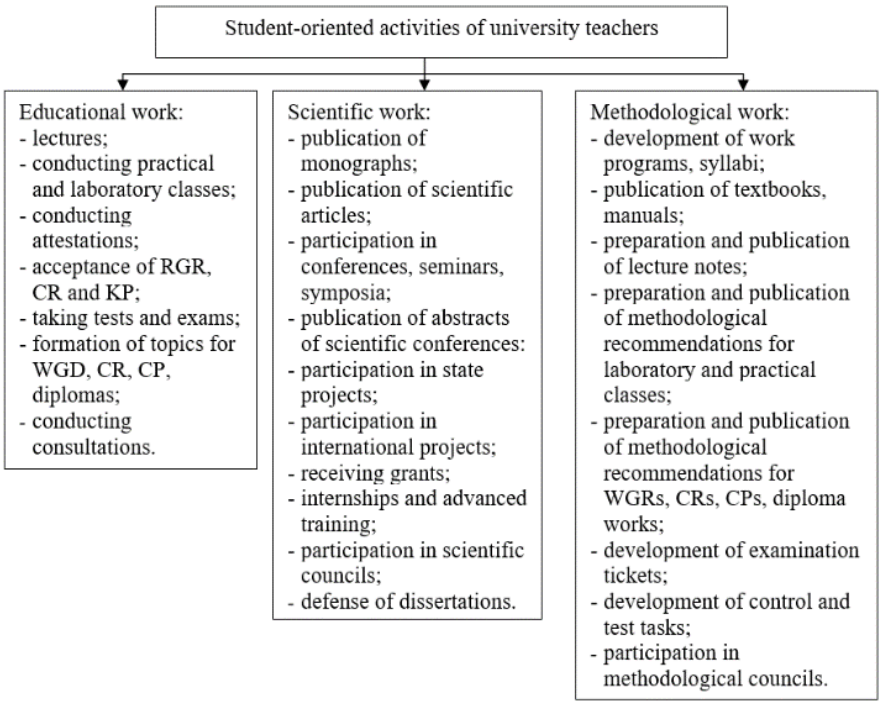

Figure 2: The student-oriented preparation business process.

Process regulation makes it possible to clearly distribute responsibilities and powers at all levels of management, which leads to improved coordination of the activities of departments and personnel, and enhances the efficiency of communications within the HEI.

The mathematical model of the business process of HEIs based on ontological analysis will be presented as follows [14].

Education system in HEIs:

$$Sis \equiv <Sp, Dc, Pg, EKTC, Bp>, \tag{1}$$

where Sp – specialties of HEIs; Dc – disciplines of HEIs; Pg – programs of disciplines; $EKTC$ – requirements for specialties of HEIs; Bp – business processes of HEIs.

Levels of education in HEIs:

$$out \equiv out(Sd, Bk, Mg, As, T), \tag{2}$$

where Sd – students; Bk – bachelor's degree students (final year students); Mg – master's degree students; As – postgraduate students; $T = \{t_i\}_{i=\overline{1,n}}$ – duration of study, i – semester number.

Education seekers:

$$In \equiv In(Ab, Prep, Av, Sd, L_{beg}, L_{out}), \tag{3}$$

where Ab – applicants; $Prep$ – instructors; Av – students who have resumed after academic leave; L_{beg} – initial training level; L_{out} – final training and competency level.

Business processes:

$$Bp: \begin{cases} general\ education \equiv Bp^1 \\ general\ professional \equiv Bp^2 \\ specialized\ by\ profession \equiv Bp^3 \end{cases}, \begin{pmatrix} Bp^1 \\ Bp^2 \\ Bp^3 \end{pmatrix} = Bp^{Par}(t_i). \tag{4}$$

Structure of business processes of a HEIs:

$$Str \equiv Str^{Par}(Bp(t_i)), \tag{5}$$

dynamics of the structure according to t_i:

$$Str(Bp(t_i)) = <Bp^1(t_i), Bp^2(t_i), Bp^3(t_i)> \tag{6}$$

where:

- $Bp^1(t_i) \equiv Bp_j^1(t_i)$, $j \in J_1$ - a set Bp, that can be compressed through early career guidance;
- $Bp^2(t_i) \equiv Bp_j^2(t_i)$, $j \in J_2$ - a set Bp, that can be compressed through early specialization;
- $Bp^3(t_i) \equiv Bp_j^3(t_i)$, $j \in J_3$ - an absolutely essential set of specialized Bp.

