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Proof of Concept Teaching for 21st Century Digital Literacy in Portugal: a Pedagogical Approach Towards a New Educational Model

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Abstract. This paper addresses an analysis of contemporary, structured, and connected pedagogical approaches to the teaching of digital proficiency/fluency in 21st-century digital literacy. We present a proof of concept and epistemological valorisation of digital literacy previously underestimated. This epistemological valorisation focuses on teaching digital literacy through understanding how teachers work - pedagogical planning, teacher training, syllabus design, practical work - enabling us to train technology producers instead of passive technology consumers, to enable agents instead of clients. The term “digital” will refer to 21st-century digital literacy. To “think digital” will refer to the mental process carried out by digital natives when conducting operations involving ICT - as their native language and framework. The pedagogical background is paramount to the structures underlying teaching of 21st-century digital literacy, characterised by its disruptive building process achieved through the acknowledgement of epistemological foundations. High school teaching of 21st century digital literacy is by no means at ground zero. The fundamental concepts to be conveyed remain the same: electric coding, input and output devices, memories, processors and transistors – the process/system is just faster and smaller. The development of a proof of concept was built according to a DSR framework, in an iterative way, giving evidence of architecture configuration, an asset of information, of tools, procedures, and attitudes.

Keywords: Pedagogical architecture, digital teaching, digital, pedagogical communication paradigm

1. Context

The former pedagogical approach to the digital society provided high school students with 3 separate stages: electricity, electronics, and coding. Our pedagogical architecture

proposal seeks to realign the pedagogical approach to 21st century digital literacy [1] in high school. Learning should be contemporary, structured, and integrate pedagogical structures that introduce concepts, technologies, coding languages, etc. The teaching of digital fluency ought to intervene in three different domains: learning spaces, what to teach and how to teach it, and feedback structures. To teach how to be “digital” would be to teach digital fluency – beyond digital usage or digital literacy. Teaching digital fluency in the 21st century requires understanding how technological components work, where they can work and why - not only what they are, or how to use them as mere tools.

This new alignment assumes a heuristic knowledge of the technology and its impact, over mechanical repetitive processes. These might be productive, but will hardly generate knowledge or digital literacy, let alone fluency. The simple development of mechanical skills falls short of the ambitions set for 21st century education. The tacit assumption that the intense / repetitive use of a tool or a method could be a valid pedagogical approach to ICT has proven not to result in digital empowerment. Hence, new strategies and pedagogical approaches are necessary to maintain a connection between users and their perception of how it works, steering them towards real life problem-solving skills. Students must be immersed in experimentation, in construction, and to be able to build their own knowledge using previous stages of acquired knowledge. This pedagogical approach addresses a conceptual redefinition of the learning context and the learning environment - this early stage of the iterative methodology will be described later. This first stage provides proof of concept for the original project [2]. The proposal is originally based on the perception of how 21st century digital skills are taught in high school – the distance between using and functioning is increasingly high.

A computational device can automate processes, but it does not and will not automatise learning. Pedagogy lies not in the computational device nor in its use. Despite an abundant proliferation of various computer support technologies in education, Portugal faces a lack of pedagogical reflection to sustain such proliferation. Despite the introduction of technology in the national education system, and despite the internet being available since the 1980s, most school crystallised in a unidirectional pattern of education: instructions are directed to students lined up in traditional spaces, facing a lecturer-style teacher who replicates concepts, teaching the same to everyone. The introduction of technology did not bring a much-needed disruption to this instructional pattern. Nor did the introduction of psychology techniques or of active methodologies that were only a panoply of platforms or ‘apps’. We should point out that the proliferation of computer platforms in education that resulted from the general demand for access to digital communications, for any and all purposes, burdened the schools’ administrations in such a way that it reallocated financial resources due to

investigation and innovative work, to “feed” administrative requirements. Both focus and educational “energy” steered away from innovation towards administration.

The existence/acquisition of technology is not, contrary to common knowledge, tantamount to innovation or modernisation in secondary education levels. Nor does it lead to a quality education, or a more sustainable organisation. Misguided use of digital hardware and software can be damaging to an organisation should the volume of technological investment not generate knowledge, innovation, or disruption – the lack of epistemological values will be detrimental. Thus, we seek to contribute to an educational enterprise that is reflexive and set on epistemological values, and on contemporary pedagogical approaches that will incorporate the grounds, structures, and development of the conditions to the adequate teaching of 21st century digital literacy.

