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Artificial intelligence governance model in personalized e-Learning

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ABSTRACT: This article proposes a governance model for the use of artificial intelligence (AI) in the context of personalized e-learning. The main objective is to frame the integration of AI in order to maximize its benefits, such as the personalization of learning, while minimizing the associated risks, including algorithmic bias, the protection of per-sonal data, and the transparency of decision making processes. These associated risks remain a significant challenge to be met. The approach consisted of relying on the ISACA COBIT 5 information system governance framework in order to propose a model that highlights the governance processes, objectives, and actions. The governance model presented is composed of several key elements, including transparency, fairness, data security, and continuous improvement, which are essential for effective AI management. It proposes guidelines to align AI with the strategic objectives of educational institutions, thus ensuring an ethical and responsible use of AI technologies in e-learning. This work also highlights the importance of an integrated approach to AI governance, where risks are controlled and benefits are optimized. The conclusions drawn show that, although ambitious, such a governance framework is essential to build trust among users and stakeholders, while ensuring learning that is more tailored to the individual needs of students. Finally, this suggested governance model will need to be continuously refined and adapted as the technology evolves, and calls for future research to test and validate the model in real-world contexts.

KEYWORDS: Artificial Intelligence, Cobit, adaptative e-learning, Strategic alignment, risk management, data security.

1 INTRODUCTION

E-learning has radically transformed the educational landscape by offering accessible and flexible learning opportunities across the globe. With the emergence of advanced technologies, artificial intelligence (AI) has become a central element in personalizing the learning experience, making it possible to meet the specific needs of each learner in real time. However, the implementation and management of these intelligent systems pose complex challenges, particularly in terms of governance.

AI governance in personalized e-learning is a rapidly expanding field, requiring a rigorous approach to ensure the quality, security, and equity of intelligent educational systems. This governance encompasses not only the supervision of AI algorithms but also data management, privacy protection, and impact assessment on the various stakeholders in the educational system. The objective is to ensure that the technologies deployed not only optimize user learning but do so in an ethical and transparent manner.

The AI governance framework for personalized e-learning must take into account several critical dimensions: algorithm performance, data privacy, recommendation fairness, and stakeholder satisfaction. The challenges are further accentuated by the diversity of learning contexts and individual learner variabilities. In addition, data protection regulations and standards impose additional constraints that must be integrated into the management of AI systems.

This article offers an in-depth exploration of the governance models needed to effectively supervise AI systems in personalized e-learning. By examining key issues and presenting mathematical and algorithmic approaches, we aim to provide practical solutions to optimize the management and control of AI technologies while respecting ethical standards and user expectations. We will also introduce governance frameworks adapted to the specificities of e-learning and methodologies to evaluate and continuously improve deployed AI systems.

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Ultimately, effective governance of AI in personalized e-learning is essential to ensure that these technologies bring tangible and equitable benefits to all stakeholders in the education system, while minimizing risks and respecting the fundamental principles of justice and transparency.

This paper is organized as follows:

- Section 2 discusses the state of the art,
- Section 3 highlights the problem,
- Section 4 presents the methodology
- Section 5 describes our contribution,
- Section 6 focuses on the discussion
- The last section includes the conclusion and perspectives.

2 STATE OF THE ART

2.1 THE PERFORMANCE OF ALGORITHMS

The ACPR has initiated exploratory work with several players in the financial sector to clarify the issues of explainability and governance of AI [1], mainly in the context of Machine Learning (2019).

According to this work, a type of ML algorithm can be more or less complex, in terms of ease of inspection of its operation. The types of algorithms also vary in efficiency, measured according to predictive or commercial performance metrics. The diagram below illustrates the trade-off between simplicity and efficiency made by the most common ML algorithms:

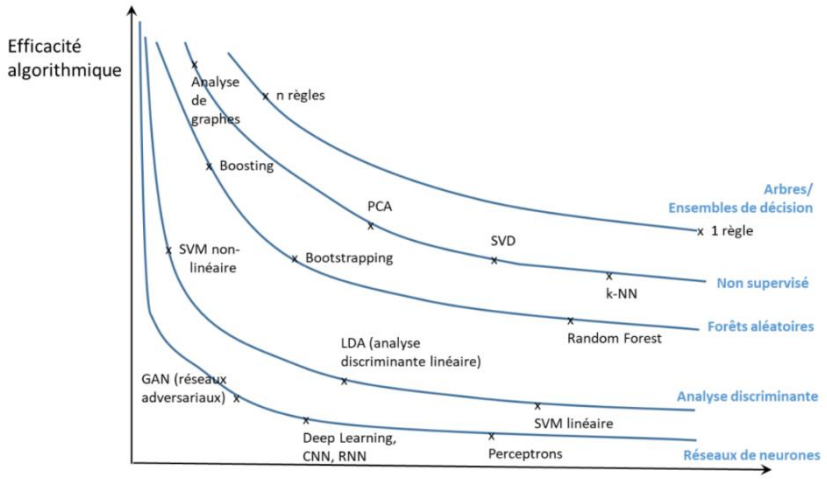

Fig. 1. Compromise between Efficiency and simplicity of an ML algorithm (Source: [1] page 65)

The requirement for explainability when integrating an algorithm or machine learning method into a business process goes beyond the simple balance between the simplicity and efficiency of the algorithm: the explanation must be intelligible and convincing for the intended audience, adapted to the use case and proportionate to the risk of the process. However, there is a trade-off between the fidelity of the explanation to the algorithm (inevitably imperfect, because the explanation simplifies the reasons why the algorithm made a certain decision based on the characteristics of the individual or transaction in question) and the sobriety of the explanation, i.e. its intuitive and understandable character for a non-expert.

