Conceptual Framework

Phygital Schools: AI at the service of Mastery Learning for All

#BetaVersion

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Authors
Ig Ibert Bittencourt, Maria Alice Carraturi,
Seiji Isotani, Marcela Lorenzoni Rabin, Glória M. A. Silva,
Thomaz Veloso, Camila Wasserman

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Editorial Production

Editorial Coordination
Eloi Capucho Ferreira

Translation and Proofreading
Carolina Alfaro de Carvalho

Graphic Design
Eloi Capucho Ferreira
Eduardo Tanoeiro

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Executive Summary

Challenge: The Effectiveness of Learning in Brazil

According to The State of Global Learning Poverty (World Bank, 2022), while in high-income countries nine out of ten children achieve basic literacy by age ten, in Brazil, only three out of ten reach this level.

According to SAEB 2023, only 56% of public school students are literate by the end of the 2nd grade of Elementary School, compared to 81% in private schools. In High School, the situation is even more concerning: 59% of graduates perform inadequately in mathematics, and only 5% demonstrate adequate learning.

Opportunity: Readiness for AI Adoption

According to the Latin American Artificial Intelligence Index (ILIA, 2025), Brazil ranks second in Latin America in terms of readiness for AI adoption based on the criteria of digital infrastructure, human talent, and data; research, development, and adoption; and governance.

According to TALIS 2024, approximately 56% of Brazilian teachers report using AI in their work, which placed the country well above the OECD average.

Vision: AI at the Service of Full Learning for All

Mastery Learning establishes the pedagogical principle that everyone can learn at a high level when they are provided adequate time, feedback, and support. Intelligent Educational Systems can be incorporated into policies and programs to enhance full learning for all.

Strategy: Phygital Schools

A Phygital School is a school that integrates, in a balanced way, the physical, digital, and social dimensions, using data and smart technologies to support Mastery Learning for all.

Physical	Digital	Social
The school's physical space. A space for teaching, learning, and social relationships. A space for coexistence, social and emotional bonds, and bodily experience. A space for the exercise of public coexistence.	Virtual space. A space for teaching, learning, and social relationships. An informational space that expands, extends, and enables the physical space from local to global.	A space for (local and global) human and community interactions that connects the physical and digital spaces.
Individual Intelligence Knowledge and continuous learning, problem-solving.	**Artificial intelligence** Ability to process data, support decision-making, and expand interactions.	**Collective intelligence** Comprehensive relationships, emotional connection, collaboration, and citizenship.

A Phygital School is a school that respects individual intelligence, promotes collective intelligence, and benefits from artificial intelligence. In this context, the Phygital School is a hub for responsible access and use of technologies and AI, for the preservation of in-person interaction, and for community connection.

Premises

PEDAGOGY	COMPETENCIES	ENABLERS	IMPLEMENTATION
Citizen-learner-transformer	Learning with, about, and for AI	Context-adapted infrastructure	Systemic and transversal approach
AI-augmented pedagogy		Responsible regulation of AI	Agile Implementation

Summary

1.

Introduction

Brazilian education faces a historic challenge: ensuring that all students have access not only to school, but to effective and meaningful learning. According to The State of Global Learning Poverty (World Bank, 2022), while in high-income countries nine out of ten children achieve basic literacy by age ten, in Brazil, only three out of ten reach this level. Despite the significant progress that has been achieved in universalizing access to Basic Education, significant gaps persist in the mastery of the essential competencies outlined in the National Common Core Curriculum (Base Nacional Comum Curricular, BNCC), including digital skills and those related to computing. The BNCC and other public policies on technology and media education recognize that the pedagogical and critical use of new technologies is an enabler of full civic participation in the 21st century. The demand for media and computational education is further driven by the impact of Artificial Intelligence (AI), which already plays a major role in social, professional, and educational activities. Although the BNCC calls for the development of computational thinking, digital culture and the digital world, these competencies are still not equitably available for all students.

Global Context

World Bank (2019) Ending Learning Poverty: What Will It Take?, 2022 Update, WB database.

In the field of education, Artificial Intelligence can expand the understanding of learning processes, support teaching practices, and assist in educational management. However, its incorporation into the educational system is not neutral: it tends to reproduce and even amplify existing inequalities when guided solely by technological availability. In order to effectively contribute to addressing these inequalities, it must be guided by clear educational objectives and be committed to equity. For this reason, the debate on AI in education should not begin with a discussion of its tools, but with the core educational challenge we seek to solve: **ensuring that everyone can learn fully.**

The Institute of Artificial Intelligence in Education (IA.Edu) operates under the guiding premise that digital transformation in education does not begin with technology, but rather with people and concrete pedagogical challenges. AI should expand the human capacity to learn, support teaching and educational management, and provide better resources for decision-making. Its value lies in strengthening pedagogical practices and helping with the consistent and equitable attainment of the right to learning.

This document introduces our proposal for a Conceptual Framework for AI at the Service of Mastery Learning for All. However, rather than building a definitive conceptual framework, our goal is to create a framework that allows for movement, updating, and reorganization, so that it can address the challenges of the contemporary world and, more importantly, those faced by Brazilian schools. Therefore, it will remain in a "beta" version to provide provisional answers whenever necessary.

The Conceptual Framework includes a theoretical and methodological framework that can inform public policies, applied research, and the development of AI-based educational solutions in support of Mastery Learning for All. It outlines principles and proposals that can ground a responsible use of AI to improve learning, reduce educational inequalities, and expand opportunities.

This document is organized into four main sections: the learning crisis in Brazil, the role of AI in learning, the vision of Mastery Learning for All, and a concrete strategy for maximizing AI's impact on Brazilian schools through the concept of Phygital Schools.

1.1. Our Challenge: The Effectiveness of Learning in Brazil

The core challenge of Brazilian education lies in ensuring that learning happens throughout the entire school career. The country has made significant progress in universalizing access to Basic Education in recent decades, but this achievement has not translated into learning for all. The phenomenon described by the World Bank (2022) as **"Learning Poverty"**—when a majority of the students spend years in school without developing the fundamental skills needed to fully exercise their social participation and transform their reality—affects 70% of children in the Global South and 80% of children in Latin America1.

The available national data confirm this situation. The results of the Basic Education Evaluation System (*Sistema de Avaliação da Educação Básica,* SAEB) for 2023 show that only 56% of public school students can be considered literate by the end of the 2nd grade of Elementary School, compared to 81% of students in private schools. In High School, the situation is even more concerning: 59% of graduates perform inadequately in mathematics, and only 5% demonstrate adequate learning. The report also highlighted that learning takes place in profoundly unequal contexts. The public school system is responsible for teaching a majority of the students in the country and a greater proportion of its socially vulnerable populations. Regional differences are also striking: the school systems in the North and Northeast report greater limitations in the availability of resources and specialized services than those in the South and Southeast regions of Brazil.

This scenario becomes even more problematic when we look at the data on access to digital technologies and connectivity for educational use. The ICT in Education survey for 2024 reveals that connectivity does not equate to effective educational use: although 88% of schools have classroom internet accessibility, only 27% of students in the municipal school systems use the internet for school activities, compared to 67% in the state school systems. Moreover, only 50% of rural schools have both internet access and computers available to students.

The rapid spread of Artificial Intelligence presents both a risk and an opportunity in this challenging context. According to the Latin American Artificial Intelligence Index (ILIA, 2025), Brazil ranks second in Latin America in terms of readiness for AI adoption considering the criteria of a) digital infrastructure, human talent, and data; b) research, development, and adoption; and c) governance. However, the ICT in Education survey (2024) highlighted a striking contradiction: while the country is at the forefront of AI innovation and 70% of its High School students already use generative AI tools in their schoolwork, only one-third of them have received guidance from schools on how to use AI tools critically and responsibly.

The body of evidence reveals that access to school does not ensure learning, connectivity does not ensure pedagogical use, and the presence of technology does not, by itself, ensure better educational outcomes. Although Brazilian education has achieved universal school enrollment, it is impacted by deep inequalities that result in millions of students who do not learn enough to fully exercise their civic participation in the 21st century. In this scenario, Artificial Intelligence can become an ally in ensuring learning for all. Brazil is in a unique position as one of the most advanced countries in Latin America in terms of its preparedness for the adoption of AI, and it already shows a significant use of AI by students and teachers. The challenge, therefore, is not so much the lack of technological capacity, but the need for educational strategies that

[1] This is the percentage of children of primary school completion age who are unable to understand a simple text.

can put this capacity at the service of those who need it most.

