A Pedagogical Framework to Teach Artificial Intelligence from an Uruguayan Experience

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Abstract: This article presents a pedagogical framework for integrating Artificial Intelligence (AI) education into the school curricula in Uruguay. Its aim is the development of students' AI literacy, focusing on critical thinking, problem-solving, creativity, and collaboration. Emphasizing computational thinking, it prepares students for the digital era and addresses the ethical and social implications of AI. The framework poses three key questions: What is AI? How does it work? What can it do? From these questions, five dimensions are established to cover the fundamentals of AI: the main definition of AI, the representation of knowledge, machine learning, the computational approach and the ethical use and social impact involved. Additionally, the framework outlines key principles and a list of competencies to guide educators and educational leaders in creating an informed, responsible, and adaptive approach towards AI and its societal impact. This comprehensive guide is instrumental for educators to effectively incorporate AI concepts and develop AI skills in students.

1 INTRODUCTION

This framework aims to establish a structure for designing study programs and planning of teaching and learning activities that promote a deep understanding of Artificial Intelligence (AI) and competencies for students to analyze, design and solve problems using computational principles. Through an integrated and multidisciplinary approach, it aims to develop AI literacy and enhances the skills of critical thinking, problem solving, creativity and collaboration. In addition, ethical and social aspects associated with the use of AI will be addressed, an approach that aims to promote an informed and responsible reflection on its impact on both society and individuals. By establishing a contextualized competency framework, this document aims to provide guidance to the community of educators and education leaders on the integration of AI and Computational Thinking (CT) within the school environment. The implementation of innovative teaching strategies combined with the use of appropriate technological tools are expected to enhance the development of key skills and competencies for the 21st century. The aim is also to foster an open and adaptive mindset in each student, in order to build foundations to face the challenges and opportunities that AI and digital technology bring.

In summary, this competency framework offers a general approach to AI education to create critical and ethical citizenship in the use and understanding of this technology and its transformative potential.

This work is organized into five main sections to provide a comprehensive exploration of the topic. Section 2 of this article examines Uruguay's process of integrating computational thinking and artificial intelligence into primary education from Ceibal's[1] perspective. Section 3 reviews other works related to AI literacy and outlines the definition of AI selected

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for this framework. Section 4 introduces the framework itself, detailing its principles and dimensions. Finally, the article concludes with a reflection on the contributions of this work.

2 URUGUAYAN CONTEXT TO AI EDUCATION FRAMEWORK DEVELOPMENT

Launched in 2007, Uruguay's Plan Ceibal has become a pioneering initiative by equipping every student and teacher in the public education system - from the first grade of primary school to the third grade of secondary school - with technological devices like laptops or tablets. This initiative has significantly narrowed the national digital gap, shrinking the technology access gap from a 13-fold difference between the wealthiest and poorest deciles in 2007 to just 1.2-fold by 2010, a ratio that has been sustained.

Ceibal not only distributes equipment but also guarantees internet access across all public educational institutions in Uruguay. It has set up a top-notch video conferencing network across 1,650 educational centers, which covers 100% of urban schools and benefits 97% of the public student body. The use of advanced equipment and fiber optic technology ensures seamless, delay-free real-time teaching sessions, thus enhancing the delivery of programs such as “Ceibal en inglés” (english program) and Computational Thinking with remote teacher participation. Uruguay's commitment to integrating technology in education has positioned it as the most digitized education system in the region and has created an innovative and inclusive digital educational landscape.

Since 2017, Ceibal and the National Education Policy Agency (ANEP[2], by its acronym in Spanish) have been at the forefront of a groundbreaking Computational Thinking program in Uruguay. This initiative introduces a collaborative educational model where a computer science-trained educator, connected via videoconferencing, works alongside the classroom teacher. Together, they execute a curriculum that spans three levels, which integrates computational thinking with a diverse range of subjects like mathematics, science, physical education, and language arts. This interdisciplinary approach enriches the students' learning experience by making the development of computational skills relevant and dynamic. Originally, voluntary and extracurricular, the program's appeal has led to significant growth. From 30 schools at the beginning, it has been expanded year by year. By 2024, it reached more than 4,000 groups from 4th to 6th grade in over 1,000 schools. This growth translates to an educational impact on over 80,000 students and includes more than 80% of urban public schools in Uruguay, which highlights the program's widespread acceptance and success.

