








AIED Unplugged: Leapfrogging the Digital Divide to Reach the Underserved

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Abstract. Artificial Intelligence in Education (AIED) is a driving force to improve education. Nevertheless, policymakers from the Global South fear that AI will increase the digital divide and reduce the opportunities for students in these regions to thrive. To address this problem, we analyzed the past 30 years of data on four aspects of the digital divide. Then, based on these findings and a series of discussions with stakeholders (e.g., policymakers), we proposed the concept of *AIED Unplugged*. An approach to creating AI-based educational technologies that do not require changes in current school settings (e.g., infrastructure), do not rely on stable internet access, and do not ask for digital skills to use them. We applied this concept to redesign an education policy in Brazil to help students improve their writing skills. Our results show a reduction in time, cost and complexity to running the policy, and a positive impact on more than 500,000 students in 7,000 schools in the country.

Keywords: Global South · public policy · educational technology

1 The Global Movement Toward AI

Artificial Intelligence (AI) has gained considerable attention in the past years from the market, governments, and civil society. AI is revolutionizing our lives to the point that moving from point A to point B has become difficult without using an intelligent digital resource. According to Ng [3], AI can be considered the new electricity. He argues that intelligent technologies will transform every industry in the next several years, just as electricity did in 100 years.

In the context of Education, AI has been considered by several educational stakeholders as a driving force of transformation to build back better after the worldwide decrease in students' performances due to the extreme measures taken during the covid-19 pandemic [2]. In May 2019, ministers of state, hundreds of

government representatives, academic institutions, highly-regarded members of civil society, and the private sector met in Beijing. The result of this meeting was the Beijing Consensus on Artificial Intelligence in Education (AIED) which reaffirmed the commitment to the 2030 Agenda for SDG and provided recommendations to governments and other stakeholders in UNESCO's Members States [9]. Following the Beijing Consensus, in 2021, UNESCO released the AI and education guidance for policy-makers [10]. This guidebook highlighted three key policy questions that need system-wide responses to fully unleash the opportunities and mitigate the potential risks: How can AI be leveraged to enhance education? How can we ensure AI's ethical, inclusive, and equitable use in education? And How can education prepare humans to live and work with AI?

Although this movement has significantly promoted more AI innovations in Education, it also highlights the clear need for a more inclusive AIED. Since AI strongly depends on digital devices and internet connectivity, **AIED has become the new source of educational inequality**. Vinuesa and colleagues [12] show that although AI has positively impacted the world's 17 most pressing needs (also known, as Sustainable Development Goals - SDGs), it also has *negatively* impacted some SDGs, such as SDG 1 (End Poverty), SDG 4 (Quality Education), and SDG 10 (Reduce Inequality).

In this context, many policymakers from Global South countries are concerned that introducing AI in Education may bring potentially unequal benefits to students. High-income students with access to the internet and other digital resources will benefit the most from using AI. Meanwhile, low-income students lacking basic infrastructure (such as electricity) at home and school may observe a decrease in the opportunities to thrive, since most jobs they currently seek and are able to get will disappear because of AI and other digital technologies.

To face the challenge of offering the benefits of AI to underserved students without the need for high amounts of infrastructure investments, we propose a novel concept referred to as *AIED Unplugged*. In this work, we will discuss the fundamentals of this concept with an example developed together with policy-makers to bypass the digital divide and use of AI to impact millions of low-income students in Brazil that have been struggling to learn Portuguese.

2 AIED Divide

AI is the “new electricity”! And this can be considered terrible news for people living in the Global South, where low-income countries are mostly located. The fear that AI will increase the gap between high- and low-income countries comes from the fact that the current digital divide has already accelerated this process [1]. The digital divide can be defined as the readiness (in terms of attitudes, access, skills, usage, and culture) of people and society to benefit from technology [8]. High-income countries not only have the needed infrastructure to benefit from technology, but most of their citizens are motivated and have the digital skills to use technology, positively impacting their personal and professional activities.

To better understand the digital divide between high-, middle- and low-income countries across the years and identify potential opportunities to support public policies, in this work, we analyzed data from international organizations such as the World Bank¹ and the US National Center for Education Statistics². We collected 30 years of data and conducted a regression analysis to create a model considering two key elements of the digital divide: infrastructure (access to electricity, internet, and device: mobile phones) and digital skills. The results of our analysis are shown in Fig. 1. The model curve based on 30 years of collected data is shown as continuous lines and the expected results for the following years (i.e., prediction) are shown as dashed lines.