1.1.2. The Potential of AI to Promote Learning

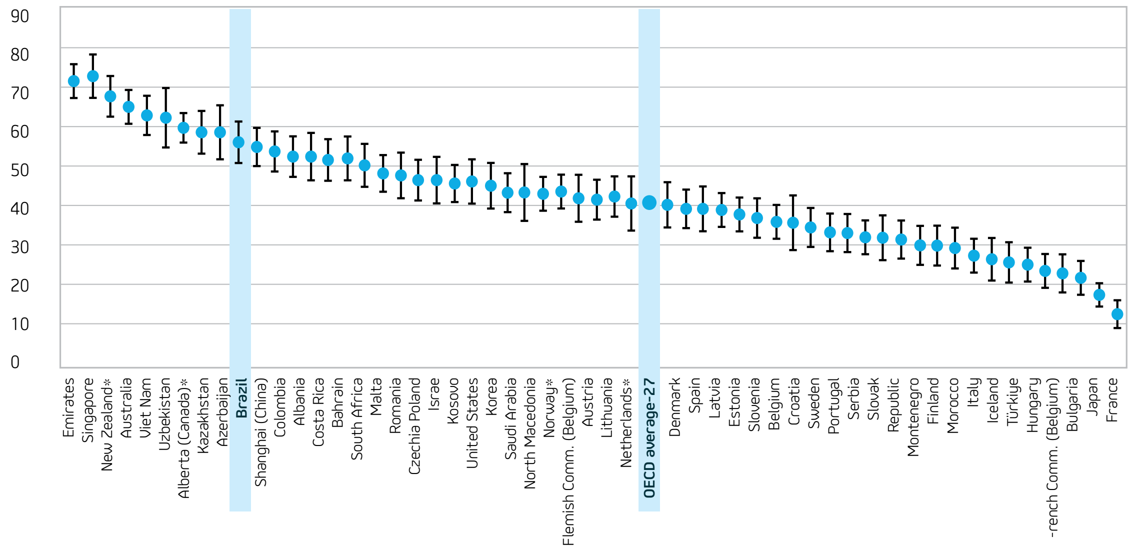
Despite facing profound educational challenges, such as learning inequalities, a shortage of resources, and significant regional disparities, **Brazil shows promising signs, with a relatively high adoption rate of Artificial Intelligence among teachers, according to OECD's Teaching and Learning International Survey, TALIS (OECD, 2024). This trend may represent a strategic opportunity for the country**

If properly guided by public policies, teacher development, and sound pedagogical principles, AI can help expand the education system's capacity to support teachers, personalize learning, and bring pedagogical innovation to schools in diverse contexts. On average, about 36% of teachers in OECD countries reported having used AI in the previous year to support activities such as lesson planning, producing class materials, and organizing content. However, the data also reveal significant variation across countries, indicating that the integration of AI into teaching practices is still undergoing consolidation and depends heavily on the educational context, public policies, and the culture of pedagogical innovation within each system.

In this context, **Brazil stands out as a particularly relevant case. According to the TALIS survey (2024), approximately 56% of Brazilian teachers reported using AI in their work, which places the country well above the OECD average** and among those with the highest adoption of technology by teachers. This result is significant because it comes from a country that faces major educational challenges, such as learning inequalities and resource constraints, in many of its schools. Paradoxically, this high adoption rate suggests that AI may represent a window of opportunity for Brazil: if supported by systemic educational policies, teacher training, and appropriate pedagogical strategies, this technology can help teachers expand their teaching capacity and contribute to addressing the country's historical educational challenges with greater equity.

Percentage of lower secondary teachers who report using AI in the last year

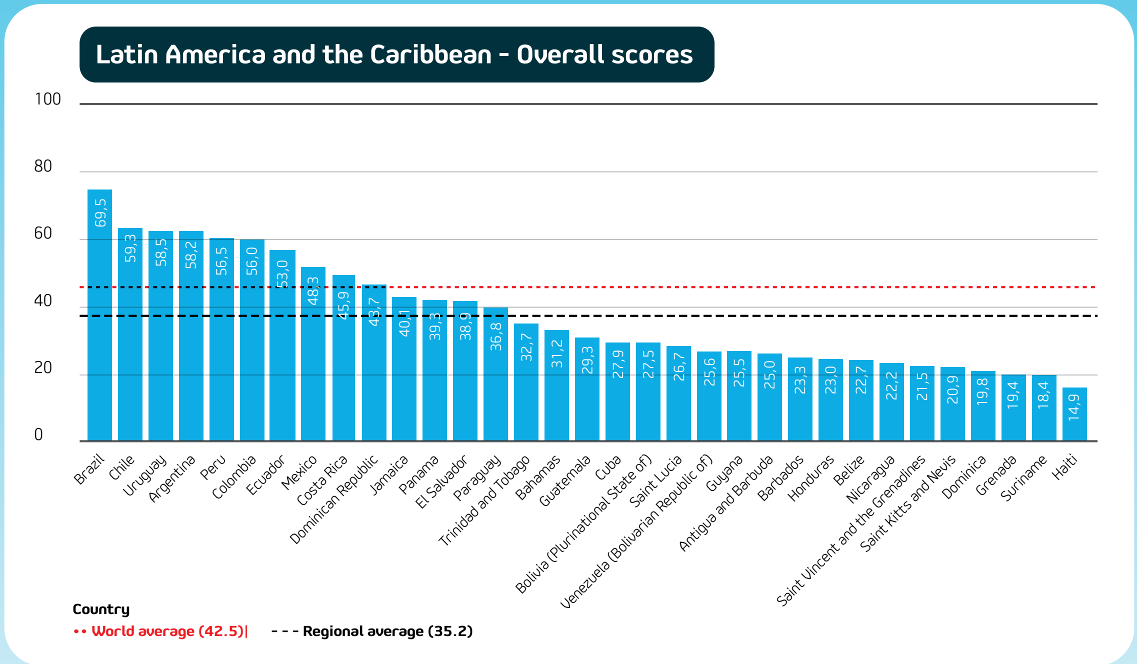
95% Confidence intervals are shown as error bars



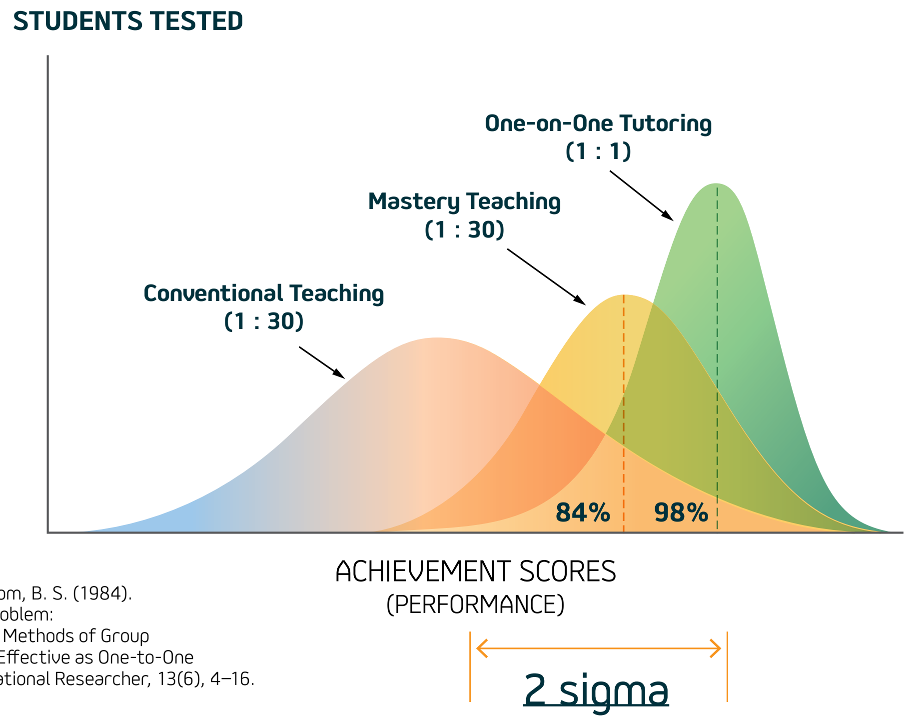
Note: *Estimates should be interpreted with caution due to higher risk of non-response bias.
Source: OECD. TALIS 2024 Database. Table 1.59

Furthermore, **the Government AI Readiness Index (Oxford Insights, 2025) stresses this potential by showing that Brazil has the highest government capacity to adopt and implement AI governance in Latin America.** The index assesses governments' readiness to use AI in addressing public challenges, such as education, health, and public management, considering factors such as governance, digital infrastructure, data, and the technological ecosystem. In the most recent results, Brazil leads the region and ranks among the world's top 50 most prepared countries, outperforming other Latin American nations and particularly standing out in the area of government capacity to implement AI-based policies and solutions.

This result suggests that, in addition to the high technology adoption rate seen among teachers, the country also has the necessary institutional conditions for scaling up the use of AI in the public sector. In other words, Brazil not only demonstrates social and educational openness to technology, but also has a foundation of state capacity and digital infrastructure that could help turn AI into a strategic tool for addressing large-scale social challenges—especially in key areas such as education, health, and inclusion policies.



The so-called 2-Sigma Problem (Bloom, 1984) showed that **students who received one-on-one tutoring tended to perform approximately two standard deviations above those who received only traditional classroom instruction, from one teacher to many students.** This finding revealed one of the greatest challenges in education: although one-on-one tutoring yields extraordinary learning gains, it is extremely difficult to scale it up in large-scale educational systems. Since then, researchers have sought pedagogical approaches that could approximate those results without relying on the availability of a human tutor for each student.



Reference: Bloom, B. S. (1984).
The 2 Sigma Problem:
The Search for Methods of Group
Instruction as Effective as One-to-One
Tutoring. Educational Researcher, 13(6), 4–16.

Among the alternatives, two approaches, Mastery Learning and Intelligent Tutoring Systems, stand out in coming close to that effect. **Evidence indicates that Intelligent Tutoring Systems can yield gains of approximately 1.05 standard deviations in student performance, coming significantly close to the results of one-on-one tutoring (Woolf, 2010).** These systems use Artificial Intelligence techniques, student modeling, and adaptive feedback to offer personalized guidance, continuous assessment, and activities that are tailored to the level of each learner.