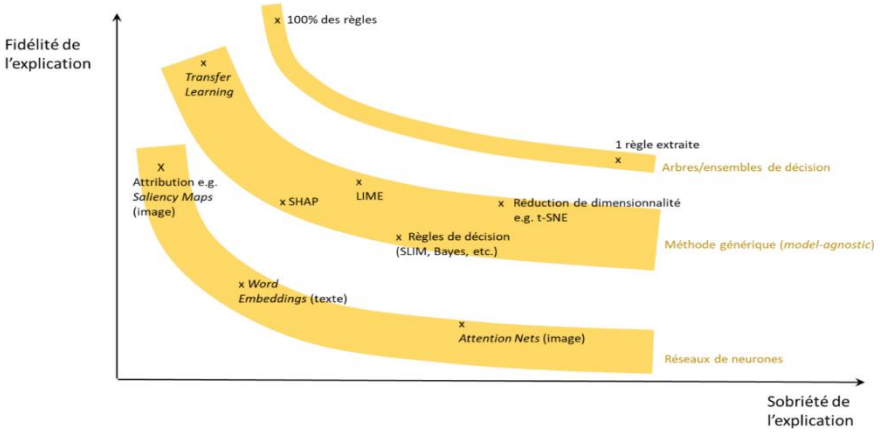

Fig. 2. Compromise between sobriety and fidelity of an explanatory method (Source: [1] page 67)

Following a study of the performance of inference algorithms in Bayesian networks by Kochi and his team [2], the results highlight the impact of certain characteristics of the input data on the execution times and error rates of inference algorithms.

2.2 DATA PRIVACY

The work of Florea et al. [3] qualitatively examined current issues related to data privacy, anonymity, informed consent and confidentiality in datacentric research in higher education. They focused on the roles of the data collector, the data subject and the data user. According to this work, current regulations mainly focus on data collection and disclosure, without sufficiently addressing data use, which has procedural implications on the complexity of research in higher education and the type of data collected. Related work [4], [5] has addressed this and emphasized that protecting personal data from AI requires clear regulation, transparency in data use, prevention of bias and discrimination, adequate security and collaboration between stake-holders.

2.3 FAIRNESS OF RECOMMENDATIONS

Work aimed at describing algorithm related biases and developing possible solutions has been carried out by Patrice Bertail et al [6]. This study presented some promising statistical or algorithmic approaches for correcting biases. A resource has been set up by Ravanera et al [7]. This resource summarizes existing research and knowledge on the relationship between AI and fairness (or inequity) and offers important points of reflection for public and private sector leaders when implementing AI. Related work by Abi et al. [8] has shown that technological advances in artificial intelligence make it possible to increase control of the population. Therefore, it is essential to ensure that companies that create these tools do not abuse them, thus bringing ethics to the heart of the debate. Ménissier et al. [9] highlighted four forms of ethics, including computer ethics, algorithmic, robotic or artificial ethics, digital ethics, and AI use ethics (or UX AI ethics). Brahmi et al. [10] examined the issue of the universality of ethical codes to ensure responsible development and use of artificial intelligence. The objective of this study was to propose a common framework that brings together various ethical codes to guide the ethical use of artificial intelligence.

All these studies show the importance of the issue of ethics but they do not address the specific case of personalized e-learning. A contextualization in the situation of personalized e-learning will highlight the specificities linked to the said context.

2.4 STAKEHOLDER SATISFACTION

The work of Lissillour et al. [11] indicates that although the implementation of artificial intelligence has been justified by transparency, aiming to provide greater visibility of processes and reveal new data to support the work of users, it can ultimately be seen as a means of increasing the capacity to control and monitor their work. Artificial intelligence has clearly illustrated itself as a tool capable of increasing stakeholder satisfaction. Stakeholder satisfaction, thanks to good governance of artificial intelligence, was highlighted by Gauthier Chassang [12] and his team in the work entitled "Towards responsible governance of AI systems organized around risk management". In this context, the application of governance will ultimately allow a clear improvement in the sustainability of Artificial Intelligence information systems (AIS) and increase the level of satisfaction of the various stakeholders. M'Bia and his collaborators [13], through a study on the development of a specific regulation for artificial intelligence and its impact on universities and private companies in Côte d'Ivoire, have shown that good

governance of AI could allow a harmonious development of AI practices to the satisfaction of stakeholders. Political actors, researchers and members of civil society involved in the global debate on AI will benefit from shared perspectives to meet the colossal challenge of ensuring ethical, inclusive and human rights respecting AI development. Farnadi et al. [14] assert that political actors, researchers and members of civil society involved in the global debate on AI will benefit from shared perspectives to meet the colossal challenge of ensuring ethical, inclusive and human rights-respecting AI development.

3 PROBLEMATIC

The integration of artificial intelligence (AI) in e-learning represents a revolution for education, offering the possibility to personalize learning paths according to the specific needs of each student. However, this opportunity comes with complex challenges, particularly in terms of AI governance, which must be addressed to ensure ethical and effective implementation.

3.1 ALGORITHMIC BIASES

Algorithmic biases are one of the most critical challenges in the use of AI for e-learning. AI algorithms, often trained on datasets that reflect existing biases in society, can perpetuate or even amplify these biases when applied in an educational context. For example, a recommendation algorithm that favors certain types of con-tent or teaching methods could disadvantage certain groups of students, creating inequalities in access to quality education. The issue of AI governance then becomes essential to establish checks and balances that ensure the fairness and inclusiveness of e-learning systems.

3.2 PERSONAL DATA PROTECTION

Personalization of e-learning relies on the collection and analysis of vast amounts of students' personal data, such as their academic performance, online behaviors, and even personal preferences. This raises major data protection concerns. Effective AI governance must include rigorous data protection policies to ensure that sensitive student information is secure, that their confidentiality is preserved, and that data is only used for legitimate and ethically acceptable purposes.

3.3 TRANSPARENCY OF DECISION-MAKING PROCESSES

Transparency is another fundamental pillar of AI governance in e-learning. Decisions made by AI systems, such as course recommendation or performance assessment, must be understandable and justifiable by users, including students and educators. Lack of transparency can lead to a lack of trust in the system and even resistance to its adoption. It is therefore crucial to develop AI models whose decision making processes are explainable and verifiable, thus enabling an informed and responsible use of AI in education.

These challenges highlight the importance of a robust governance framework for AI in e-learning. The central question that emerges is: How can we establish an AI governance framework that ensures effective personalization of e-learning, while preventing bias, protecting personal data, and ensuring transparency in decision making processes?

Answering this question involves defining standards and practices that allow us to leverage the benefits of AI while minimizing its risks. This governance framework will need to be flexible to adapt to the rapid evolution of technologies, while remaining rigid on ethical principles and user rights.