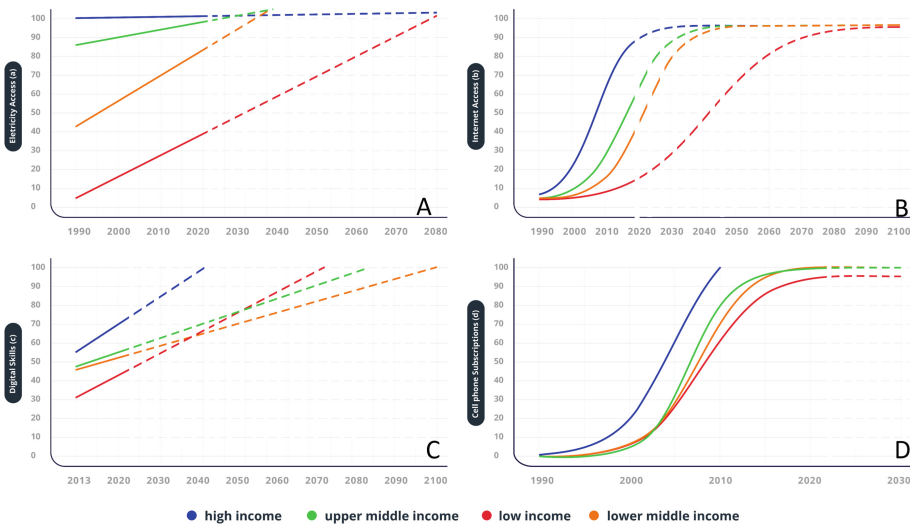


Fig. 1. Digital Divide among high-, middle- and low-income countries: (A) Electricity access; (B) Internet access/usage; (C) Digital Skills; (D) Cellphone access/subscription.

According to Fig. 1, great disparities exist between high-, middle- and low-income countries. For example, Fig. 1A shows that Only 40% of the population in low-income countries have access to electricity while high-income countries are very close to 100%. Furthermore, it will take over 50 years for low-income countries to reach the same level of access to electricity currently available in high- and upper-middle-income countries. The same pattern can be observed regarding internet access/usage and digital literacy as the regression models presented in Figs. 1B and 1C indicate that low-income countries will reach the same levels of high-income countries only after the year of 2100.

Furthermore, in the context of education, according to a policy brief from UNICEF published in 2021, it is estimated that 1.4 trillion dollars will be

¹ <https://data.worldbank.org/>.

² <https://nces.ed.gov/surveys/icils/>.

required in the coming decade to reduce the digital divide and enable students to benefit from technology during the learning process [13].

Although policymakers have responded to this threat, there are several digital divides, and they are continually changing. In this context, the challenge of benefiting from AI in Education is even higher since most research and applications of AI require internet connectivity and physical devices for all students (i.e., affordability). Affordability determines individual access to AI and abilities to participate fully in the AI revolution. The required infrastructure and skills to develop and use AIED applications restrict its potential benefits to locations with sufficient computing power, access to relevant internet bandwidth, and high levels of digital skill personnel. This is what we refer to as the **AIED Divide**.

The AIED Divide transcends geographic, socioeconomic, gender, and race boundaries. It demands temporal, material, mental, social, and cultural resources to enable the meaningful use of AIED solutions and promote better educational outcomes. Nevertheless, there is an important lesson the covid-19 pandemic brought to many fields, including AI and Education: we can build back better and restore opportunities for children and youth to gain the skills to build a more inclusive and sustainable society [7]. To do this, we need to reimagine our technology and its appropriation to promote a pedagogy of cooperation and solidarity, bringing to the discussion different stakeholders with complementary and even contradictory views to improve the world [10].

3 AIED Unplugged: Fundamentals

Although there is a nearly 100-year gap (see Fig. 1) hard to bridge the global north and south, it is possible to reimagine the future and bypass the various digital divide we face in the world. As a movement to build back better, we can promote more creative and innovative ways to create public policies that help the development and use of AI technologies to tackle the challenges of education and, thereby, reach minorities and marginalized communities such as migrants, underserved students, internally displaced people, refugees, imprisoned people, indigenous peoples, students with special rights (instead of special needs), people affected by natural disasters or wars, and so on. By facing the challenge of ensuring opportunities for quality learning for all, different approaches to thinking of AI in Education can be observed as potential ways of leapfrogging the AIED divide, for example, through the use of mobile solutions that are already accessible worldwide, including in low-income countries as shown in Fig. 1D).