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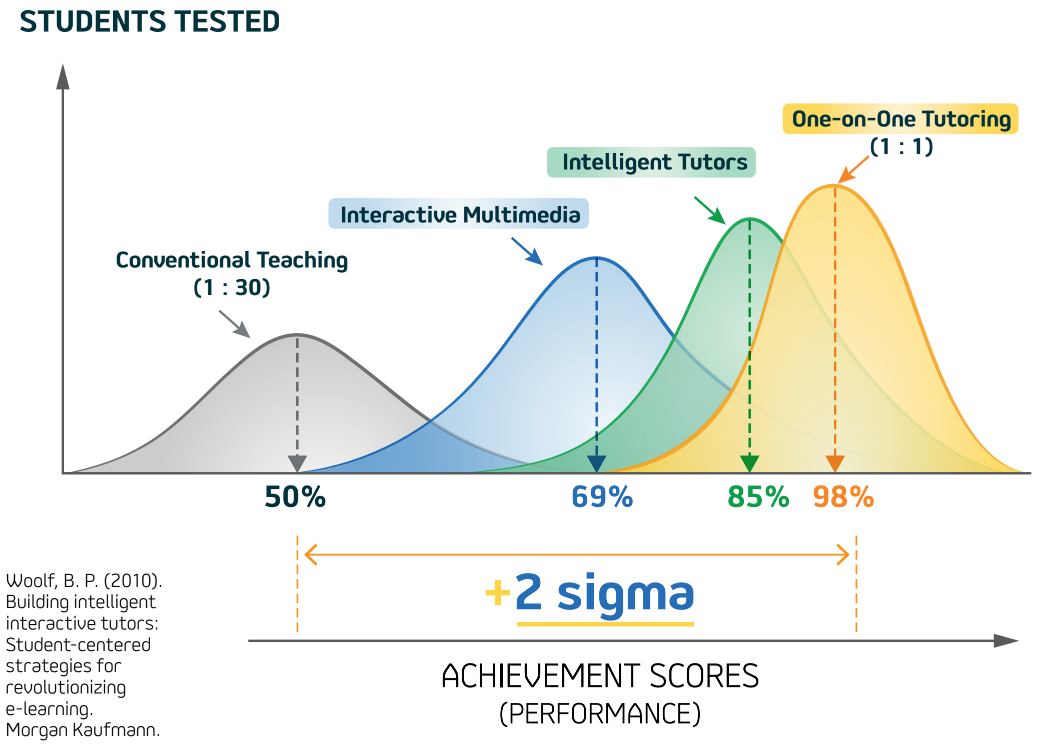


Woolf, B. P. (2010).
Building intelligent
interactive tutors:
Student-centered
strategies for
revolutionizing
e-learning.
Morgan Kaufmann.

While Mastery (or) Learning relies heavily on additional instructional time and teacher mediation, Intelligent Educational Systems have a much greater scalability potential. Once developed, these systems can support thousands or millions of students simultaneously while maintaining high levels of personalization and, in many cases, costing significantly less than human-resource-dependent pedagogical interventions. For this reason, many researchers view AI-based educational systems as one of the most promising strategies to achieve benefits that are comparable to one-on-one tutoring, but are viable for large-scale educational systems.

1.2. Our Vision: Mastery Learning for All

In this context, the convergence of Intelligent Educational Systems and Mastery Learning creates a historic opportunity in education. While Mastery Learning adheres to the pedagogical principle that everyone can learn at a high level when given adequate time, feedback, and support, Intelligent Educational Systems provide the technological infrastructure and computational processing power necessary to make this principle viable on a large scale. By combining continuous assessment, personalized learning paths, and immediate feedback, these technologies can support teachers and students, allowing students to move forward only after they have mastered essential concepts and skills. Therefore, what was once a pedagogical ideal difficult to implement in massive educational systems can become increasingly attainable, bringing us closer to a scenario where Mastery Learning ceases to be the exception and becomes a reality for everyone.

Learning transcends the mastery of cognitive skills in reading, writing, and mathematics, although these are essential to the exercise of civic participation. **It is a broader concept aligned with the many facets of a holistic education. It was through the lens of the learner—who has a social life, participates in social networks, uses technology, and is critical and conscious—that we developed the concept of the citizen-learner-transformer student. This is an active individual, capable of understanding their context, learning throughout life, and transforming the world, so that it becomes a better place for everyone.** Therefore, learning involves mastering intellectual, affective, social, physical, cultural, digital, ethical, creative, entrepreneurial, and human rights competencies.

In this sense, the potential of Intelligent Educational Systems and Mastery Learning goes beyond improving academic results for individual subjects. If Mastery Learning seeks to shape the student as a citizen-learner-transformer, in line with the principles of the BNCC, then AI-based educational technologies should work as tools that support this holistic development. Achieving learning for all and creating citizens-learners-transformers require more than introducing new technologies or specific methodologies; they depend, above all, on the transformation of the school. It is in the school considered in its broadest sense—as a space for social interaction and intellectual, social, ethical, and cultural development—that the objective conditions for promoting such a holistic development will be found. Therefore, any proposal regarding learning must recognize that the central space for this transformation is the school itself.

In view of the complexity and the speed of change in the 21st century, it is inconceivable that schools are still disconnected from the digital and social world. We need an expanded school system that embraces the complexities of post-modernity and is capable of addressing the challenges of lifelong learning. These social and digital dimensions, present in today's organizations, are driven by a strategy that promotes change and by the assimilation of new ways of life, culture, and behavior.

Despite the complexity we face in the area of education in the contemporary world—a digital, social, and physical world, which demands increasingly diverse knowledge and attitudes—we propose an alternative: the "Phygital" world (Meira, 2022; Meira, Pompéia, 2025; Meira, 2026).

1.3. Our Strategy: Toward Phygital Schools

To operate in a multifaceted world—one that is simultaneously hyperconnected and analog, that brings people closer and pushes them apart, that promotes massification and individualization—we seek to ground ourselves in concepts that support the interpretation, understanding, or even the strangeness of the current world. This is the case with the concept of "Phygital."

According to Meira (2021):

> *everything will be phygital: markets, companies, teams, people [and cities, countries, governments...] are transitioning from the physical [or analog] to an articulation of the physical which becomes enabled, augmented, and extended by the digital, and both are orchestrated by the social in [near] real time (p.5).*

According to the author, the new reality of the Phygital space brings together:

- **The architecture:** The world is no longer just physical; it is augmented by the digital dimension (the gateway to connections and transactions), and orchestrated by the social dimension (which coordinates behaviors locally and globally).
- **The agents:** Interactions in this space are not limited to people; they also involve companies, governments, and "things" (artifacts of all kinds).
- **The consequence:** This change is not a simple technological update; it is a systemic transformation that affects the creation, delivery, and capture of value, demanding new business models and competencies across all organizations.

As a national strategy, the Phygital space must be embedded in schools and in the education of future generations. Failing to act now bears the risk of widening educational inequalities and limiting the country's ability to prepare its citizens for a world increasingly mediated by digital technologies and Artificial Intelligence.

It is essential to recognize that AI is not just a new tool, but a fundamental part of a new strategic space that involves individual, social, and artificial intelligences, interconnected and considered together to create solutions that must meet the needs of people, groups, and communities (MEIRA, 2023, p.7).

According to the author, democratization, inclusion in the digital world and access to AI as an equitable advancement depend on understanding this triad of interconnected intelligences.

- **Individual intelligence:** This is the intelligence built up over a lifetime through interaction with others and with the physical and social environment. It is through our engagement with the world that we assimilate and integrate information into existing cognitive structures in a process of dynamic and progressive equilibrium. The individual intelligence comprises both capabilities and limitations, reflecting gradual transformations in mental structures. It is, therefore, the ability to learn, reason, solve problems, and adapt.
- **Collective intelligence:**[*] This is a process of building knowledge within a network that is distributed among individuals (no one knows everything, but everyone knows something). It arises from collaboration, interaction, and sharing enhanced by digital technologies. Collective intelligence is the effective mobilization of competencies generating new knowledge collaboratively.
- **Artificial intelligence:** Built on the individual and social intelligences, these are machines programmed to "think" or act intelligently, and to adapt based on information and experience. It can be designed and used to improve people's quality of life, promote inclusion and equity, and solve social and environmental problems.

AI has the potential to extend and enhance the individual and collective intelligences. It can facilitate individual and collaborative learning, connect students with complementary interests and skills, and foster a richer and more diverse social learning environment.

These three dimensions of intelligence are interdependent and must work together to generate solutions that meet human needs. Individual intelligence involves knowledge and continuous learning; social intelligence refers to collaboration and collective dynamics; and artificial intelligence concerns the ability of machines to process data and support decision-making. The three are integrated into the Phygital School strategy.

The Phygital School integrates, in a balanced way, the physical, digital, and social dimensions, using data and smart technologies in the service of Mastery Learning for All. The concept of "phygital" stems from the recognition that the contemporary world already integrates this dynamic into daily life. Students, teachers, and families continually navigate between physical spaces—which can be expanded by digital environments—and participate in social, physical, and virtual interactions. Becoming phygital, however, is a pedagogical and political choice guided by the conviction that this integration can help us address educational inequalities and shape citizen-learners-transformers in the 21st century.

The Phygital School strategy is based on a few premises that guide its implementation: the three intelligences, student-centeredness, AI-enhanced pedagogy, learning with and about AI, context-adapted infrastructure, responsible regulation, systemic approach, and agile implementation.

[*] LÉVY, Pierre. A inteligência coletiva: por uma antropologia do ciberespaço. São Paulo: Loyola, 1998. A questão é: como usaremos as novas tecnologias de forma significativa para aumentar a inteligência humana coletiva? Entrevista à Fronteiras do Pensamento, 2019. Disponível em: https://www.fronteiras.com/leia/exibir/pierre-levy-a-questao-e-como-usaremos-as-novas-tecnologias-de-forma-significativa-para-aumentar-a-inteligencia-humana-coletiva. Acesso em 8/04/2026.