The quest for this ideal governance is not only a technical issue, but also a societal issue, requiring the collaboration of multiple stakeholders, including AI developers, educators, policy makers, and end users. This analysis will aim to explore the com-ponents of such a governance framework, identify best practices, and propose concrete solutions to address the challenges posed by AI in e-learning.

4 METHODOLOGY

Our approach begins with a literature review. The latter allows:

- To explore the key concepts of AI Governance (Notions, principles, and existing standards (COBIT, ISO/IEC 38500, etc.), personalized e-learning (Definition, associated technologies, and specific challenges), Governance in e-learning (Current practices, limitations, and opportunities).
- To make a critical analysis through synthesis of existing AI governance models and identification of gaps in their application to personalized e-learning.

The proposed governance model includes frameworks such as COBIT, as well as risk management, compliance, and security practices. The COBIT (Control Objectives for Information and Related Technology) framework is COBIT is a process oriented approach, organized into four domains: planning, building, executing, and measuring, in parallel with the Deming cycle [15], [16]. It includes 37 distinct processes, encompassing activities and an even greater number of "control practices". A complement to this approach is the "information systems assessment" component, called Val IT.

COBIT 5 can be adapted for all types of business models, technology environments, all industries, geographies, and corporate cultures. It can be applied to:

- Information security;
- Risk management;
- Governance and management of the company's information system;
- Audit activities;
- Compliance with laws and regulations;
- Financial operations or corporate social responsibility reporting.

The COBIT 5 framework simplifies governance challenges with just five principles and seven enablers. It allows integration with other approaches and standards, including TOGAF, PMBOK, PRINCE2, COSO, ISO/IEC 20000, ISO/IEC 27001, ITIL, PCI DSS, Law Sarbanes-Oxley and Bâle III.

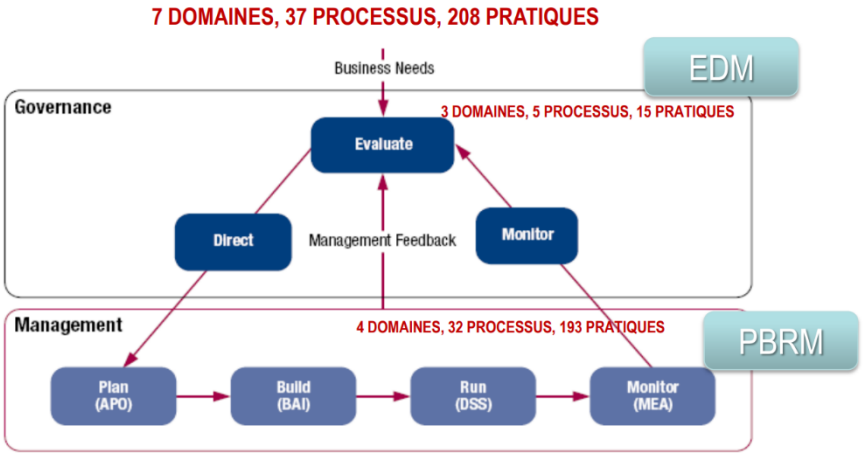

Fig. 3. Presentation COBIT 5 (Source: ISACA)

We present a framework based on COBIT Design Factors, adjusted to the specific needs of AI in e-learning: value creation, Risk management.

- Resource optimization.

5 CONTRIBUTION

Creating a COBIT 5 based personalized e-learning artificial intelligence (AI) governance model involves adapting COBIT 5 principles and processes to the specificities of AI in a digital education environment. COBIT 5 (Control Objectives for Information and Related Technologies) is an information systems governance framework that provides guidelines to ensure strategic alignment, effective risk management, and resource optimization.

Before getting into more details, we propose this diagram which illustrates the broad outlines of the seven areas of COBIT 5 applied to e-learning personalized by artificial intelligence.