Teachers:

$$Prep = \cup_{t_i \in T}(Prep\,B_p^1 \cup Prep\,B_p^2 \cup Prep\,B_p^3). \tag{7}$$

Individuals who have completed education at all levels as of the moment T:

$$out(T) = Sis(In(T), Prep(T), T, L_{out}) \tag{8}$$

Business process system of HEI:

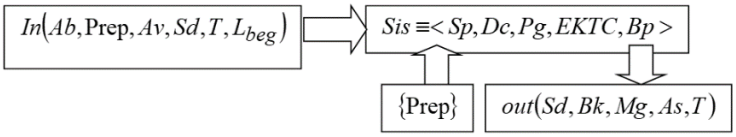

Figure 3: Knowledge modules in the business processes of learning in HEI.

Let's denote the parameters of the HEI's business process:

$$Par = < Sp_j, Dc_k, Pg_l, EKTC_m >. \tag{9}$$

Then the generalized criterion for optimizing the HEI's business process system can be formulated as follows:

$$S \overset{def}{\equiv} \underset{\rightarrow max\ out(T)}{\left\{ Crit\left\{ Bp^{Par}(t_i), In(t_i), Ogr(t_i), \{Bp\}_{t_i}, Str\{Bp\}_{t_i} \right\} \right\} opt}, \tag{10}$$

and partial criteria for optimizing the HEI's business process system:

- $K_1 : S \underset{Res}{\rightarrow} min$, where Res represents consumed resources;
- $K_2 : S \underset{Deg}{\rightarrow} max$, where Deg is the provision of the education level;
- $S = S(K_1, K_2)$.

Subprocesses at $\cup_{t_i} Bp(t_i)$ allow for merging flows to conduct lectures and identify new Bp based on the criterion of increasing the capacity of lecture flows in each time interval t_i. The methodological basis is the Gantt chart.

We assume that:

- Bp – sections of the chain methodology of education (CM);
- $Dc_{i,j}$ – the discipline corresponding to the sets of ordered sequences $\{CM_j\}$ of the specialty Sp_i;
- $Bp_{k,l}$ – l – subprocess of a process Bp_k;
- ~ – arrangement;
- $\{Bp_m\}$ – summation of Bp;
- $\forall i : Sp_i \rightarrow \{D_{i,j}\}$ $\forall$ of specialty i $\exists$ summation of $\{D_{i,j}\}$;
- $\forall i : Sp_i \rightarrow \{D_{i,j}\}^{\mathbb{D}_{ij}}$;
- $\forall i, j : D_{i,j} \rightarrow \{Bp_{i,j,k}\}^{\mathbb{D}_{ij}}$;
- $\forall i, j : D_{i,j} \rightarrow \{Bp_{i,j,k}\}$, $\cap_i D_{i,j} \neq \varnothing$ – optimization resource through business processes.

Then, the Bp has its value in terms of costs $(Z\,Bp)$ and significance in terms of revenue $(D\,Bp)$ in the class of $\{Bp(Sp, Dc)\}$, $\forall t_i$ provided that a specified level of knowledge Deg is achieved.

Requirements of the Ministry of Education and Science:

- $Mz = \cup_i T m_i = \cup_i \cup_j L k_{i,j}$, where Mz – is a knowledge module, Tm- is a topic, Lk – is a lecture;
- course – determined by the number of semesters, measured in hours and credits;

- semester – defined by the number of hours (240) and credits (30);
- discipline – defined as Mz;
- session – knowledge assessment for disciplines;
- the cost of a knowledge module is $\sum_i \left(K_i \cdot Nor\, m_i\right) + ArAu + ArEq$, where K_i – is the number of hours per discipline, $Norm$ – is the time norm of the i teacher, $ArAu$ - is the cost of renting a classroom, $ArEq$ - is the cost of renting equipment;
- $|T|$ – the number of semesters for different types of education (8 – for bachelors, 11 – for masters, 17 – for Ph.D., 21 – for doctors of science).