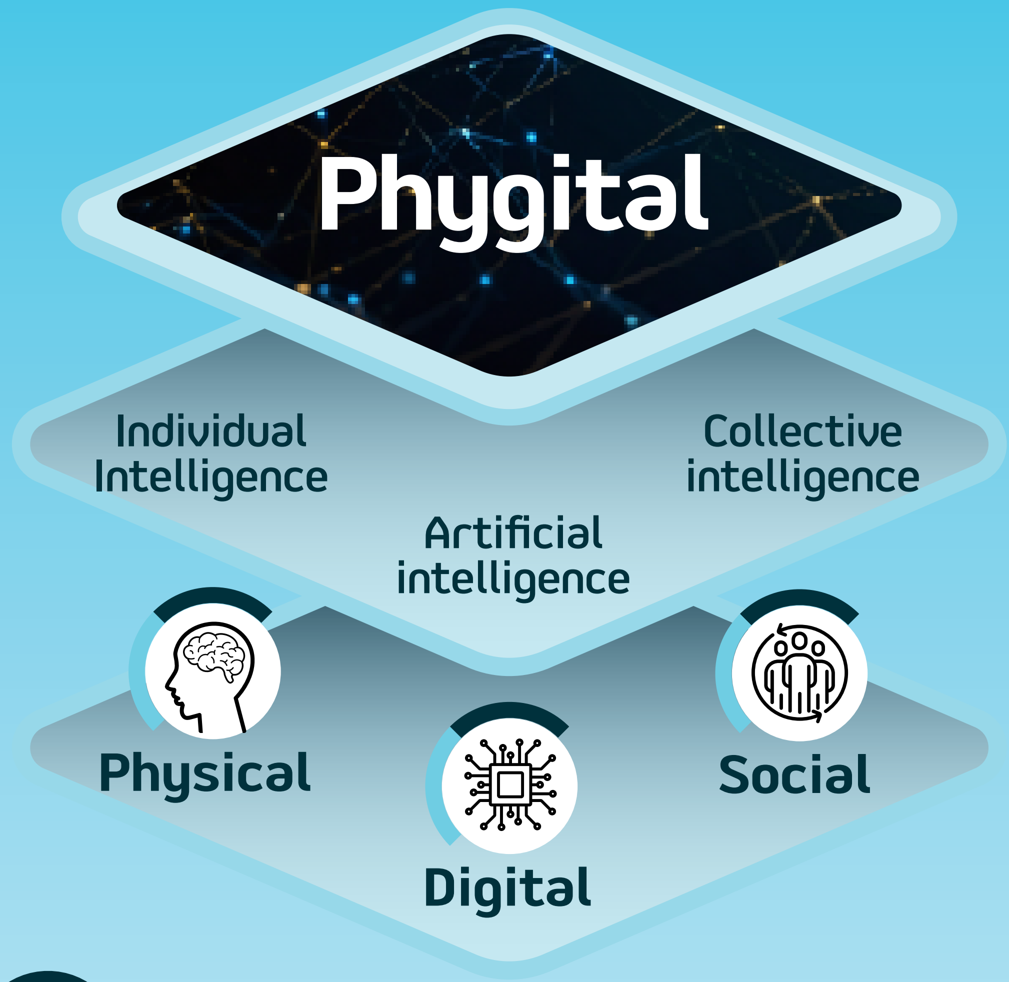
2. Phygital Schools: A Theoretical Framework

The transformation of schools into Phygital Schools implies adopting educational innovation as a systemic policy through the alignment of educational goals, professional competencies, institutional conditions, and implementation processes within a single framework for action. To make this integration clearer, IA.Edu has adapted and updated the Four in Balance model—vision, competence, digital educational resources, and infrastructure (Kennisnet, 2011; 2015)—interpreting the strategy as the balance between four interdependent, complementary, and essential pillars: pedagogy, competencies, enablers, and implementation. This chapter introduces the conceptual framework of Phygital Schools based on these dimensions, and details their principles and levels of maturity..

2.1. The Phygital School: Integrating the Physical, Digital, and Social Dimensions

Regardless of any institutional decisions, students and teachers already interact with intelligent digital systems on a daily basis when they use search engines, educational platforms, or generative AI applications. In other words, schools are already part of a phygital ecosystem in which the physical, digital, and social dimensions continuously intersect.

Physical Dimension	Digital Dimension	Social Dimension
The school's physical space. A space for teaching, learning, and social relationships. A space for coexistence, social bonds, emotional bonds, and bodily experience. A space for the exercise of public coexistence.	Virtual space. A space for teaching, learning, and social relationships. An informational space that expands, extends, and enables the physical space from local to global.	Physical and virtual space. A space for teaching, learning, and social relationships. A space for human and community interaction (local and global) connecting the physical and digital spaces.



2.2. Learning in the Physical Dimension

The physical dimension of a school is a space of shared presence, socialization, and the exercise of public life. It is in this physical space that more effective bonds between teachers and students are formed, that bodily and emotional expressions manifest, and that communities of belonging are created. Research on effective learning (Bloom, 1984; Queiroga et al., 2024) confirms that a pedagogical relationship mediated by adult mentors is one of the most consistent factors in the development of learning, especially for students in vulnerable situations. The school is the locus of pedagogical action in Basic Education and enables the Phygital School.

Its arrangements within the Phygital School should foster both moments of direct instruction and spaces for collaboration, inquiry, civic participation, and creativity. These environments must take into account the specific contextual challenges of rural and urban schools, and those of indigenous and quilombola communities, which have distinct territorialities that must be respected and valued in the pedagogical design. That being said, the physical space of the Phygital School is expanded and extended by the digital realm.

2.3. Learning in the Digital Dimension

The digital dimension of the Phygital School is the expanded and extended space of the physical dimension, where digital tools can also serve as teaching and learning environments. These tools open up a vast array of possibilities for the digital realm: a space for continuous monitoring, an environment for creation and experimentation, and a means of interacting in unprecedented ways with knowledge, others, and the world. In this dimension, Artificial Intelligence acts simultaneously as an organizational support tool—making the learning process observable, measurable, and efficient, while also facilitating pedagogical and school management—and as an amplifier of pedagogical possibilities, expanding the horizons of what can be taught, learned, and created.

With regard to augmentation, AI has the potential to open up paths that until now have been inaccessible to most students. Intelligent educational systems adapt explanations to each student's pace and level, providing the right support at the right time without relying solely on the teacher's availability. AI-powered creation tools allow students to compose music, write stories, produce images, and develop prototypes, helping them to become creators rather than mere consumers of digital content. Simulation and augmented-reality environments make abstract phenomena experiential, manipulable, and contextual. Generative AI further expands the possibilities for interacting with knowledge in multiple formats and languages, reducing linguistic and accessibility barriers that have historically excluded significant portions of Brazilian students (OECD, 2026).

Lastly, learning in the digital world also implies learning about the digital world. Students should not be merely skilled in the use of digital tools; they must understand how they work, the logic and values that structure them, and how to think about and use them in critical, ethical, and creative ways. This is addressed in depth in section 2.2.3.

2.4. Learning in the Social Dimension

The social dimension of the Phygital School is the space that cuts across the other two. It is a layer of collective intelligence where one navigates between the physical and digital worlds to learn, interact, and stay informed locally and globally. The social dimension of the Phygital School recognizes that knowledge is constructed collectively, whether through in-person exchanges in the classroom or through interactions mediated by digital platforms.

This dimension is especially relevant in the Brazilian context, where school often represents the primary space for socialization, access to services, and identity formation for children and youth from culturally more modest backgrounds. Preserving and strengthening social bonds at school is central to ensuring that learning takes place and is sustained over time.

The Phygital School does not abandon the physical building, but rather enhances, expands, and extends it through digital means. Learning is not restricted to the four walls of the classroom; it is distributed throughout society and takes place in a network that allows students to interact and access content even when they are not physically present at school. **The Phygital School is a school that respects individual intelligence, promotes collective intelligence, and benefits from artificial intelligence.** In this context, the Phygital School is a hub for responsible access and use of technologies and AI, for the preservation of in-person interactions and community bonds. It is also open enough to allow the expansion of its boundaries by connecting students, teachers, and communities to broader networks of knowledge and social participation.

3.

Prerequisites for the Phygital School

The transformation of schools into Phygital Schools requires effective and context-specific implementation strategies that can address both human and technical elements. To this end, inspired by the *Four in Balance (Kennisnet, 2011; 2015)*[2] , IA.Edu introduces an updated take on the four pillars: through **pedagogy**, we realize the vision of Mastery Learning for All; we maintain **competencies**; we combine digital educational resources with infrastructure and other enablers in the **enablers** pillar; and we introduce the new **implementation** pillar. The structure below is proposed both as a path and as an end goal to be reached. It accounts for the differences in and the contexts behind schools and recognizes the diverse scenarios illustrated here, outlining which systemic transformations are necessary for the successful and sustainable implementation of the Phygital Schools.

The Phygital School uses data and smart technologies to integrate, in a balanced way, the physical, digital, and social dimensions. It employs a **pedagogy** that fosters Mastery Learning for all and is reflected in the curriculum, its conception of the student, the use of an augmented pedagogy, and school management, and requires **competencies** for students, teachers, and management that are developed with, about, and for AI. Furthermore, it requires the existence of **enablers** (infrastructure and regulation) with a direct impact on the school, so as to facilitate and ensure an appropriate, agile, and context-specific **implementation**.

[2] Widely adopted in the Conceptual Framework of the Center for Innovation in Brazilian Education (CIEB, 2020), it is included in the Connected Education Innovation Program (PIEC, 2021), as well as in the National Digital Education Policy (PNED, 2023).