This pedagogical approach results from identifying the need to reduce the gap between the use of digital tools and the awareness of how they work. This led to the questioning of how to empower students for digital fluency. Should it be through digital skills, or through the improvement of digital proficiency and awareness?

For clarification, when using the term “digital” we refer to the pedagogical architecture being proposed. Terms such as 'electronic platform', 'computers', 'robotics', 'ICT', 'digital application', 'digital tools', 'platforms', 'learning platforms', 'new technologies', Internet, informatics, etc., are often indistinctly used, though they are not interchangeable. Thus, the term “digital” as a noun rather than as an adjective, refers to and includes this entire value chain. “Digital” is assumed as a concept including the spectrum of hardware devices, software, ‘machine learning’, IoT (Internet of Things), Industry 4.0 or even 'Artificial Intelligence'. It includes, in addition to ‘System and Communications Hardware and Software’, applications of the educational processes it supports, as well as the representation of its relationships with humans. Taking “digital” as a noun in education is also the recognition that more discussion is needed amongst educational experts regarding the ambiguity of the lexicon. “Digital” refers to digital literacy/fluency - the ability to function in the digital world as a native, fluent in the language, capable of using the tools, sufficiently skilled to function with hardware, software, languages, and technologies, and able to create innovation and knowledge.

1.1. Literature

The democratisation of ICT in Portuguese education was always based on national government programmes, consistently introduced in public schools. That first programme – *Minerva* (1985-1995) – was introduced by the Ministry of Education (ME) and overseen by the Planning and Studies Office and the Department of Programming and Financial Management. *Minerva* was developed in articulation with higher education institutions. Programme *Nónio Século XXI* (1996-2002) sought not only to integrate ICT, but also to enforce a series of measures to redesign the national

educational system, stimulating new pedagogical practices. The *UARTE* (1997 – 2003) project, supervised by the Ministry of Science and Technology, sought to provide Internet access to all national primary and secondary, equipping school libraries with a computer and Internet connections. In 2005, the ME created EDUTIC unit as part of the Information and Evaluation Office for the Education System. That same year, all the competences exercised by EDUTIC were transferred to the Computers, Networks, and Internet at School Mission Team. The purpose was to install computers, networks, and Internet at School Mission Team. The purpose was to install computers, networks, and *School Internet* – access to the internet in school facilities. The unit designed, developed, implemented, and evaluated mobilising and integrating initiatives in the use computers in the teaching and learning processes. The latest governmental programme for ICT and digital literacy - *Technological Plan for Education (PTE)* began in 2007, and sought school modernisation to create *in situ* spaces of interactivity and knowledge transfer. This was the first programme that focused on the certification of the digital skills of education agents, and on preparing children and young people for the knowledge society. This programme is still active in Portuguese public schools, focusing on the upkeeping and updating of technological assets (Fig.1).

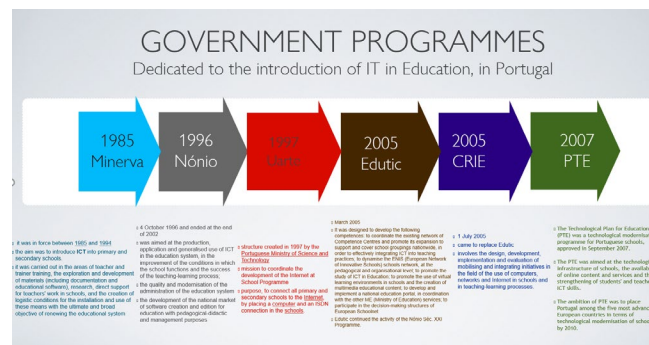


Fig. 1: Temporal introduction of Portuguese digital governmental programmes or education [3]