The functioning of an electronic document (ED) in a university is conditioned by:

- The university's three-level organizational and technical structure;
- Prescribed requirements for the EP;
- Prescribed requirements for educational outcomes;
- Operation within the legal field;
- Existing regulations for document formatting;
- Existing regulations for document submission;
- Requirements for the minimal structure depending on type and kind of document.

Specific features of EDs in universities include:

- Specific access schemes;
- Logging of actions related to ED submission;
- Procedures for introducing corrections to an ED;
- Procedures for creating a new ED;
- Automatic verification and consistency checking of an ED;
- Ordering EDs in accordance with the university's EP;
- Presence of a dynamic teaching timetable;
- Changing requirements for student competencies and corresponding adjustments to study plans.

The model of the document of the EBP is conditioned by the following constraints:

- Different levels of the organizational structure of the EP correspond to different tasks and EBPs;
- Different EP subsystems correspond to different tasks and EBPs;
- The notion of the state of a university EP.;
- The goal of the university EP is its target (final) state;
- A given student group is mapped to non-repeating EBPs;
- Within one faculty and one cohort (course), student groups are mapped to identical EBPs;
- Different cohorts within one faculty are mapped to different EBPs;
- The notion of the system time of the university EP;
- The notion of EBP synchronization within the university EP;
- Synchronization among EP subsystems;
- Synchronization of EBPs within an EP subsystem;
- The university curriculum as a representation of university EBPs;
- Curriculum tasks: content alignment of EBPs; sequencing alignment; and resource alignment for university EBPs;

- A document can be viewed as a relation between organizational levels of the university and levels of EBP implementation along the pattern INITIATOR (In) – EXECUTOR (Ex);
- Documents are bound to EBP tasks;
- Document functions within EBPs include accounting, control, and directive roles.

For modeling the document of the EBP of a university, let us consider the following.

Let V be the information space.

Let $A \subset V$, where $A=\{e_i\}_A$ is the system of events, and e_i are the information units that constitute A.

Let $\exists \bar{f}_A | \bar{f}_A : V \to V$, $\forall i=\overline{1,n}\, \bar{f}_A(e_i) \in V.\, dnt(e_i) \supset dnt(A)$, where $dnt()$ is a denotation.

Since $A \subset V$, then $\{e_i\} \in V \Rightarrow V \subset \cup \bar{f}_A(e_i)$.

$\cap_{i=1}^{n} \bar{f}_A(e_i) = Ob(V, A, \{e_i\})$, where Ob are the information objects of V.

Thus, A, $\{e_i\}$, e_i, $\bar{f}_A^{-1}(e_i)$, Ob are the information objects of the space V.

Let us denote $\{e_i\}^{min}$ with respect to the system

$A \Leftrightarrow^{def} \forall j: \cap_{i=1, i\neq j}^{n} \bar{f}_A(e_i) = Ob_j(V, A, \{e_i\}, e_j) \subset Ob(V, A, \{e_i\})$.

Let $\{A_j\}^k$ be the k EP, that is $\forall j\, A_j^k \subset V$, where A_j^k is the event of the k process. $Str\{A_j\}^k$ is the structure of the k EP, which is defined by partial ordering.

Then $\cup_k Str\{A_j\}^k$ is the structure of the EP as a whole with respect to $\cup_k \{A_j\}^k$.

Then $\{\cup_j \cup_k \{A_j\}^k\}^{min} \equiv \{A_j\}^0$ is the ontology of the EP $A_i \neq A_j, i \neq j$.

$$\left| \cup_j \cup_k \{A_j\}^k \right| \supseteq \left| \{A_j\}^0 \right| \tag{11}$$

$$\cup_k Str\{A_j\}^k \subseteq Str\{A_j\}^0 \tag{12}$$

$A^0 \equiv \{A_j^0\}$ the system of basic concepts of the ontology of the EP.