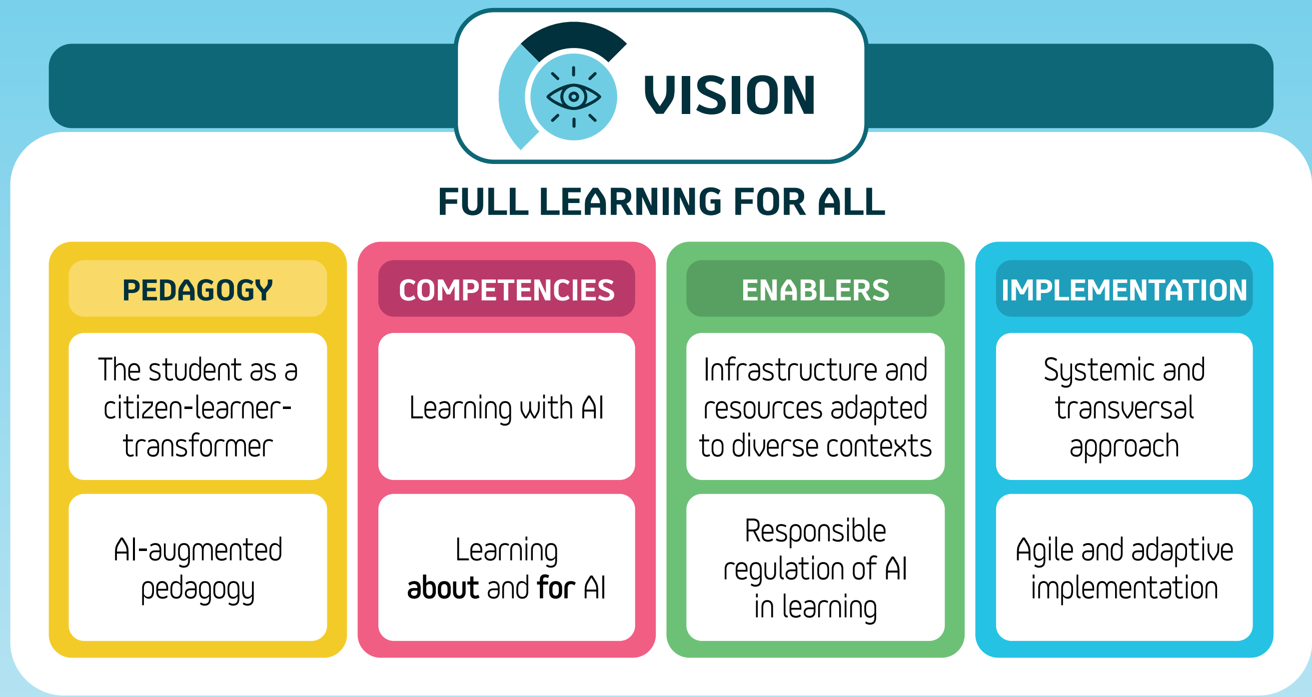
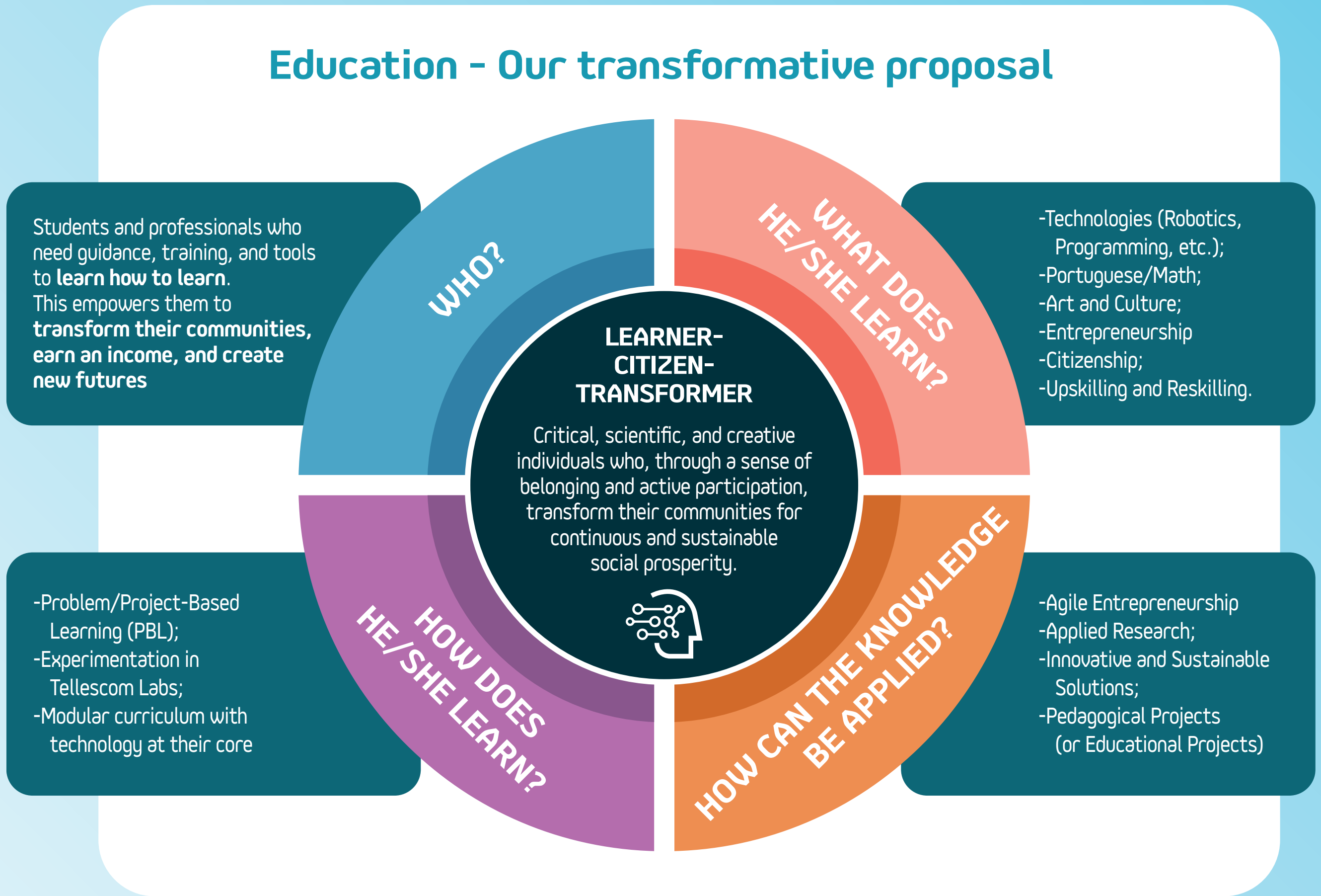


Figure 2 : Four in Balance model for Digital Schools. Source: IA.Edu (2026), adapted from Kennisnet (2011; 2015).

3.1 Pedagogy

3.1.1. The Student as a Citizen-Learner-Transformer

The view of AI as an enabler of learning that promotes educational equity sees students as citizen-learners-transformers—critical, scientific, and creative individuals capable of transforming their communities through a sense of belonging and active participation, and generating continuous and sustainable social prosperity. These **learners** will operate within a new strategic space for action, decision-making, and innovation by means of the triad of intelligences.



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The three intelligences—individual, social, and artificial—are increasingly present in schools, not in isolation, but integrated into teaching and learning processes. The individual intelligence (the learning subject) is present in cognitive development, reflection, problem- and conflict-solving, inspiration, and creation. Collective intelligence (learning from others) is present in the interactions among students, teachers, and the community, in the collective construction of knowledge, in group work, collaborative projects, debates, conversation circles, and problem-based learning, as well as in social-emotional skills such as empathy, communication, and cooperation. Artificial intelligence (technology as learning aids) is present in digital tools that analyze data, generate content, or support decision-making. It can also be found in adaptive platforms that adjust the content to the learner's level, respecting the learner's pace and level of knowledge, and can answer questions, give explanations, support research, perform intelligent correction, and assist in performance analysis.

Thus, the student synthesizes a hybrid experience in which there is no longer a distinction between online and offline, since all our experiences, relationships, and decisions are digitally mediated. We live in a world where digital life and "real" life are interconnected. Technology is no longer an external tool and has become an integral part of human life. As argued by Floridi (2015), with uninterrupted connectivity, the individual must learn during their lives to navigate their "onlife" lives.

This perspective on **citizenship** goes beyond the notion of a "responsible citizen" who follows established rules and fulfills their duties (Westheimer & Kahne, 2004). The goal is to shape citizens that are oriented toward social justice and are capable of critically analyzing the social, political, and economic structures of the place they occupy in the world. In the digital age, this type of citizenship is expanded to encompass the ethical, critical, and creative use of technology. Digital citizens not only master technological tools but also understand and question the power relations embedded in technology, and envision new democratic and equitable digital futures.

Finally, the **transformative** subject also introduces a dimension marked by agency and by action that is guided by social justice. Transformers are not content to merely participate in existing structures; they analyze, debate, and take action to change systems that reproduce inequalities, playing an active role in imagining and creating new futures. In the teaching and learning with, about, and for AI, this implies training students who are not passive consumers of technology, but co-creators who can use existing tools in an emancipatory way, or discover new practices and technologies that address local or global challenges.

3.1.2. AI-Augmented Pedagogy

Given the challenges and inequalities in access, and the competencies observed in the Brazilian context, it is unlikely that the integration of AI into educational systems will follow a single path. Based on reference studies (UNESCO, 2021; IDB, 2025), we have identified two distinct axes that currently shape the possibilities for its use: automation and augmentation. Both strategies have the potential to impact learning in a positive way. Understanding how they differ is essential for the development of relevant and effective policies for the diverse settings that exist in Brazil.

The use of AI for automation refers to the ability to perform repetitive, structured, or large-scale tasks with greater speed, greater precision, or at a lower cost than when humans perform the same tasks. Examples include the automated generation of lesson plans, the automatic grading of assignments or essays, the monitoring of student attendance or engagement, and the analysis of large volumes of data in support of pedagogical and administrative decision-making.

Automation, however, is not without risks: if poorly developed or implemented, it can produce materials that are generic and indifferent to minorities, reinforce biases, and replace humans in teaching roles that require human sensitivity. UNESCO (2021) warns that automating activities without a process of reflection and appreciation for current practices may lead to pedagogical impoverishment. For Queiroga et al. (2024), this path requires robust, high-quality, and representative databases that enable education leaders to make decisions based on real people and challenges.

The augmentation of learning through AI focuses on expanding and enriching human capacity. This occurs when technology allows teachers or students to explore pathways that would not be open to them without digital support, such as explanations adapted to different proficiency levels, diverse formats, resources for accessibility and inclusion, and the deepening and enhancement of teaching practice. International evidence (IDB, 2025) shows that the success of AI for learning, especially in contexts marked by historical inequalities such as in Latin America, depends less on the access to devices that on meaningful pedagogy and structured implementation.