In 2021, the curriculum evolved to incorporate artificial intelligence, keeping pace with global technological advancements. By 2024, to reflect its expanded scope, the program was aptly renamed "Computational Thinking and Artificial Intelligence", marking a new chapter in Uruguay's commitment to innovative and inclusive educational practices. In the development of computational thinking within the educational system, there is a concerted effort to establish a comprehensive framework for teaching and learning the theoretical and practical aspects of artificial intelligence. The framework presented in this article stems from the collaboration of Ceibal’s Computational Thinking team and the Research, Development, and Innovation area, with the goal of establishing a framework upon which the Uruguayan teaching community can work within educational institutions as well as incorporate these concepts into the classroom. This initiative goes beyond simple tool usage and seeks to establish a solid foundation in AI literacy. The goal is to equip students with the knowledge and skills necessary to face the challenges and leverage the opportunities that AI technology will present in the near future. With an emphasis on fostering a deep understanding of AI and CT, the program ensures that students are prepared to be not only proficient users but also forward-thinking innovators in the evolving AI landscape.

3 RELATED WORK

The rapid expansion of AI in different aspects of our lives has generated the need to prepare students to interact effectively with this evolving technology. In the education field, a pedagogical approach would allow students to understand and use AI in a critical and creative way. In this context, computational thinking and its associated competencies have been identified as fundamental to develop cognitive and metacognitive skills necessary to address the challenges of the digital age.

[2] https://www.anep.edu.uy/

3.1 Computational Thinking and Artificial Intelligence

While the Computational Thinking Reference Framework (Ceibal, 2022) constitutes a starting point for the approach to AI, there are some innovations associated with machine learning and AI that make it necessary to extend this framework to address them (Tedre et al., 2021). Machine learning and artificial intelligence introduces new concepts such as data cleaning, algorithm training and evaluation, as well as problems associated with this process, such as bias.

These changes imply the need for a new framework to address the issue. In this regard, Tedre et al. (2021) propose the development of a new computational thinking framework to approach computational learning and AI. Although this is a possible path, and Ceibal's Computational Thinking Reference Framework (Ceibal, 2022) probably requires adjusting to the advances observed in the subject, in this case we opted for a different alternative. This paper proposes a more limited and specific framework to address AI, allowing the educational community to move forward quickly and effectively without entering into more fundamental reviews, which could delay the incorporation of this subject in the short term. It is important to recognize the deep connection between computational thinking and AI, which materializes, for example, in the shared principles and elements of the dimensions that make up both frameworks.

3.2 Artificial Intelligence

Before delving into the principles and dimensions of the framework, it is pertinent to note that the term "Artificial Intelligence" was coined in 1956, at an academic meeting at Dartmouth University in the United States organized by John McCarthy and other colleagues. As indicated in the UNESCO survey on AI curricula (UNESCO, 2023), the definition of the term has evolved over time, and today refers mostly to "machines that replicate certain characteristics of human intelligence, such as perception, learning, reasoning, problem solving, linguistic interaction and creative work". It is worth noting that AI education not only addresses learning the scientific and technological foundations of AI, but also the knowledge and critical reflection on how to develop reliable AI and the consequences of not doing so (Long & Magerko, 2020).

4 FRAMEWORK

This framework aims to become a tool to promote AI literacy, understood as a set of competencies that allows people to know and critically evaluate AI technologies, use AI tools, communicate and collaborate with AI (Long & Magerko, 2020), and also promote different ways of thinking that potentially allow people to create through AI.

4.1 Framework Principles

Principles are fundamental characteristics and are incorporated transversally into all work proposals. In this sense, they are not intrinsic elements of computational thinking or artificial intelligence, but guidelines for the construction of proposals and activities to generate learning environments. The principles recommended for implementing this framework in the classroom are outlined below:

- **Equity.** Educate taking into account individual differences and needs, without economic, demographic, geographical, ethnic or gender conditions impacting on students' education.
- **Collaboration.** Work as a team independently and synergistically. Develop strong interpersonal skills. Organize the group of students to take on challenges. Make challenging decisions and contribute to other people's learning.
- **Creativity.** Have an entrepreneurial vision, ask appropriate questions to generate opportunities and new ideas. Transform those ideas into actions with a social impact.
- **Autonomy.** Promote exploration without fear of making mistakes, taking risks and taking the initiative as a strategy to actively engage in the creation process, fostering the intrinsic motivation of each student.
- **Critical Perspective.** Critically evaluate information and arguments, identify patterns and connections, develop meaningful knowledge and apply it to the real world.
- **Active Methodology.** Use methods, techniques and strategies that place the student at the center of the teaching/learning process and encourage their active participation building their own learning experience.