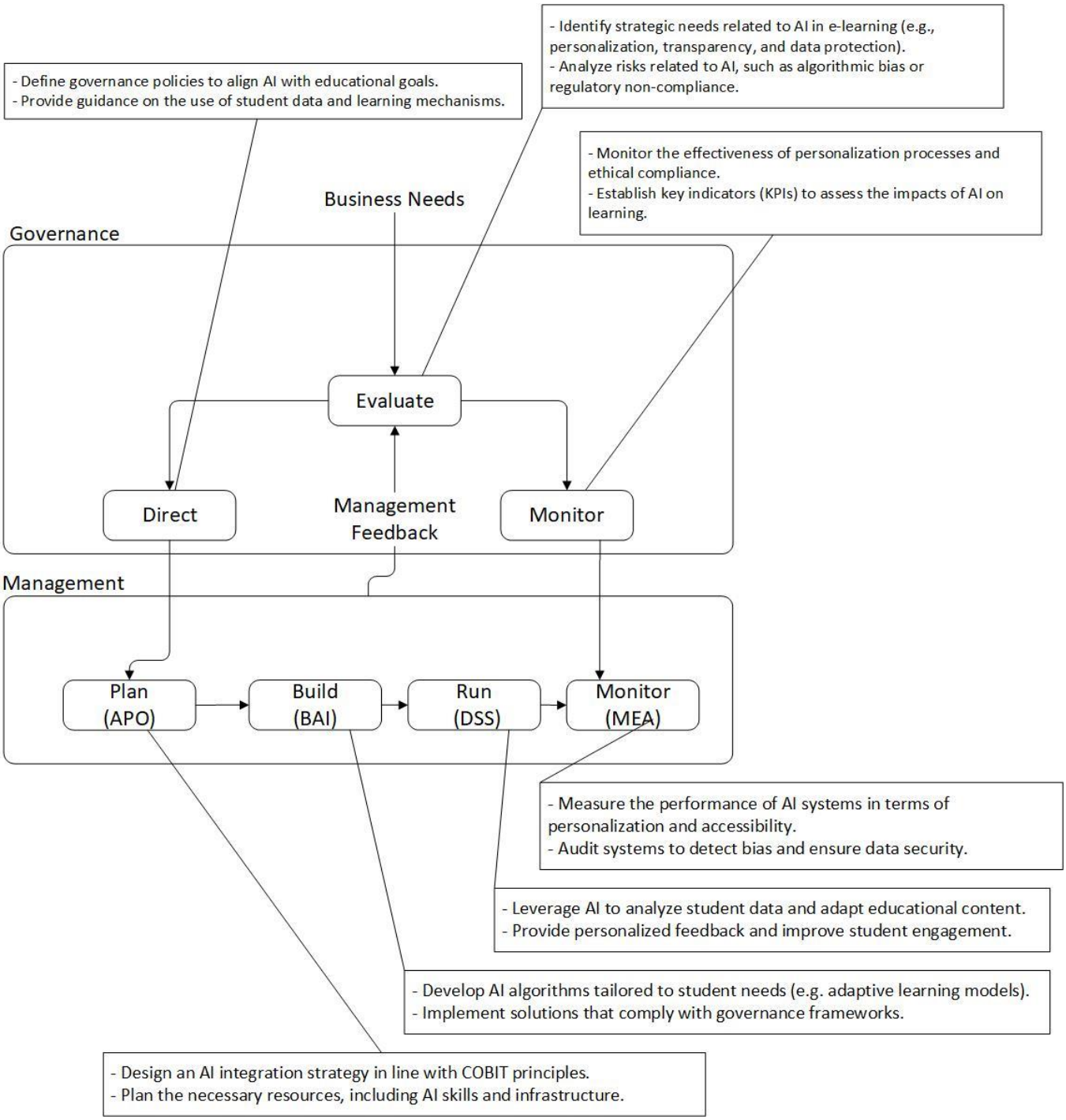

Fig. 4. Illustration of COBIT 5 areas applied to personalized e-learning by artificial intelligence

5.1 COBIT 5 AND PROCESSES APPLICATED TO AI GOVERNANCE IN PERSONALIZED E-LEARNING

Below we will present cobit processes applied to the governance of artificial intelligence in personalized e-learning.

Table 1. Table of COBIT 5 and processes applicated to AI governance in personalized e-learning

1. Strategic Alignment	
Objective	Ensure that AI in the e-learning system is aligned with the strategic objectives of the educational institution.
Governance Process	EDM01 – Ensure alignment of stakeholders and strategic objectives. This process involves defining clear objectives for AI, such as improving learning outcomes, increasing student engagement, and personalizing educational pathways.
Actions	Definition of AI objectives: Align AI capabilities with educational objectives, such as improving student retention and optimizing learning pathways. Stakeholder engagement: Ensure that teachers, administrators, and students participate in defining AI objectives.
2. Risk Management	
Objective	Identify, assess, and mitigate risks related to the use of AI in e-learning, such as algorithmic bias, privacy issues, and technical failures.
Governance Process	EDM03 – Ensure Risk Management. This process focuses on establishing proactive risk management, including identifying AI specific risks and putting mitigation plans in place.
Actions	AI Risk Assessment: Identify potential risks, such as prediction errors or breaches of student privacy. Incident Response Plan: Develop plans to respond quickly to AI related incidents, such as system failures or bias in recommendations.
3. Resource Optimization	
Objective	Optimize the use of resources (human, financial, technological) to maximize the effectiveness of AI in the e-learning system.
Governance Process	APO07 – Manage Human Resources and APO08 – Manage Relationships. These processes address skills management, continuous user training, and management of relationships with technology vendors.
Actions	Skills Management: Train teachers and administrators on AI tools to ensure optimal use. Vendor Management: Collaborate with AI solution vendors to ensure that tools are updated and aligned with educational needs.
4. Monitoring and Evaluation	
Objective	Measure and monitor the effectiveness of AI in e-learning to ensure that it meets defined objectives and quality standards.
Governance Process	MEV01 – Monitor and evaluate performance and compliance. This process involves the continuous evaluation of AI performance and compliance with regulations and internal policies.
Actions	Continuous evaluation: Establish KPIs (Key Performance Indicators) to measure the impact of AI on student engagement and learning outcomes. Audit and compliance: Conduct regular audits to ensure that AI complies with quality standards and regulations in force, such as the GDPR for data protection.
5. Innovation and Continuous Improvement	
	Objective: Encourage innovation and continuous improvement of AI to adapt to technological developments and changing student needs.
Governance Process	BAI09 – Manage innovation. This process focuses on the continuous integration of new technologies and the improvement of existing processes to meet new educational requirements.
Actions	Technology monitoring: Monitor developments in the field of AI and e-learning to integrate relevant innovations. Continuous improvement: Implement continuous improvement cycles to refine AI algorithms and adapt them to user feedback.

This COBIT 5 based AI governance model for e-learning relies on structured processes to align AI technologies with educational objectives, manage risks, optimize resources, monitor performance, and encourage innovation. This framework ensures that AI is deployed efficiently, ethically, and aligned with the needs of students and the institution, while respecting applicable regulations.

5.2 MATHEMATICAL MODELING OF AN ARTIFICIAL INTELLIGENCE GOVERNANCE MODEL

Mathematical modeling of a COBIT 5 based AI governance model in personalized e-learning allows quantifying and optimizing the interactions between strategic objectives, governance processes, and system performance. This mathematical approach helps identify levers for improvement and ensures that AI is used efficiently, ethically, and aligned with educational objectives.

5.2.1 DEFINITION OF VARIABLES AND PARAMETERS

Table 2. of definition of variable and parameters

A: Strategic alignment of AI with educational objectives. R: Management of AI risks. C: Complexity and effectiveness of governance processes. P: AI performance (measured by improvement of learning outcomes, student engagement, etc.). E: Operational effectiveness of AI (optimization of resources, personalization of lessons). S: Monitoring and continuous evaluation of AI. I: Innovation and continuous improvement. Gs : Structure of governance processes. Rm: Management of human and material resources. F: Frequency of audits and controls.	K: Effectiveness of performance indicators. O: Educational objectives of the institution. G: Overall strategic alignment. P_r: Probability of AI risks. M: Risk mitigation measures. Q: Quality of lessons. N: Number of students. T: Time spent using AI. R&D: Investment in research and development. T_n : Ability to adapt to new technologies.

5.2.2 COBIT BASED GOVERNANCE FUNCTIONS

- Strategic Alignment

Strategic alignment (A) is crucial to ensure that AI supports educational objectives. This function can be modeled as a weighted combination of the educational objectives (O) and the overall strategic alignment of the institution (G).

$A=\alpha_1 \cdot O+\alpha_2 G$, α_1 and α_2 are weights that indicate the relative importance of the educational objectives and the overall strategic alignment. A strong strategic alignment ensures that AI is used to achieve the institution's priority educational objectives.