Automation and augmentation are not irreconcilable or mutually exclusive paths; both have the potential to contribute to the improvement of learning with equity. Their successful implementation can combine strategies, provided they are contextually grounded in the expectations of the school districts, the distribution of infrastructure, the level of teacher training, learning challenges, and local characteristics.

3.2 Competencies

3.2.1. Learning with AI and About AI

The integration of AI in Brazilian schools should not be limited to its role as a pedagogical tool. Beyond its use in automating or enhancing learning experiences, AI must also become the subject of study. Learning about AI involves studying it as a technological, political, and social phenomenon, so that teachers and students can be capable of analyzing, understanding, questioning, evaluating, and, ultimately, creating better digital futures.

The citizen-learner-transformer, acting within the current context of opacity in AI systems and their increasingly pervasive presence in daily life, understands AI as a space that is not neutral, but rather reflects, amplifies, or combats historical relations of inequality. The PISA 2029 Media and Artificial Intelligence Literacy (MAIL) Assessment Framework (OECD, 2026) emphasizes that, without a critical understanding of how AI filters and presents reality, students are exposed to subtle manipulations that shape their perceptions, beliefs, and behaviors.

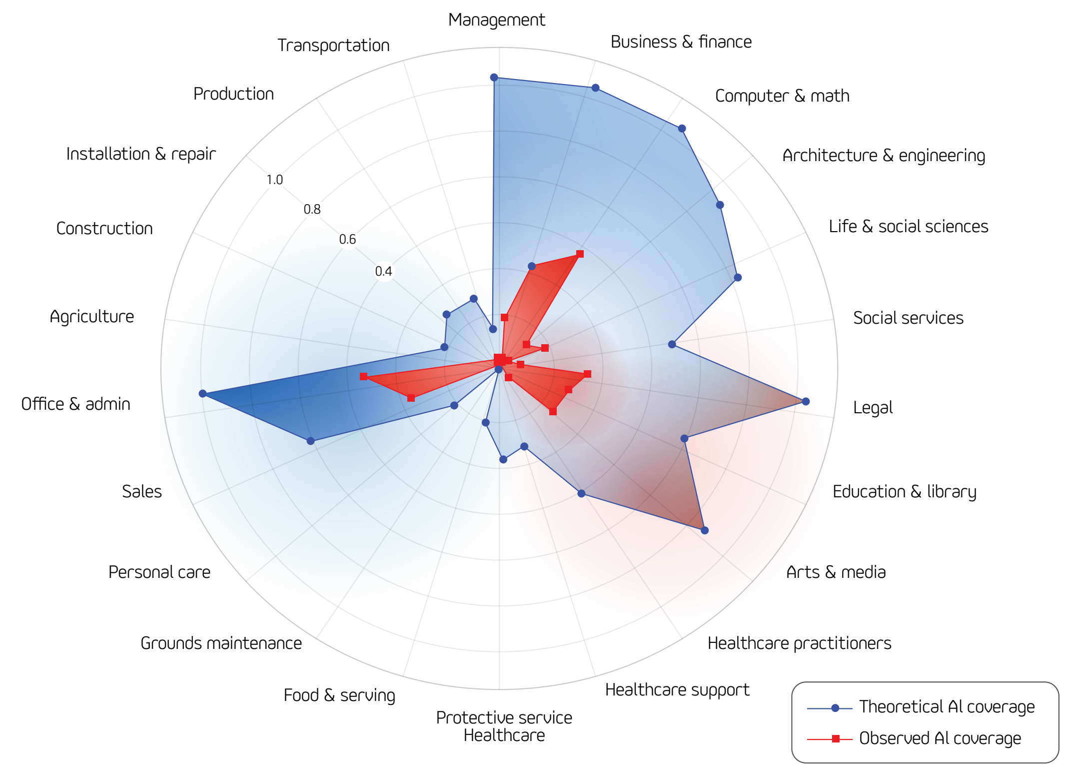
Some of the key national and international documents (AIEDU, 2025; CIEB, 2024; OECD, 2026) agree on the urgency and need for an education that considers the critical and ethical dimensions of Artificial Intelligence. For IA.Edu, this education is underpinned by five knowledge dimensions, with a progressive level of complexity, that are aligned with the computing standards of the BNCC (Wasserman et al., 2025):

Dimension	Description
AI Literacy	Recognizing, understanding, and discussing the presence of AI in daily life, and promoting an understanding of what AI is, where it is present, and how it influences people's lives.
AI and Society	Addressing the ethical, social, and cultural implications of the use of AI, fostering discussions on privacy, accountability, algorithmic justice, and digital citizenship.
The Role of Data	Understanding how machines learn from information, highlighting the need to structure and analyze data critically to avoid biases and ensure representativeness.
How AI Thinks	Understanding the logic and mechanisms that guide the functioning of intelligent systems, such as rules, algorithms, and decision-making structures.
Creating with AI	Encouraging experimentation and the creation of solutions using AI tools, and promoting the development of practical, innovative projects committed to ethical values.

Figure 3: Five Dimensions of AI Knowledge in Basic Education.
Source: Wasserman et al. (2025).

Furthermore, the rapid evolution of AI has the potential to profoundly transform labor relations, redefining tasks, skills, and professions in virtually every sector of the economy. Recent studies indicate that AI is likely to particularly affect knowledge-intensive occupations, in which activities such as information analysis, content production, decision-making, and problem-solving can be partially supported or enhanced by intelligent systems. The graph below, based on the study "Labor Market Impacts of AI: a new measure and early evidence" (Anthropic, 2026), illustrates this dynamic by comparing AI's theoretical capacity to perform tasks in different professional fields with its current observed use. In this context, education emerges as one of the sectors with the greatest theoretical potential for impact, along with other fields such as business, computing, law, and management.

Theoretical capability and observed usage by occupational category



Anthropic. (2026). Labor Market Impacts of AI:
A New Measure and Early Evidence.
Accessed at: https://www.anthropic.com/research/labor-market-impacts

Graph 2: Theoretical capability and observed exposure by occupational category
The figure shows the share of occupational tasks that machine learning models could, in theory, perform (the blue area), and our own measure of the observed use based on usage data (the red area).

This scenario underscores the importance of advancing an "Education about AI" agenda that prepares students and teachers not only to use AI-based tools, but also to critically understand how they work, their social implications, and their role in the future of work. If AI is set to profoundly transform professions and professional practices, education must anticipate these changes rather than merely react to shifts in the labor market. It is essential to equip students and teachers to act, adapt, and lead in a world increasingly mediated by intelligent systems. Teacher training supports and enables this type of learning, and should encompass the teaching about AI, the teaching with AI, the critical understanding of AI, and the use of AI in professional development (Wasserman et al., 2026).

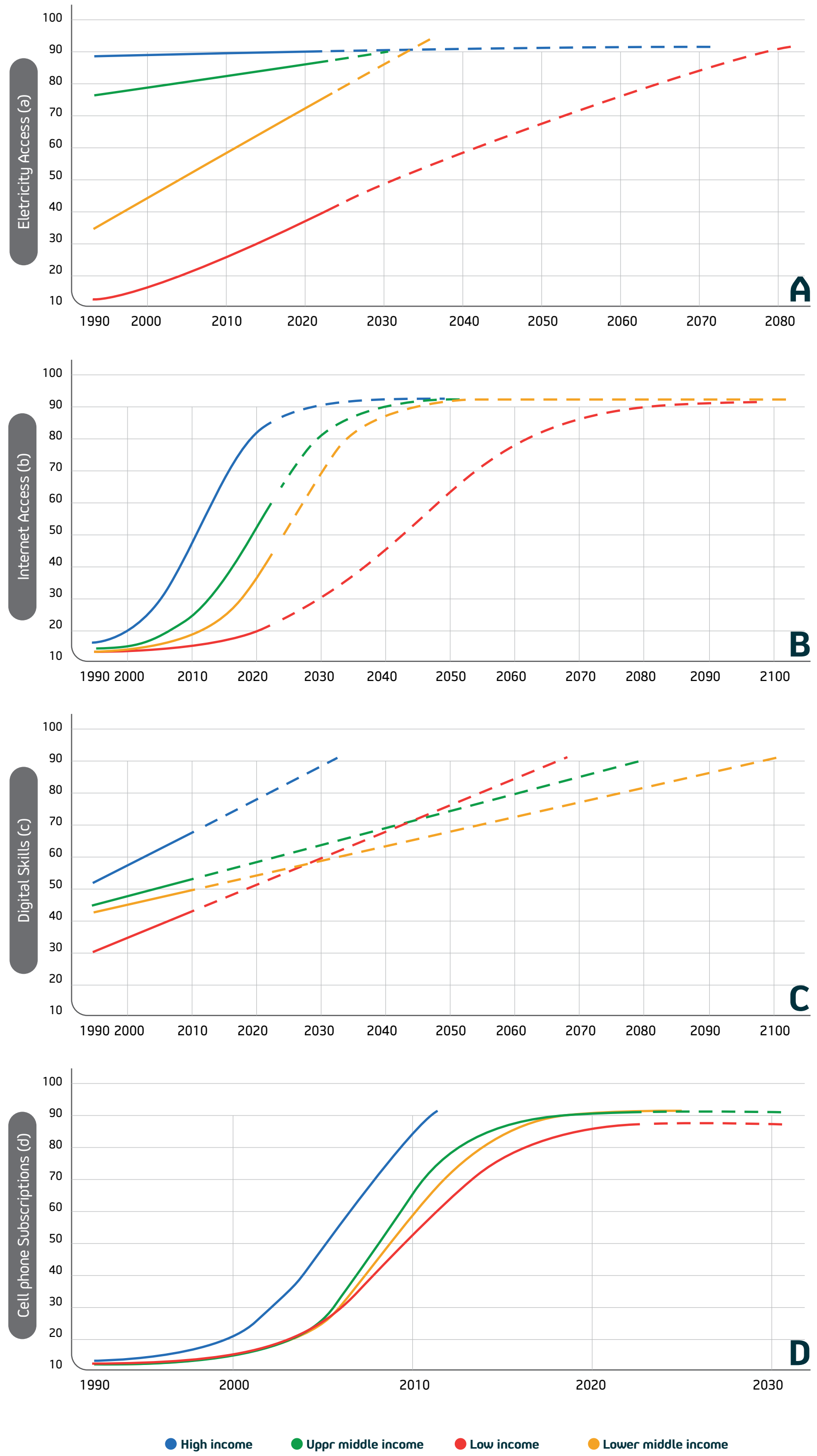
3.3 Enablers

3.3.1. Infrastructure and Resources Adapted to Diverse Contexts

The implementation of Phygital Schools can be supported by a uniform or advanced technological infrastructure, but this is not essential. The starting point should be to recognize the reality of each school and each school district, identifying the available conditions (connectivity, devices, physical spaces, teaching materials, teacher proficiency levels), and planning the appropriate implementation pathways for each context (CIEB, 2024; Wasserman et al., 2025).