Despite the opportunities for innovations to address the problems of the AIED divide, a literature review carried out by Nye [4] shows that very few Intelligent tutoring systems and other AI technologies for education have been developed to address the challenges of the developing world. According to Nye, most AIED technologies require digital skills, do not allow hardware sharing, and cannot be used on low-cost mobile devices. These problems persist throughout the years, as indicated by a more recent report from UNESCO [5].

Inspired to innovate in the field, since 2017 we have been conducting a series of workshops, interviews, meetings and policy design activities together with

policymakers, teachers, students and other stakeholders in the field of education in Brazil. We have been defining, testing, and refining key elements that are fundamental to creating education policies with the support of AI technologies and reaching communities that are usually left behind due to the limitations described in the section *AIED Divide*.

As a result, we proposed the concept of *AIED Unplugged*. The term “unplugged” refers to the fact that in our context: (i) AI solutions should not constantly access the internet; and (ii) the target users (e.g., students) lack digital skills and access to resources (hardware, internet, etc.) being disconnected from the digital world [4]. AIED Unplugged extends and operationalizes the ideas of Juggad innovations [6] in the field of AI in Education. Juggad innovation is a concept that originated in India and focused on finding creative and accessible solutions to problems. Two important elements of Juggad innovation are *resourcefulness*, the ability to find creative solutions using the resources that are already available in a particular setting; and *simplicity*, the focus on creating solutions that are easy to use (not requiring extensive training of users) and maintain. Considering that, the key elements of the **AIED Unplugged** are:

- **Conformity.** Rather than disrupting the educational environment, requiring extensive training and changes in infrastructure, the AI-based solution should be developed considering the available infrastructure, resources and pedagogical practices.
- **Disconnect.** The AI-based solution should not require internet access to work. Conversely, it should use the internet whenever available to update AI models, collect data and provide user feedback.
- **Proxy.** We cannot assume that target users (e.g., students) own hardware to access an AI-based solution or have the skills to create a login account in a system. Thus, The AI-based solution may consider a proxy between the target user and the AI solution.
- **Multi-user.** AI-based solutions should be created considering that hardware and software are constantly shared among users and proxies. Thus, any solution that requires users to log in or need to record individual interactions to update the AI models (e.g., the user model in an intelligent tutoring system) will most likely not work in our context.
- **Unskillfulness.** AI-based solutions should be created to be simple enough that do not require additional digital skills other than what most people with access to a cellphone already possess (such as clicking an icon, taking a picture, sending/writing a message, making calls, etc.).

The objective of AIED Unplugged is to transform the way we think, design, build, and use intelligent educational technologies to overcome the lack of infrastructure, digital skills and other aspects of the AIED divide that are prevalent in lower-middle- and low-income countries. The ultimate goal of AIED Unplugged is to leapfrog the divide and use AI technology to benefit underserved students and communities. Technology leapfrogging, following the AIED Unplugged approach, is seen as a way to rapidly increase the pace of a country’s economic development

and thereby reduce the gap between developed and developing nations. Indeed, Leapfrogging experiences have been successfully applied in several countries of the Global South for different purposes, including education [11].

4 Redesigning an Education Policy with AIED Unplugged

To carry out a policy for national assessment and identify the level of writing skills of K-12 students in Brazil, the federal government requests students in public schools to write essays. These essays are written on a piece of paper and are physically mailed to a center that is responsible for digitalizing and distributing the essays for peer review. This center is also responsible for mailing back the results of these assessments back to schools and students. The whole process takes about four months to complete and cannot be used for formative assessments (that would help students to learn). According to policymakers involved in this policy, the status-quo solution to carry out the national assessment for writing skills is high-cost, time-consuming and complex due to: (i) the need for expensive industrial scanners; (ii) the use of mail services that need to reach places with limited access (e.g., schools in the middle of the Amazon forest or in semi-arid regions with no roads); (iii) the necessity of paying people to evaluate the essays; (iv) the requirement of training to evaluate the essays using a specific rubric; and (v) the need for controlling the peer review process.

Using the concept of AIED Unplugged in this work we aimed at improving the writing skills of K-12 students without increasing the burden on teachers and considering the social inequalities of the country, which means a high number of schools without internet access and digital devices, a high rate of students and teachers with low or intermediate levels of digital skills, lack of qualified/trained teachers in many vulnerable schools (especially in North and Northeast of Brazil), and lack of pedagogical practices that focus on provide formative feedback on writing essays.