- Risk Management

Risk management (R) depends on the complexity of the system (C), the probability of risks (P_r), and the effectiveness of mitigation measures (M). $R=\beta_1 \cdot C-\beta_2 \cdot P_r \cdot M$. This equation shows that the more complex the system, the more the risks increase, but these risks can be mitigated by effective management measures (M). The coefficients β_1 and β_2 indicate the relative impact of complexity and mitigation measures on risk management.

- Complexity and Effectiveness of Governance Processes

Complexity (C) is influenced by the structure of governance processes (G_s) and resource management (R_m).

$C=\gamma_1 \cdot G_s+\gamma_2 R_m$. System complexity is directly related to how governance processes are structured and how resources are managed. Better governance structure and effective resource management can reduce system complexity.

- AI Performance

AI performance (P) is a function of strategic alignment (A), operational effectiveness (E), and risk management (R).

$P=\delta_1 \cdot A+\delta_2 \cdot E-\delta_3 \cdot R$. This equation shows that improving strategic alignment and operational efficiency increases AI performance, while poor risk management decreases it. The coefficients δ_1, $\delta 2$ and $\delta 3$ reflect the relative importance of these factors.

- Operational Efficiency

Operational efficiency (E) depends on the quality of lessons (Q), the number of students (N), and the time spent (T).

$E=\epsilon_1 \cdot Q+\epsilon_2 \cdot N+\epsilon_3 \cdot T$. More efficient AI allows for better lesson personalization and improved student engagement. Therefore, operational efficiency is a key indicator of AI success in the e-learning system.

- Monitoring and Continuous Evaluation

Monitoring and evaluation (S) are based on the frequency of audits (F) and the effectiveness of performance indicators (K).

$S=v_1 \cdot F+v_2 \cdot K$. Regular monitoring and well defined performance indicators are essential to ensure that AI is working properly and to detect potential problems before they affect learning outcomes.

- Innovation and Continuous Improvement

Innovation (I) depends on investment in research and development (R&D) and the ability to adapt to new technologies (T_n).

$I = \emptyset_1.R\&D + \emptyset_2 T_n$. To remain competitive and meet the evolving needs of students, it is crucial to invest in innovation and adapt quickly to new technologies. This equation shows the importance of these two.

5.2.3 OBJECTIVE FUNCTION

The overall objective of governance could be to maximize performance (P) while minimizing risks (R) and complexity (C).

Maximize $Z = P - \lambda_1 \cdot R - \lambda_2 \cdot C$. This objective function aims to optimize the performance of the AI system while controlling risks and reducing complexity. The coefficients λ_1 and λ_2 represent the relative importance of risk management and complexity reduction in the overall optimization of the system.

5.2.4 OPTIMIZATION

This model can be optimized using techniques such as linear or nonlinear programming, depending on the nature of the relationships between the variables. The goal is to find the optimal values of the governance variables (such as G_s, R, F, etc.) that maximize performance while respecting the constraints related to risks and complexity. The mathematical modeling of an AI governance model in e-learning based on COBIT 5 allows to formalize and optimize the complex relationships between governance processes and system performance. By applying these equations, institutions can identify areas for improvement, minimize risks, and maximize the effectiveness of AI to improve learning outcomes. The comments added to each step of the model help to understand the implications of each variable and possible actions to improve AI governance in a digital education environment.

5.3 ADVANCED MATHEMATICAL MODEL OF ARTIFICIAL INTELLIGENCE GOVERNANCE IN PERSONALIZED E-LEARNING BASED ON COBIT 5

To create a mathematical model of AI governance in personalized e-learning based on COBIT 5 with detailed comments, we need to translate the COBIT 5 processes and objectives into mathematical expressions. The comments provided in each step explain the choices and their alignment with COBIT 5.

5.3.1 DEFINITION OF VARIABLES AND PARAMETERS

Key variables and parameters are defined to capture the different aspects of AI governance in e-learning.

L: Number of lessons. This variable represents the total content of the e-learning, influencing the complexity of the AI system.

S: Number of students. The number of students impacts the load on the AI and the ability to personalize the learning experience.

E: AI efficiency. $E \in [0,1]$. It measures the accuracy of AI recommendations and the relevance of answers, crucial for the quality of e-learning.

T: Total time spent by the AI on each student. T>0.The time that the AI spends on each student influences the personalization and effectiveness of interactions

P: Student engagement $P \in [0,1]$. It represents the rate of student interactions with the system, indicative of their engagement.

C: Cost of implementing and maintaining AI. C>0. It includes expenses related to development, maintenance, and governance in line with COBIT 5.

G: Governance. G∈ [0,1] Represents the application of COBIT 5 processes, influencing the overall effectiveness of the system.

R: Return on educational investment (ROI). R>0. It measures the improvement in student performance, linked to COBIT 5 benefits management objectives.

A: AI adaptability. A∈ [0,1]. It indicates the ability of AI to adapt to individual student needs, aligned with COBIT 5 resource management and value creation.

F: Data security. F∈ [0,1]. Index of compliance with data security standards, crucial for risk management under COBIT 5.

5.3.2 OBJECTIVE FUNCTION

The objective is to maximize AI effectiveness, engagement, adaptability, security, and educational ROI while minimizing costs, in line with COBIT 5 principles.

Maximize $Z = w_1 \cdot E + w_2 \cdot P + w_3 \cdot R + w_4 \cdot A + w_5 \cdot F - w_6 \cdot C$. Weights $w_1, w_2, w_3, w_4, w_5, w_6$ reflect the relative importance of each criterion, defined according to the governance priorities established by COBIT 5. These weights can be adjusted to reflect specific organizational priorities.

5.3.3 CONSTRAINTS

Constraints are established to ensure that the model remains within the limits defined by COBIT 5:

Time Constraint (APO, DSS): This constraint ensures that the total time spent by the AI remains below a predefined threshold, aligned with operational efficiency.

Participation Constraint (EDM, MEA): $P \geq P_{\min}$. It ensures that student participation does not fall below a minimum threshold, ensuring sufficient engagement to achieve learning objectives.

Cost Constraint (APO, BAI): $C \leq C_{\max}$. This constraint limits expenses to stay within a pre-established budget, in line with COBIT 5 resource and cost management.