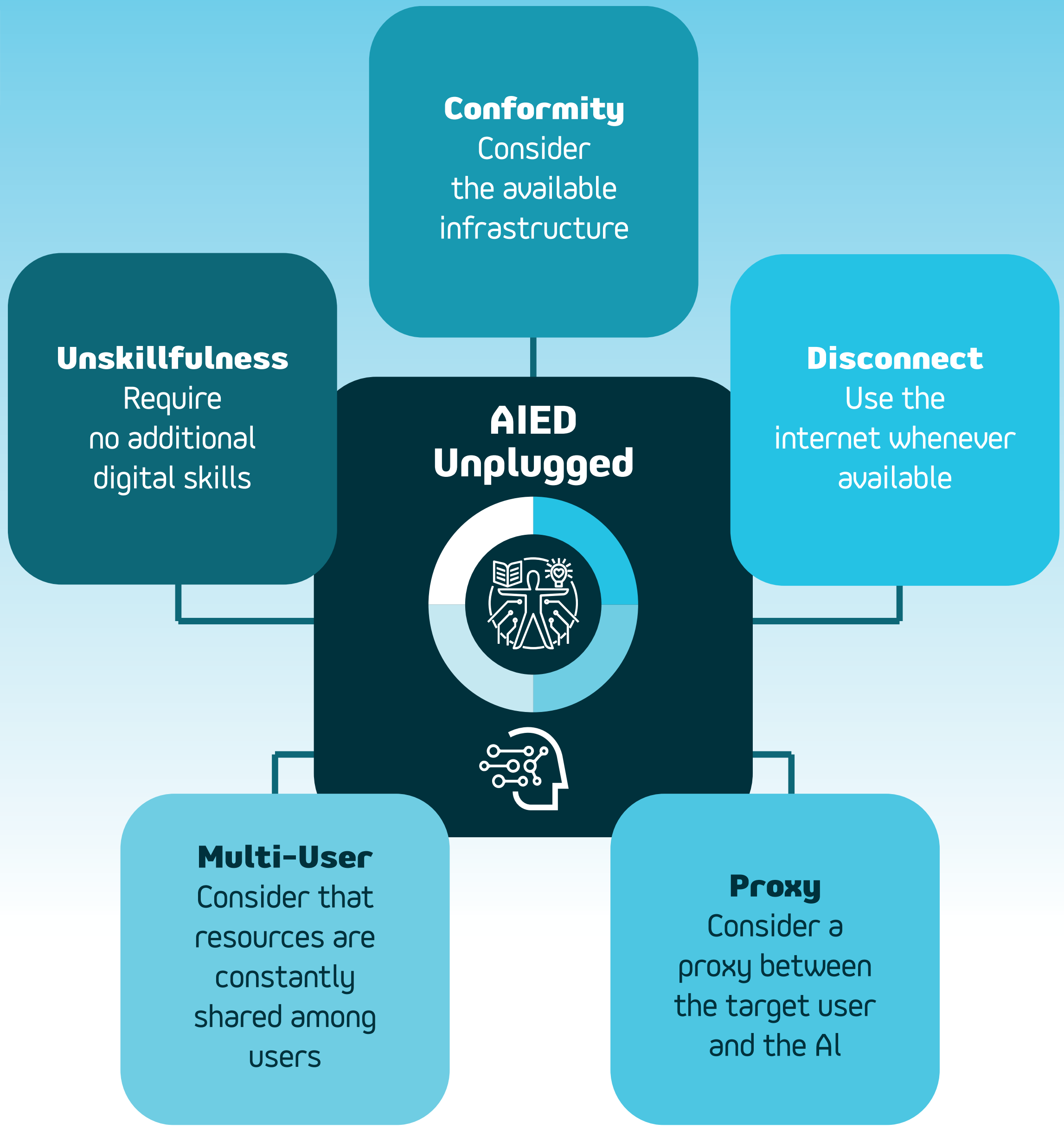
Opportunities for learning automation and augmentation exist in both low-resource and high-resource contexts, although they may require adaptations. High-resource contexts can support the use of adaptive learning platforms, Intelligent Tutoring Systems, pedagogical dashboards, simulators, and interactive environments that expand the possibilities for individualized support and the enhanced skills. On the other hand, **low-resource contexts call for strategies based on the principles of Artificial Intelligence for Education Unplugged (AIED-U) (Isotani et al., 2023), which promote the development of skills related to computational thinking, data analysis, and algorithmic logic in accessible ways.** The concept, developed by the founders of the IA.Edu Institute, Seiji Isotani and Ig Ibert Bittencourt (Demerval et al., 2025), in collaboration with the UNESCO UNITWIN Chair on Artificial Intelligence Unplugged in Education, is designed to address the structural asymmetries of the Global South, where infrastructure heterogeneity across networks and territories is the rule, not the exception. In these contexts, conditioning the education about and with AI to technological availability would reproduce, in the field of education, the very inequalities it seeks to address.

The graph below illustrates the historical inequalities in access (to electricity, the internet, digital skills, and mobile phones), and projects how much time would be needed to achieve universal access across different income levels. Mobile phones are the exception, underscoring the importance of AI solutions that account for infrastructure realities in the Global South that are distinct from those of high-resource countries.



Source: Isotani et al, (2023).

Artificial Intelligence for Education Unplugged operates through analog pedagogical activities, predominantly offline solutions, multiple users sharing a single device, increased teacher mediation, simulations and investigative projects, as illustrated in the figure below. This approach ensures that educational innovation is not restricted to networks with greater availability or technological maturity.



The table below presents a matrix relating the level of resources available in educational networks (high or low) to distinct forms of AI use in education: automation and augmentation. This distinction is important because it shows that AI can play different roles within the educational system, according to the logic of automation or augmentation.

	Automation	Augmentation
High Resource	• Automated grading • Written work analysis • Attendance monitoring • Assisted material generation • Focus on educational management efficiency	• Intelligent educational systems • Adaptive and personalized platforms • Predictive analysis of dropout risk • Pedagogical dashboards for continuous monitoring
Low Resource	• Basic data collection and organization systems • Tools to support instructional planning • Use of AI in departments of education	• Computer-free computational thinking activities • Data analysis and algorithmic logic through analog activities • Investigative projects

The matrix also highlights that AI-based educational strategies must account for infrastructure inequalities within educational systems. In high-resource settings, it is possible to combine administrative automation with advanced pedagogical augmentation tools. However, in low-resource settings, where connectivity, devices, or digital infrastructure are limited, it is necessary to adopt approaches adapted to the local reality.

This is where the concept of AIED Unplugged comes into play. **Rather than assuming that educational innovation necessarily depends on sophisticated digital technologies, AIED Unplugged proposes exploring the principles of Artificial Intelligence and computational thinking through analog, investigative activities based on data generated by the students themselves. Thus, even in environments with limited technological resources, it is possible to develop AI-related skills, such as data analysis, algorithmic logic, and computational reasoning.** This way, AIED Unplugged expands the scope of pedagogical augmentation in low-resource contexts, ensuring that educational innovation does not depend exclusively on advanced technological infrastructure, and can emerge from pedagogical creativity and the mobilization of accessible educational practices..

3.3.2. Responsible Regulation of AI for Learning

The debate over the regulation of Artificial Intelligence in education has been happening for years in Brazil. In 2026, the Ministry of Education (MEC) published the Framework for the Responsible Development and Use of Artificial Intelligence in Education. The document presents ethical, pedagogical, and technical guidelines aimed at the responsible integration of AI into educational systems, reaffirming the centrality of the pedagogical project, the need for meaningful human oversight in decision-making processes, and the commitment to promoting educational equity and inclusion.

The National Education Council has been developing specific guidelines for the use of AI in basic and higher education, signaling the progressive consolidation of an educational regulatory framework aimed at the responsible integration of these technologies. This movement points toward the development of public policies aimed at protecting rights and recommending precautions regarding AI (Carraturi, 2025).

Responsible regulation should guide the integration of AI to support teaching and educational management, while preserving educators' professional autonomy and the educational purpose of school practices. Another key pillar is a commitment to equity. Data-driven systems can reproduce or exacerbate historical patterns of exclusion if they are not continuously evaluated and adjusted. Regulation must establish parameters so that the development and implementation of technological solutions are geared toward reducing educational inequalities, ensuring that their benefits also reach contexts with greater social vulnerability and more limited infrastructure conditions.