Since 1985, we can identify three differentiating moments of intervention: Introducing computers at the school (*Minerva* and *Nónio*); Bringing schools on-line – internet connectivity at school facilities (*UARTE*); Hardware maintenance (*PTE*). None of the aforementioned government programmes presented a pedagogical axis, a vision, or a structuring pedagogical design for a true systemic, global and transformational model. Thus, it is necessary to revisit the pedagogical context of continuity and adaptability – how did schools keep up with the EU digital transformation Agenda? [4]. Thus, it is an opportunity to implement the concept of the digital literacy instead of technological skills (an upgrade), and digital literacy instead of mechanical digital skills. Should literacy be set as an educational objective, the particularities of the “digital”

should be analysed: how it appeared; how it was built; why was it built; what difficulties were overcome; what successes, failures, challenges, and evolution stages were overcome. Challenges set for students should encourage reflection on their relationship with the digital world and digital knowledge. The inclusion of the relationship between students and the digital world acknowledges the value of a cultural asset common to the communication paradigm [5], information assets, tangible pedagogical assets, and culturally accepted procedures and attitudes [6]. Our pedagogical architecture proposal recommends a feedback structure, following the concepts of John Hattie [7], Paul Black and Dylan William [8], that, deprived of judgement or assessment, seeks to provide support and guidance to students and to the community. These support and guidance functions have a signalling function to support the capture of meanings, so that the action of exploring can make sense within such an architecture. The feedback structure, though sometimes not explicit in its action, is set to underpin verification and improvement.

The digital society influenced everyday life from the 1980s when the computer evolved into its domestic form as the 'Personal Computer' (PC). The computational devices' epistemological foundations led to the need for automated support of human operations (initially only for calculus), and led to a use of automation in the information processing, with concerns about integration and recording of the operations properties considered relevant, to extract valuable information, to extract knowledge. In this evolution the need to put these machines 'talking' with each other also arises. It is through the use of this functionality that a new dimension such as the internet emerges. It is through this potential that phenomena with both positive impacts and negative impacts for humanity are born. The on-going digital impact also increases the demand for digitally literate citizens. Citizens should be able to use digital tools in a wide range of circumstances, and above all, able to adapt flexibly to ever-changing environments and ecosystems, where there are clearly social implications. From a social and cultural perspective, "digital" awareness offers opportunities to transform, create, and innovate. It is in this balance, between knowledge and its interpretation, its questioning and its construction, that it is considered relevant to contemplate teaching digital skills. "Digital", in this architecture, means deepening the dimension of digital literacy – the relationship with the digital world and 21st century digital skills and its awareness begins in the cradle.

2. Research Plan and Methods

The project that originated this architecture involves the construction of an artefact – a construction for a certain purpose. The purpose of the construction of this artefact is to develop a pedagogical process for teaching 21st century digital literacy – by intervening

in the pedagogical components, the teaching/learning environment of teachers' relationship with the praxis, and the learners' relationship with knowledge.

The methodology includes the following points: the creation of a new artefact – development and implementation to redesign practice to achieve the goal – to redesign the traditional pedagogical approach to digital training, shaped towards a true process of creating digital actors – digitally fluent and proficient. The artefact results from inputs from literature and research field work. Thus, we believe it stands before a typical 'DSR' research scenario [9]. The construction was developed iteratively, and each iteration was evaluated. The re-evaluation of the problem should refine the quality of the design process, each iteration and so on. This building and evaluating cycle is also typical, and happens several times before the final artefact design is considered completed [10]. DSR can be seen as a realisation of three cycles closely related to research activities [11]. A relevance cycle initiates the DSR, in an iterative process with the application context, which not only provides the requirements for the research but also its 'inputs'. The rigor cycle iterates between the artifact design and the block that provides the knowledge for the project. This was the path followed by this project.