Governance Constraint (EDM, APO, MEA): $G \geq G_{\min}$. It ensures that governance practices meet a minimum threshold of compliance with COBIT 5 processes.

Data Security Constraint (DSS, MEA): $F \geq F_{\min}$. It ensures that data security standards are not compromised, in line with COBIT 5 risk management and security.

5.3.4 MATHEMATICAL MODELING OF COMPONENTS

- Efficiency of AI:

$E=f_1$ (L, S,T, G), This function can include terms that capture the effect of the number of lessons, students, time spent, and quality of governance on AI effectiveness. The claim that the effectiveness of artificial intelligence (AI) in an e-learning system is a function of the number of lessons, the number of students, the time spent, and the quality of governance is based on several factors that directly influence the performance and impact of AI in an educational environment. Here is a detailed justification:

- Number of Lessons

The number of lessons available in an e-learning system directly influences the effectiveness of AI in personalizing learning and managing educational paths. A higher number of lessons means that AI has more data to analyze student preferences, needs, and performance. This diversity allows AI to better understand the different possible learning paths and offer more accurate recommendations tailored to individual needs. With a larger number of lessons, AI can better personalize learning paths by suggesting specific content to each student based on their progress and difficulties. AI can adjust lessons in real time, improving learning efficiency. AI can use data from multiple lessons to analyze student engagement levels, identify points of interest decline, and adjust content or teaching method to keep engagement high.

- Number of Students

The number of students using the system influences the effectiveness of AI by enriching the data available for training and continuous improvement of models. A large number of students provides a large amount of data, allowing AI to train on diverse and large datasets. This improves the accuracy of algorithms and the ability of AI to generalize learning to different student profiles. With more students, AI can leverage social and collaborative interactions to improve learning. For example, AI can recommend study groups or partners based on similarities in educational backgrounds, thereby enhancing the effectiveness of collective learning. A large number of students allows AI to more easily detect patterns and trends in learning behaviors, which can lead to more accurate recommendations and optimization of teaching strategies.

- Time Spent

The time spent by students and teachers interacting with the system influences the effectiveness of AI by providing richer data and allowing for more refined adaptation of content. The more time spent on the system, the more data the AI has to refine its predictions and adjust learning content in real time. This continuous feedback improves the accuracy and effectiveness of AI recommendations. The time students spend on the platform can be analyzed to understand engagement and retention of information. AI can then adjust workload, lesson difficulty, or teaching pace to maximize learning effectiveness. With more time spent, AI has more opportunities to interact with students in real time, provide immediate feedback, and dynamically adjust learning paths, improving the overall effectiveness of the educational process.

- Quality of Governance

The quality of governance in AI management influences its effectiveness by defining policies, procedures, and standards that ensure that AI operates optimally and ethically. Good governance ensures that AI is aligned with the educational goals of the institution. This includes setting clear priorities, such as equity in access to educational resources, data protection, and continuous improvement of AI models. Governance ensures that AI complies with ethical standards and data regulations. By setting strict rules for data management and algorithm training, governance ensures that AI operates responsibly, which is essential for its long-term credibility and effectiveness. Strong governance establishes mechanisms for continuous evaluation of the effectiveness of AI. This includes regular audits, analysis of user feedback, and adjustment of AI usage policies.

- Student Participation:

$P=f_2$ (S, L,E). Participation is influenced by class size, available content, and AI's effectiveness in personalizing learning experiences. The claim that student engagement is boosted by diverse content, larger student populations, and more effective AI is based on several key principles that influence student engagement in an e-learning environment.

- Diverse Content and Engagement

Diverse content (represented by the number of lessons) provides students with a wide range of resources and perspectives, enriching the learning experience and maintaining their interest. Diverse content prevents monotony and maintains student interest. When lessons cover a range of topics and are presented in a variety of ways (videos, articles, interactive quizzes), students are more likely to stay engaged because they can choose the formats that best fit their learning preferences. Diverse content allows AI to personalize the learning experience by providing lessons tailored to each student's specific needs. This directly addresses their gaps or interests, thereby increasing their active participation. Diversified content exposes students to a variety of skills and knowledge, encouraging them to participate more to master different areas and develop a more holistic understanding.

- High Student Population (Network Effect) and Participation

A higher student population creates a network effect, where interaction between students enriches the learning experience and encourages increased participation. In an e-learning environment with a large number of students, opportunities for social interaction increase. Discussions, forums, and group activities become more dynamic and engaging, encouraging students to actively participate to exchange ideas, ask questions, and learn from others. A higher student population fosters collaborative learning. Students can engage in group projects, debates, and peer tutoring sessions, which boosts their participation through a sense of belonging and mutual learning. When students see their peers actively participating, it can motivate them to engage more themselves. This network effect creates a positive dynamic where each person's participation reinforces that of others.

- More Effective AI and Participation

More effective AI is able to personalize the learning experience, provide timely and relevant feedback, and keep students engaged. Effective AI can adapt the content, pace, and recommendations based on each student's performance and preferences. When students receive lessons and exercises that are precisely tailored to their level and needs, they are more

likely to actively participate. An effective AI provides immediate feedback on student performance, helping them quickly understand their mistakes and improve. This rapid feedback increases student engagement, as students see the direct impact of their participation on their progress. A well-functioning AI is able to detect when a student needs additional help or motivation, and can provide encouragement or additional resources in real time. This supports students in their moments of doubt or difficulty, helping them stay engaged and active in their learning.

- AI Cost

$C=f_3$ (L, S,G). Costs are related to the complexity of the system (number of lessons and students) and the level of governance required by COBIT 5. The claim that costs increase with system complexity and governance requirements, but that these costs are necessary for effective risk and resource management, is based on fundamental principles related to the design, implementation, and management of artificial intelligence (AI) systems in an e-learning environment.

- System Complexity and Costs

System complexity, which includes variables such as the number of lessons, the diversity of features, and the adaptability of the AI, leads to higher costs due to the increased resources required to design, develop, maintain, and optimize the system. A more complex AI system requires more time and expertise to design and develop. This includes integrating multiple algorithms, analyzing large amounts of data, and creating sophisticated user interfaces. Once the system is in place, its ongoing maintenance to ensure that it remains performant and secure also increases costs. A complex system requires more robust infrastructures, such as powerful servers, large storage capacity, and advanced cloud computing solutions. These infrastructures, which must be sized to handle many users simultaneously and process large volumes of data, increase costs. Developing personalization and adaptability capabilities within AI, which are essential to provide a personalized learning experience, is costly. These features require continuous analysis of user data and regular updating of AI models, which requires additional resources.