By establishing guidelines, responsibilities, and usage criteria, regulation helps reduce uncertainty and support the informed adoption of Artificial Intelligence by school networks. Its effectiveness, however, depends on consistent and context-specific implementation processes. In this sense, countries in the Global South, such as Brazil, face the challenge of balancing simultaneous demands: promoting technological innovation at a pace compatible with global transformations while ensuring that its implementation occurs responsibly, based on evidence, and sensitive to the historical, social, and cultural realities of educational systems.

However, regulation should not hinder or impede technological advancement or experimentation with AI in education and society. This is a technology that needs to be learned, developed, and appropriated, as its presence will become ubiquitous in all dimensions of contemporary life. Brazil has unique conditions to lead this development in the Global South, provided that regulation does not create barriers to the country's technological and economic development..

3.4 Implementation

3.4.1. Systemic Approach and Transversal Transformation

Educational reforms fail more often due to implementation failures than to conceptual weaknesses (Matt Andrews, Building State Capability). Therefore, we believe that just as important as defining what we want for Brazilian education is to collectively build the conditions for this to happen. In the Brazilian context, this occurs when we start from concrete realities, taking into account diverse schools, their infrastructure, teaching capacities, socioeconomic and cultural contexts, as well as their priority educational challenges. Thus, we recognize that the Phygital School is not a single, uniform destination, but a horizon that each school or network follows from where it stands, with multiple paths toward improving learning.

This transversal transformation encompasses the continuous training of teachers and administrators in the pedagogical use of AI, curriculum alignment, the development of school cultures that value data analysis and evidence-based decision-making, the creation of monitoring and evaluation mechanisms that allow for continuous adjustments, and the promotion of collaborative spaces among education professionals within and across school systems, but is not limited to these aspects. It also depends on coordination among all stakeholders—students, families, administrators, department staff, third-sector partners, and academia—to ensure consistency between rhetoric and practice and with other ongoing policies.

AI initiatives that do not align with current curriculum standards, teacher training programs, or digital inclusion policies risk creating confusion, duplication, and institutional burnout. The implementation of the Phygital School is, therefore, an iterative, adaptive process built on shared responsibility.

A fundamental element when considering the implementation of any educational strategy is the **Science of Implementation**. It is not enough to define good policies, produce robust evidence, or develop promising technologies; it is necessary to understand how these solutions can be effectively adopted, adapted, and sustained in the real-world contexts of schools and school systems. The Science of Implementation provides methods and principles to bridge the gap between what we know works and what actually happens in classrooms, taking into account factors such as institutional capacities, organizational culture, teacher training, local conditions, and most importantly, the recognition that no solution design can anticipate unknown elements that may arise during the implementation process. By incorporating this perspective, educational strategies can cease to be merely conceptual proposals and become viable paths to systemic transformation.

3.4.2. Agile and Adaptive Implementation

Agile implementation recognizes that the implementation plan should not be definitive and unchangeable over time. Its advantage lies precisely in its incremental and iterative nature, in its flexibility, and in its ability to adapt to local realities as new learnings emerge. It therefore requires the creation of active listening mechanisms that allow for the incorporation of the perspectives of teachers, administrators, students, and families throughout the process.

In this sense, the implementation of complex educational policies, such as those related to the Phygital School, demands approaches that are more adaptive and sensitive to the context. **Strategies such as Problem-Driven Iterative Adaptation (PDIA) have gained prominence for promoting a lightweight, agile implementation focused on addressing real-world problems, allowing solutions to be developed, tested, and refined iteratively within the educational systems themselves. Instead of large-scale reforms designed centrally and implemented rigidly, PDIA values short cycles of experimentation, institutional learning, and continuous adjustments, strengthening local implementation capacities.** Within the Conceptual Framework for Phygital Schools, we believe that this path is more prudent, as it recognizes the complexity of educational systems and allows the school's digital transformation to occur in a progressive, contextualized, and sustainable manner.

It is also worth noting that the implementation of Artificial Intelligence policies at the service of Mastery Learning requires the coordinated action of multiple actors, each with specific and complementary responsibilities. This is not an initiative that can be led by a single sector or institution.

Federal, state, and local governments play a central role in creating the systemic conditions necessary for educational transformation. The federal government is responsible for establishing regulatory frameworks, curriculum guidelines, funding programs, and evaluation mechanisms at the national level. State and municipal departments are responsible for translating these guidelines into context-specific policies, training teaching and technical staff, and monitoring outcomes within the school systems under their jurisdiction.

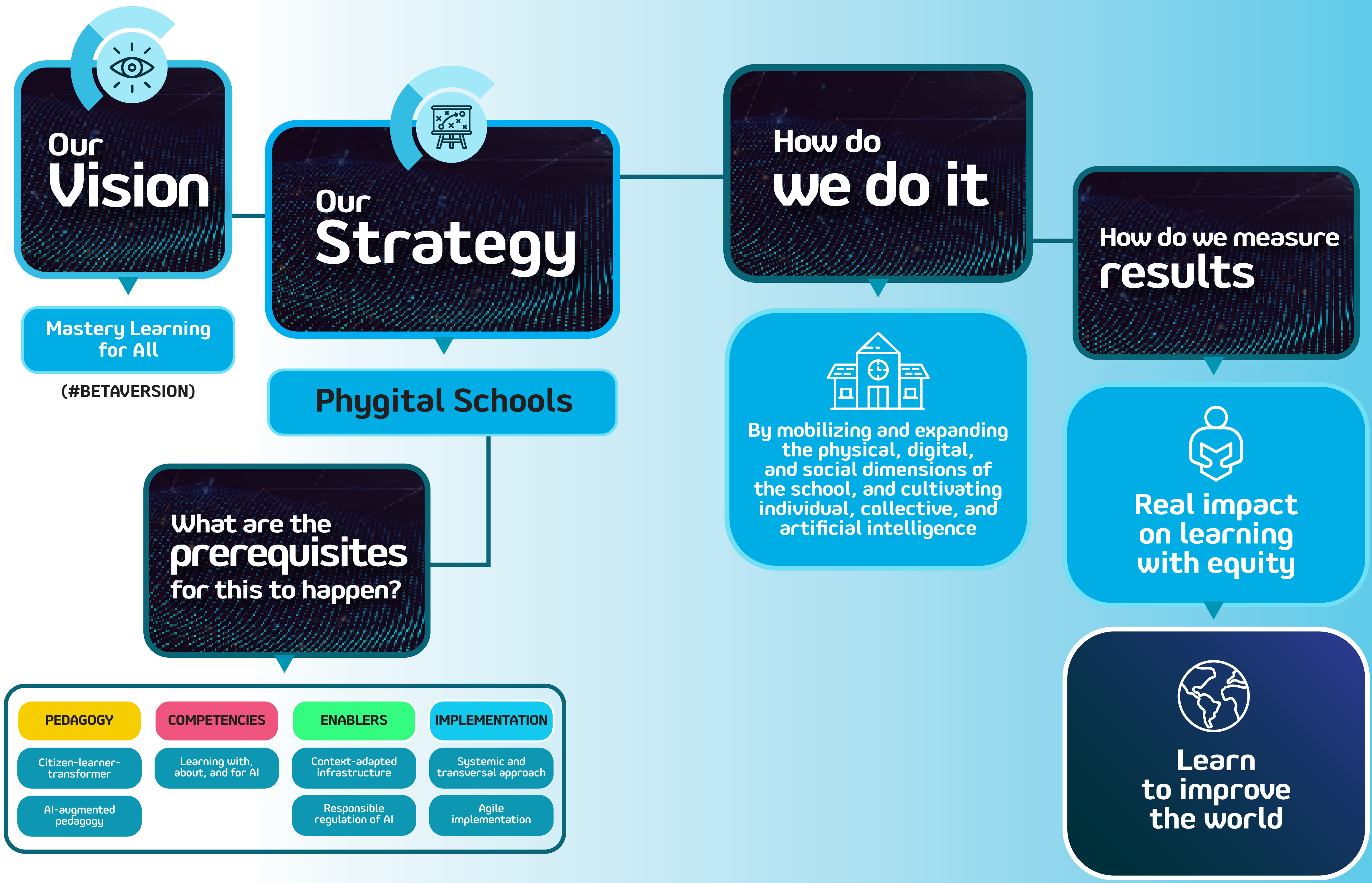
Research institutions and universities are responsible for producing applied knowledge on the use of AI in education, evaluating the impact of interventions, developing innovative, responsible, and context-specific pedagogical and technological solutions, and training the professionals who will implement the strategy in school systems. The cooperation between research and practice is a fundamental condition for the strategy to advance in an evidence-based manner.

The private sector and technology companies can contribute to the development of platforms and infrastructure capable of expanding schools' pedagogical possibilities. However, the participation of these actors must occur within a clear regulatory framework, guided by the public interest and the educational objectives defined by national policy.

Civil society organizations, foundations, and international bodies can contribute to strengthening the strategy through technical support, funding for innovative projects, and the dissemination of best practices. These institutions often act as catalysts for educational innovation, promoting experiments and independent evaluations that complement the public sector's efforts.

Finally, it is essential to recognize the role of students and their families as active participants in the process of educational transformation. Building an educational culture aligned with the phyigital society depends on the engagement of all stakeholders in the educational process, including students as protagonists and not merely recipients of the strategy..

4. Conceptual Framework



5.

Final thoughts

This Conceptual Framework outlines IA.Edu's position on how Artificial Intelligence can contribute to the transformation of Brazilian education, committed to Mastery Learning for all and implemented with respect for the country's diverse realities. This Conceptual Framework is a proposed path from Brazil for Brazil.

This document is a first draft of a living conceptual framework, which should be continuously revised and enriched based on evidence gathered in the field, dialogue with partners, and active listening to educational networks and school communities.
It is an invitation to co-construct quality public education for all.

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Avenida Alvaro Otacilio, 3.731
Jatiuca, Maceió (AL) - 57036-850 - Brasil
contato.iaedu@org.br

iaedu.org.br