4.2 Framework Dimensions

Dimensions are concepts or powerful ideas that allow teachers to design and implement pedagogical

proposals. They are directly connected to the skills to AI literacy (Kim et al., 2021; Long & Magerko, 2020; Ng et al., 2021; Olari & Romeike, 2021; Sentance & Waite, 2002; Touretzky et al., 2019).

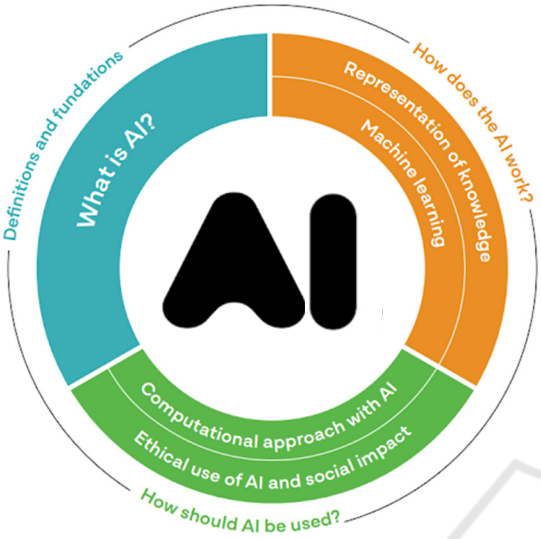

Figure 1: Dimensions of the AI referential framework.

We will explore each dimension, providing a description of its scope and listing some of the associated competencies that we consider relevant. At the end of each dimension, we include a table (Tables 1–5) summarizing the big ideas and competencies aligned with relevant reference literature: AI Literacy competencies (Long & Magerko, 2020) and the five big ideas in AI from AI4K12.org (Touretzky et al., 2019).

4.2.1 What Is AI?

A dimension associated with the first contact with AI is defined, which seeks to encompass the basic concepts and the introduction to the topic. It is, therefore, a dimension with a strong emphasis on the identification and recognition of the subject. Taking the AI Literacy framework as a guide (Long & Magerko, 2020), we can identify competencies associated with this dimension, not only by asking "What is AI?", but also "What can AI do?" The approach to the subject is expected to have an exploratory and experimental component, so it is important to emphasize the practical nature of this dimension, which goes beyond identifying AI. This point is closely related to active methodologies, since it focuses mainly on getting to know possible user applications and experimenting with them so that the familiarization with AI takes place through the use of AI tools. It is also important to connect the very definition of AI to the concepts of intelligence, the discussion of which also enriches the debate on what a machine must accomplish to be considered intelligent.

The specific competencies highlighted within this dimension are:

- Distinguish between devices that use and do not use AI.
- To know systems that include AI components.
- Identify the properties that differentiate an AI-based system from a rule-based system.
- Engage in learning about AI basic functions. Understand the basics of machine learning.
- Use tools with AI. Learn about and how to use different applications that use AI as an end user, focusing on generative or game-related tools.
- Critically analyze and discuss those characteristics that make an entity "intelligent".
- Distinguish between general and narrow artificial intelligence.

Table 1: The relation of the first dimension to other relevant publications.

Big ideas AI4K12 (Touretzky et al., 2019)	Competencies AI Literacy (Long & Magerko, 2020)
#1 Perception #2 Representation and reasoning #3 Learning #4 Natural interaction	#1 Recognize AI #2 Understand intelligence #4 General versus narrow

4.2.2 How Does AI Work?

There are two closely related dimensions, which we include within the same question focused on how AI is built. In this sense, these dimensions seek to learn more about the fundamental concepts behind the more technical aspects of the area, in order to use, understand and develop AI techniques.