- Governance Requirements and Costs

Establishing strong governance, aligned with frameworks such as COBIT 5, increases costs due to requirements related to compliance, risk management, and resource optimization. Complying with standards and regulations for data protection, AI ethics, and risk management imposes additional costs. This includes developing policies, training staff, and implementing control mechanisms to ensure that the AI system complies with legal and ethical requirements. Strict governance requires monitoring and auditing systems to identify and mitigate potential risks, whether related to data security, the integrity of AI algorithms, or operational efficiency. These risk management measures require dedicated resources and advanced technologies, which translate into additional costs. Effective governance also involves the continuous optimization of resources to maximize output while minimizing waste. This optimization may require investments in advanced management tools, automated processes, and sophisticated reporting systems, which add to initial and operational costs.

- The Necessity of these Costs

Although these costs are high, they are essential to ensure effective risk and resource management, thus ensuring the sustainability and reliability of the AI system in an e-learning environment. Investing in system complexity and rigorous governance helps prevent costly long-term problems, such as security breaches, service interruptions, and AI errors. Preventing these problems through good governance reduces the risk of financial and reputational losses. A well-governed system optimizes the use of resources, ensuring that each technological or operational investment provides maximum educational and operational value. This optimization maximizes benefits while controlling long term costs. Strong governance and rigorous risk management strengthen the trust of users (students, educators, administrators) in the e-learning system. This trust translates into stronger buy-in and more frequent usage, thereby increasing the profitability of the system. Investments in complexity and governance enable the system to remain resilient to changes, whether technological, regulatory or related to user needs. This ability to adapt quickly without compromising security or efficiency is crucial for long-term success.

- Educational Return on Investment (ROI):

$R=f_4$ (S, E,P). ROI is determined by improved student outcomes, AI effectiveness and engagement, which is central to benefit management under COBIT 5. The claim that the return on investment (ROI) in an e-learning system is related to the number of students, AI effectiveness, and participation is based on principles that show how these factors influence both the economic profitability of the system and the improvement of educational outcomes.

- Number of Students and ROI

A larger number of students leads to significant economic leverage, which increases the ROI due to the large-scale impact and the profitability of fixed costs. The larger the number of students, the more fixed costs (AI development, technology

infrastructure, etc.) are amortized over a broad base, thus reducing the average cost per student. This leads to an improvement in ROI because revenue increases with the number of students, while costs per student decrease. A higher number of students means that the positive results generated by AI and e-learning systems reach a larger population. This can attract more enrollments and partnerships (with institutions or companies), thus increasing revenue and improving ROI. A large number of students can create a network effect where engagement and interaction between students stimulates interest and participation, further strengthening the perceived value of the system and, therefore, its attractiveness and profitability.

- AI Effectiveness and ROI

AI effectiveness increases ROI by optimizing the learning experience, leading to better educational outcomes and greater student satisfaction. Effective AI personalizes learning, allowing students to learn at their own pace and according to their specific needs. This personalization improves academic performance and graduation rates, which builds the platform's reputation and attracts more students, thereby increasing ROI. Effective AI reduces operational costs by automating many administrative and educational tasks (such as progress tracking, grading, and feedback). This cost reduction, combined with improved efficiency, helps increase ROI. Effective AI can identify students at risk of dropping out and proactively intervene to retain them. Better student retention means reduced potential revenue losses, which also improves ROI.

- Participation and ROI

Active student participation is a key indicator of the success of the e-learning system. Increased participation improves educational outcomes and increases satisfaction, which contributes to a better ROI. Students who actively participate in courses and educational activities tend to perform better. This success translates into better overall educational outcomes, which can attract more students and investments, increasing ROI. High engagement is often associated with higher student satisfaction, leading to better retention and long-term loyalty. Loyal students are more likely to pursue additional studies within the same platform, increasing recurring revenue and ROI. Active engagement can also generate positive word of mouth, where satisfied students recommend the system to others. This word of mouth can attract new students without high marketing costs, increasing ROI.

- AI Adaptability:

$A=f_5(E, G,T)$. The ability of AI to adapt is a function of its efficiency, the level of governance, and the time devoted to each student. The claim that the adaptability of an e-learning system is enhanced by effective AI, strong governance, and efficient time management is based on fundamental concepts that show how these elements combine to enhance the system's ability to respond to changing user needs.

- AI Effectiveness and Adaptability

Effective AI is able to quickly process data, analyze user interactions, and provide personalized responses in real time, which enhances the adaptability of the system. Effective AI can continuously analyze student performance and adjust learning content or learning paths in a personalized manner. For example, if a student is struggling with a specific concept, AI can immediately suggest additional resources tailored to their needs, making the system more responsive and adaptable. A powerful AI can anticipate students' future needs based on predictive models, allowing adaptations to be prepared before problems even emerge. This ability to anticipate and adapt proactively improves the learning experience and user satisfaction. AI can also continuously adjust teaching strategies based on the results obtained, making the system more flexible in the face of changes in student profiles and performance.

- Strong Governance and Adaptability

Strong governance establishes clear frameworks and guidelines to guide the adaptation of the system, ensuring that AI and other system components operate in a coherent manner and aligned with educational objectives. Strong governance, such as that based on the COBIT 5 framework, provides clear guidelines on how AI should adapt to different situations. These guidelines may include protocols to adjust algorithms based on user feedback or to meet regulatory requirements, ensuring that system adaptation is both effective and compliant. Governance includes mechanisms to identify and mitigate risks associated with adaptations, such as algorithmic bias or security breaches. By ensuring rigorous oversight, governance allows for rapid adaptation to challenges while minimizing risks. Good governance ensures that system adaptations are aligned with the educational and strategic objectives of the institution, ensuring that each change contributes to the overall mission of the e-learning system.