The minimal system of documents: $Doc(\{e_i\}_{A^0})$ is the system of basic documents of the EP, where $\forall i \exists dnt(e_i)$ is the entity of the i document. A document is an element of the information space. Moreover, $\{e_i\}_{A^0}$ with operations $\cup$, $\cap$ forms an algebra $Al(\{e_i\}_{A^0})$. Thus, $\forall al \in Al(\{e_i\}_{A^0})$, where $\exists Doc(al): al \leftrightarrow Doc(al)$.

To model the structure $Str(\{A_j\}^0)$, it is expedient to apply Petri nets [13], which include:

- initially basic concepts $\{e_i(0)\}$, where the argument defines the time index;
- events and document templates that recur (periodically or aperiodically), together with the dynamics of events as reflected in documents;
- episodic events and documents;
- new (previously unforeseen) events and documents;
- parallel event processes and subnetworks of the EP (their properties, definitions, and operations);
- basic concepts, finite concepts, and intervals of concept formation.

This approach allows us to formulate the goal of optimizing the EP as follows: to determine $\{e_i(0)\}$ so that in the process of implementing scenarios $\{t_j\}$, additional criteria $\{e_i(t_j)\}$ are identified that ensure increased reliability by identifying inaccuracies and inaccuracies for timely elimination of inconsistencies.

Thus, the model of the document of the EBP of a university is information that has a defined form, structure, and purpose, enabling it to be preserved, transmitted, and used within the framework of the institution's information sources, the three-level management structure, the system of business processes, the constraints conditioning the functioning of the electronic document, and the specific features of electronic documents in HEIs.

Different university documents comprise different sets of requisites. The number of requisites that characterize a document is determined by the document's purpose, its intended use, the requirements for its content and form, and the method of documentation.

The aggregate of requisites that make up a document is called the document form. For each document, the principal characteristic sets are:

$$D=<A,T,S,D^S,D^C> \tag{13}$$

where A — the set of attributes (requisites); T — the set of temporal features; D^S — the set of structural features; and D^C — the document content.

Examples of attribute features (A) include:

$$A=<A^N,A^F,A^T,A^M,A^P,A^R> \tag{14}$$

A^N — name (title) of the document; A^F — author; A^T — addressee; A^M — signature; A^P — resolution; A^R — approval stamp.

Examples of temporal features (T) include:

$$T=<T^C,T^R,T^S,T^F,T^I> \tag{15}$$

T^C when the document was created; T^R when it was received by the addressee (for outgoing documents); T^S when it took effect or was accepted for processing; T^F when it lost force or work was completed; T^I and the execution time interval.

6. Discussion of results

Considering the above, using the proposed mathematical ontology model yields an optimal structure of a university's business processes, primarily pedagogical ones, for subsequent description and formalization as regulations that underpin the process approach to management.

Future work includes developing effective pathways for implementing the activity model of HEIs based on the process approach, together with piloting and experimental validation of the effectiveness of the management model.

The constructed model makes it possible to relate, and present at the most general level, the resources of applicants, the resources of instructors, and the administrative resources of the university directed toward attaining different levels of education. Thus, the model can serve as a representative of the class of mathematical models of university business-process ontologies [15], specializing to individual instances by specifying concrete functional dependencies.

It becomes feasible to build a neural network and train it on top of an agent-based (simulation) model to analyze the real-world activity of an actual university under various specified criteria.

One avenue for further development is to include a forecasting subsystem to determine or predict the magnitude and dynamics of demand for the university's educational services.

7. Conclusions

Based on the ontological analysis of business processes for managing the EP of a HEI and on management technologies, we have examined the essence of the "document of the EBP of a

university" as a leading instrument ensuring the quality of educational services, with due account of the formation of both general and specific managerial competencies for institutional governance, grounded in information modeling of business processes for an electronic document management system. Competence is treated as a category of educational outcomes integrating the quality characteristics of a graduate.

The paper proposes a concept and methods for mathematical modeling of the ontology and optimization of business processes under conditions relevant to university business-process design. The proposed model of the document of the EBP allows mathematical modeling and optimization of business processes without constraints on their complexity, and supports the creation of software suites for numerical (not merely descriptive) business-process design.

Declaration on Generative AI

The authors have not employed any Generative AI tools.

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