To follow the key elements of the AIED Unplugged (vide Sect. 3) we did not require any change in the school settings and infrastructure nor asked teachers and students to learn new digital skills. We create an AI application for mobile devices that allows the digitalization, correction, and pedagogical diagnosis of handwritten texts in Portuguese. The overall flow of the technology is shown in Fig. 2. The students' essays are obtained from sheets of paper with QR codes and markings (Fig. 2-1). The teacher acts as a proxy of students using the mobile application, which has a simple menu automatically populated with students' names in the class (Fig. 2-2), and takes a photo of their essays. The photos remain on the mobile device and are uploaded to a server when an internet connection is available. When the photo is uploaded, the server uses Computer Vision to make the segmentation of the image into Portuguese words (Fig. 2-3 to Fig. 2-5). The current accuracy of this process is between 92% to 95%. Then, we use Natural Language Processing to automatically assess the essays according to a specific rubric (Fig. 2-6). To provide feedback for students and support for

teachers we developed paper-based dashboards that can be printed to work with students (Fig. 2-7). Finally, we are developing an unplugged intelligent tutoring system to provide paper-based feedback to students and recommend following educational resources to improve writing skills Fig. 2-8).

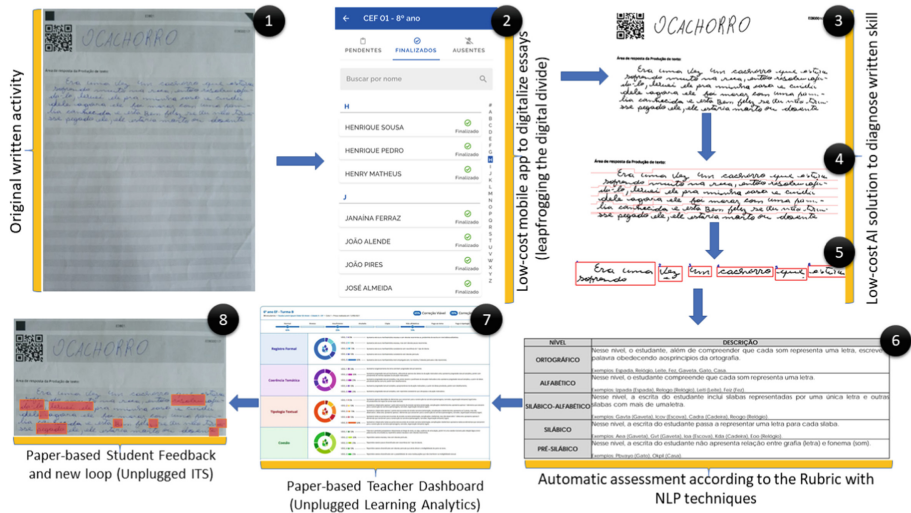


Fig. 2. An AI technology created using the concept of AIED Unplugged

We have been using this technology since 2022. To date, more than 1.5 million essays produced by over 500,000 k-12 students in 7,000 different schools in Brazil have been assessed. The maximum time from the beginning of the process to the end of it is 72 h. This means that students receive formative feedback on their essays in less than three days. This is a radical change compared to the previous solution that required four months to complete the same task as discussed at the beginning of this section. The costs and complexity of assessing essays nationwide were also reduced. Furthermore, as a result of this work, we have created the largest dataset³ of essays written in Brazilian Portuguese with their respective transcripts.

Due to the success of our work in completely redesigning the implementation of a policy, the Brazilian Ministry of Education and the World Bank worked together to pass a decree creating the Brazilian Policy of Learning Recovery in Basic Education⁴ which aims to encourage the development and use of AIED Unplugged-based technologies to help improve current practices that guarantee quality and equity in education.

Based on this experience, we intend to further explore and better conceptualize the definition of AIED Unplugged. We want to enable the design of policies

³ This dataset will be released freely to the public in 2023–2024.
⁴ http://www.planalto.gov.br/ccivil_03/_ato2019-2022/2022/decreto/D11079.htm.

that use AI technologies to bypass the problem of the AIED Divide and extend the benefits of AI to those who do not have access to technology. Particularly for this policy, our future work will extend the concept of AIED Unplugged to create intelligent tutoring systems that can work in multi-user settings, with multiple learner models running simultaneously, and using a paper-based interface where hints and feedback are given to a proxy (e.g., a teacher) who will then adapt its practices to improve students' learning experiences.

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