- Effective Time Management and Adaptability

Effective time management allows the e-learning system to respond quickly to student needs, which is essential for real time adaptation. Effective time management ensures that critical tasks, such as responding to urgent student needs or

adjusting learning content, are prioritized. This ensures that the system can adapt quickly and efficiently to changing user needs. Optimized time management minimizes the time between identifying an adaptation need and implementing it, thereby maintaining student engagement and improving their learning experience. By managing time effectively, resources (such as AI processing capabilities or human intervention) are optimally allocated, allowing the system to adapt without causing overload or delay.

- Data Security:

$F=f_6$ (G). Data security mainly depends on the rigor of governance processes, which is essential to manage risks according to COBIT 5. The claim that strict governance ensures better data security and minimizes compliance risks is based on fundamental principles of information systems management and data protection. Here is a detailed rationale:

- Establishing Clear Security Policies

Strict governance requires the development of robust security policies that clearly define data management protocols and safeguards. Strict governance establishes clear standards for data security, including policies on encryption, data access, and identity management. These standards ensure that all sensitive data is protected by proven methods, thereby minimizing the risk of breaches. Governance also includes regular training programs to raise awareness of data security practices among staff. By ensuring that all actors in the system understand the risks and best practices, governance reduces the risks of reckless or non compliant behavior that could compromise data security.

- Continuous Monitoring and Auditing

Strict governance provides for continuous monitoring and auditing mechanisms to quickly detect and correct any vulnerabilities or non compliance. Regular audits, required by strict governance, verify that all security policies are correctly implemented and that information systems meet compliance standards. These audits identify potential vulnerabilities and allow them to be corrected before they are exploited. Strict governance sets up real time monitoring systems that quickly detect any suspicious activity or attempts at unauthorized access to data. This continuous monitoring reduces the response time in the event of an incident, thus limiting the potential impact on data security.

- Risk Management and Incident Response

Strict governance incorporates risk management strategies and incident response plans, which helps minimize the impacts in the event of a data breach. Strict governance involves regular assessment of data security risks. By identifying potential threats, organizations can put in place specific preventive measures to mitigate these risks. Well structured governance includes an incident response plan that defines the steps to take in the event of a data security breach. This plan allows for a rapid response to contain the breach, assess the damage, notify affected parties, and take necessary corrective measures, thereby limiting the impacts on compliance.

- Compliance with Regulations and Standards

Strict governance ensures that the system complies with all relevant data protection regulations and standards, thereby minimizing legal and financial risks.

6 DISCUSSION

6.1 EFFICIENCY OF AI

The effectiveness of AI in an e-learning system is strongly influenced by the number of lessons available, the number of students, the time spent using the system, and the quality of governance. A larger number of lessons enriches the data available for personalization, while a larger number of students improves the training of models. The time spent allows for more precise adaptation of content, and good governance ensures that AI operates optimally, ethically, and in a way that is aligned with educational objectives. These factors combine to maximize AI effectiveness and improve learning outcomes.

6.2 STUDENT PARTICIPATION

Student engagement in an e-learning environment is significantly influenced by the diversity of content, the number of students, and the effectiveness of the AI. Diverse content maintains interest and meets the varied needs of students, while a high number of students promotes social interaction and collaborative learning. More effective AI, finally, personalizes the learning experience and provides responsive support, which increases student engagement and stimulates active participation.

These elements combine to create a dynamic and motivating learning environment, where participation is naturally encouraged and supported.

6.3 AI COST

The costs associated with system complexity and governance requirements are indeed high, but they are justified by the need to effectively manage risks and resources. A complex and well governed AI system is better equipped to prevent problems, maximize benefits, build user trust, and adapt to future changes. So while these initial costs may seem high, they represent a crucial investment in the sustainability, reliability, and effectiveness of an AI based e-learning system.

6.4 EDUCATIONAL RETURN ON INVESTMENT (ROI)

ROI in an e-learning system is strongly influenced by the number of students, the effectiveness of AI, and active engagement. Large numbers of students help amortize costs and increase revenue. Effective AI optimizes the learning experience, improves educational outcomes, reduces costs, and increases retention. Finally, increased student engagement leads to better educational outcomes, greater satisfaction, and retention, which directly contributes to increased ROI. These elements interact to create a virtuous cycle where improved educational outcomes and student satisfaction lead to increased and sustainable profitability.

6.5 AI ADAPTABILITY

The adaptability of the e-learning system is greatly enhanced by AI efficiency, strong governance, and effective time management. Effective AI enables real time adjustments and optimizes the user experience. Strong governance provides the frameworks for these adjustments to be made consistently and securely, in alignment with strategic objectives. Finally, effective time management ensures that adaptations are implemented quickly, without compromising the quality or effectiveness of the system. These elements combine to create a highly adaptable e-learning system that can effectively meet the diverse and evolving needs of students.

6.6 DATA SECURITY

Strict governance is essential to ensure better data security and minimize compliance risks. By establishing clear security policies, implementing continuous monitoring and auditing mechanisms, proactively managing risks, and ensuring compli-ance with regulations, rigorous governance protects sensitive data and reduces the risk of security incidents. This proactive and systematic approach not only strengthens data security, but also the trust of users and regulators, which is crucial for the sustainability and reputation of the organization.

7 CONCLUSION

In this article, we explored the challenges and opportunities related to the implementation of artificial intelligence (AI) in the field of personalized e-learning. In particular, we developed a governance model based on the COBIT 5 framework, which aims to frame the use of AI to maximize benefits while minimizing associated risks, such as algorithmic bias, personal data protection, and transparency of decision making processes.

The proposed model highlights the importance of an integrated approach where AI governance is aligned with the strategic objectives of the educational institution. Personalizing learning, although a powerful lever to improve student experience and outcomes, requires rigorous supervision to avoid ethical deviations and ensure a fair and responsible use of AI.

Our analyses show that AI governance must be based on several key pillars: transparency, fairness, data security, and continuous improvement. By adopting robust governance, institutions can not only leverage AI capabilities to deliver learning that is more tailored to individual needs, but also build trust in these technologies among users and stakeholders.

The AI governance model for personalized e-learning that we have proposed provides a framework to guide educational institutions in implementing AI ethically and effectively. However, it is essential to continue refining this model as the tech-nology evolves and new challenges emerge. Future research could focus on empirically evaluating this model in real world settings, to validate its effectiveness and identify potential improvements.

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