Representation of Knowledge. A first dimension regarding the functioning of AI is connected to the computational representation of knowledge. In other words, we seek to answer the question of how knowledge is modeled on a computer. It involves working with data, sensors, representations and the analysis of the human role in definitions associated with these elements (Long & Magerko, 2020; Olari & Romeike, 2021).

The specific competencies highlighted within this dimension are:

- Recognize basic concepts about data types.
- Collect relevant information from a dataset for further processing using AI-based tools.
- Visualize data with AI algorithms.
- To know that different sensors generate different data and to identify sensors in different devices.
- Identify that computers perceive the world using sensors.
- Recognize different computational representations of knowledge and describe some examples.
- Explain results, including errors, when analyzing AI-provided answers, and challenge them with questions.
- Recognize the key role that humans play in the computational representation of knowledge in AI-based solutions.

Table 2: The relation of the second dimension to other relevant publications.

Big ideas AI4K12 (Touretzky et al., 2019)	Competencies AI Literacy (Long & Magerko, 2020)
#1 Perception #2 Representation and reasoning #4 Natural interaction	#7 Representations #10 Human role in AI #11 Data literacy #15 Sensors

Machine Learning. The second dimension of the framework associated with how AI works focuses on machine learning, that is, the mechanisms that allow a computer to learn. It involves defining a specific task and using algorithms so that machines acquire the knowledge necessary to carry it out successfully. Within machine learning, data learning stands out, which includes the analysis and processing of large volumes of information to extract relevant patterns and knowledge. Through machine learning, computers are able to learn autonomously from data, identifying regularities and generating predictive or descriptive models. Programming plays a fundamental role, since it allows the implementation of learning algorithms and the development of intelligent solutions. In addition, the human role in the definition of tasks, the evaluation of results, the interpretation of models and ethical responsibility in the use of AI should be considered (Kim et al., 2021; Long & Magerko, 2020; Ng et al., 2021; Sentance & Waite, 2002).

The specific competencies highlighted within this dimension are:

- Recognize that computers are able to learn from data, including their own.
- Describe how training data can affect the results of an AI algorithm.
- Recognize and describe examples of how a computer reasons and makes decisions. Learn about the simulation of the human logical reasoning process with a computer model.
- Know the learning process of machines, as well as the associated practices and challenges involved.
- Recognize that computers are programmable agents to whom it is possible to indicate the tasks to do through a sequence of code.
- Design and program applications that use AI. Evaluate, predict and design using AI applications.
- Explore models created by others. Remix or reuse code.
- Understand that humans play a key role in programming, model selection, and fine-tuning of AI systems.

Table 3: The relation of the third dimension to other relevant publications.

Big ideas AI4K12 (Touretzky et al., 2019)	Competencies AI Literacy (Long & Magerko, 2020)
#2 Representation and reasoning #3 Learning #4 Natural interaction	#8 Decision making #9 Machine learning steps #10 Human role in AI #12 Learning from data #13 Critical interpretation of data #14 Action and reaction #17 Programmability

4.2.3 How Should AI Be Used?

To address this question, two dimensions are proposed. Students should understand both the potential applications of AI and the effects and consequences of this technology.

Computational Approach with AI. This dimension is analogous and complementary to that of Ceibal's Computational Thinking framework (2022) called “computational problems”. This dimension addresses the computational approach that involves strategies for solving problems, such as dividing them into parts, implementing different solutions, evaluating

their viability and scope, in this case, particularly involving the possibility of identifying AI strengths and weaknesses. This involves identifying the most appropriate problems or sub-problems to be addressed through an AI-based solution (Kim et al., 2021; Long & Magerko, 2020; Ng et al., 2021).

The specific competencies highlighted within this dimension are:

- Learn about the current AI field of application: Computer vision, speech recognition and translation, sound, text and image generation, among others.
- Use AI for problem solving. Apply knowledge, concepts and applications of AI in different scenarios.
- Recognize the type of problems where AI can be directly applied and those that represent a bigger challenge for AI.
- Discern when the use of AI is appropriate and when it is best to use other tools.

Table 4: The relation of the fourth dimension to other relevant publications.

Big ideas AI4K12 (Touretzky et al., 2019)	Competencies AI Literacy (Long & Magerko, 2020)
#1 Perception #2 Representation and reasoning #3 Learning #4 Natural interaction	#1 Recognize AI #3 Interdisciplinarity #5 AI strengths and weaknesses #12 Learning from data #14 Action and reaction #17 Programmability

Ethical Use of AI and Social Impact. The ethical and social dimension is related to the question "How should AI be used?", that is, to the ethical aspects and the social impact connected to the use of AI. It is essential to promote a critical vision and acknowledge the impact AI has on society (Touretzky et al., 2019). This implies a critical analysis of AI data, understanding that it must be analyzed and interpreted rigorously and within its context. Also, interdisciplinary work plays a crucial role in recognizing that there are different actors in technology and understanding how they can collaborate to create more complete and efficient solutions. We also need to be able to imagine the future of AI, exploring its potential applications and considering its effects on the world (Kim et al., 2021; Long & Magerko, 2020).

The specific competencies highlighted within this dimension are:

- Identify that the use of AI has a social impact, identifying the positive and negative effects of AI on society and having a critical perspective on the use of AI technology.
- Understand that data must often be analyzed and interpreted and cannot be considered without those processes, since AI technologies can mirror or amplify biases, stereotypes, and human inequalities
- Imagine the possible applications of AI in the future and consider the effects of those applications globally.
- Recognize collaboration with other actors, bearing in mind that there are many different ways of thinking and developing "intelligent" machines.

Table 5: The relation of the fifth dimension to other relevant publications.

Big ideas AI4K12 (Touretzky et al., 2019)	Competencies AI Literacy (Long & Magerko, 2020)
#5 Social impact	#3 Interdisciplinarity #6 Imagine the AI of the future #10 Human role in AI #13 Critical interpretation of data #16 Ethics

5 FINAL DISCUSSION AND CONCLUSIONS

According to the literature, there are few comprehensive frameworks dedicated to teaching artificial intelligence at the primary and secondary levels. This paper has introduced a novel pedagogical framework designed to promote AI literacy within the Uruguayan educational system. The proposed framework aims to strategically integrate AI into the curriculum, empowering educators and education leaders to adopt it as a foundational tool for designing lesson plans and institutional strategies.

The framework is envisioned as a reference point for the development of workshops, courses, classroom activities, and educational materials. Its flexibility and broad scope allow for adaptation across diverse age groups and topics, making it suitable for both primary and secondary education. Educators can choose to address all dimensions of the

framework or focus on specific areas depending on the intended depth and objectives. For instance, an introductory workshop could center only on the first dimension, "What is AI?", while a multi-week course could delve exclusively into the social and ethical implications of AI, as outlined in the framework's final dimension. These decisions involve instantiating the framework into concrete activities by defining specific content and pedagogical strategies.

From the Uruguayan experience, this framework has already been utilized to design activities such as those featured in the book "Building Artificial Intelligence for Education" (Ceibal, 2024) and in teacher training workshops. For example, one activity connects the process of writing a story using a conversational AI system to competencies promoted within the framework's first dimension. Other types of experiences have been workshops of two or three hours, both with teachers and students, where a first approach to the subject is provided. In some cases a first quick pass is made through all the framework dimensions, while in other cases a specific focus has been made on one of them.

Based on these experiences, the proposed framework has proven to be a valuable tool for establishing a common vision of the dimensions that should be addressed to integrate AI into the educational system. Feedback from both teachers and students has been overwhelmingly positive regarding the activities and publications developed. This response indicates that the content is both engaging and well-suited to the targeted educational levels. Future efforts will focus on gathering feedback from teaching practices to refine the framework further, ensuring its long-term relevance and effectiveness.

In parallel with the development of this framework, Uruguay's educational system has transitioned from a content-based curriculum to a competency-based model. As part of this shift, computational thinking has been officially incorporated as a core competency. The existing computational thinking framework has guided the development of learning progressions that outline the processes students must follow to acquire these competencies.

The AI framework presented here serves as a starting point to extend this work by developing similar progressions for AI-related competencies. Future efforts may explore the integration of the computational thinking and AI frameworks, assessing whether they should remain distinct or if the computational thinking framework could be adapted to include AI literacy competencies. These considerations, along with the continuous refinement of the AI framework, will be central to future research and development in this area.

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