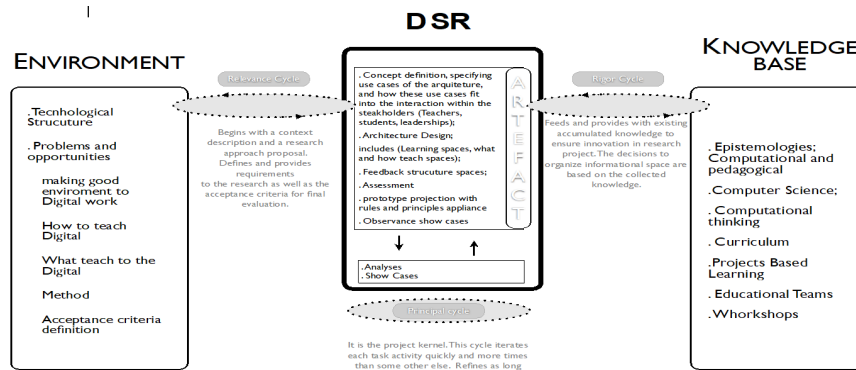


Fig 2: Methodological framework applied (adapted from Hevner & Chatterjee [11])

Figure 2 embodies the definitive representation of the methodological framework adopted in this research project. The three constituent blocks of the 'framework' stand out, and their adaptation to the reality of this project to the tasks that are part of its construction, as well as the iterative cycles that, along with the moments of evaluation, mark the whole dynamics of the project and promote its relevance and rigor. In a summary of the framework, the cycles represent the dynamics of the research that takes place in the context identified in the 'Environment' Block and receives the 'inputs' with contribution to innovation from the 'Knowledge Base' Block.

The 'environment' Block – clearly and precisely characterises the environmental element of this project, represented in this specific sector. It includes the needs and

requirements of the project, identifying in the educational environment the relevance in the following areas of application: i) Structure and culture of the organic units or schools, in relation to what is in the focus of the research project – the technological infrastructure made available to the community, as well as the way of teaching and learning digital literacy, and with the digital technologies; ii) Creation of favourable conditions for the smooth running of the implementation. It focuses on the process and on people, and on the conditions available; iii) The characterisation of the acceptance criteria will be revisited in the evaluation phase of the project to dictate or not its success. In an initial phase, from the teaching side, these criteria relate to the functional success of the implementation of the pilot demonstration case. The same happens on the learners' side, where it is relevant that they go further, autonomously.

The 'Design Science Research' Block – the activities of creating, designing, and recording the representation of the implementation proposed in this project. In this block, two groups of tasks are worked on: i) The production of a viable artefact – understood in our project in the form of 'construction' and identifying the constituent components for prescriptive implementation, as well as the new ideas sought that serve the intentional purpose of aligning the educational activity in and with digital technologies; ii) Justification and validation of the artefact – The demonstration activity is exercised through demonstration cases and seeks to affirm the viability of the prescription in its usefulness and in its explanation. These cases are produced in real environments – on a school floor and with information produced in the laboratory preparation.

The 'Knowledge Base' Block – stores the concepts on which the research is based. These concepts are obtained by collecting information from already developed, evaluated, and mature scientific work (theories, axioms, taxonomies, methods, etc.). It is composed of epistemological foundational work, from which more mature, substantiated and applied knowledge is derived. Some examples are the body of theoretical grounding of algorithmic thinking, the epistemological foundations of pedagogical paradigms or even from computer science principals. This block also includes information collected in the field, from workshops held at different times.

It is important that the elements described above and the iterative way in which the project progresses, strengthen the placement of the work in a 'Design Science' research paradigm. In the faithful execution of this way of research, it is also important that the identification of the iterative work cycles that operate between the blocks presented, make the final implementation presented stronger.

3. Learning Spaces: From a Classroom to a Digital lab

Physical spaces designed for the teaching and learning of ICT in secondary school have been the subject of study since the year 2000. There is a trend towards studying the

transition from the classroom to what are called learning spaces. Some examples: "Learning spaces" [12], "Learning spaces: involving teaching staff to improve pedagogy" [13] and the work "Designing learning spaces" [14]. These works highlight concerns in the interconnection between the physical design of spaces and how it may or may not have impact on the organisation of individuals, on their relationships, and on how teaching and learning take place. The proposal is to upgrade from a mere space to a learning environment.

Our proposal resorts to a teaching and learning space based on the organisational architecture of the inviting classroom project of the 'Future Classroom Lab' [15] - a work resulting from the iTEC project [16]. The configuration in AP_PDF is adapted, with the resources organised to ensure "digital" inception via the teaching and learning process and not to use digital tools as a means to an end – but as an end in itself.

This configuration adds resources that facilitate the connection to the particularities of the "digital", that allows us to deconstruct how they were built, why they were built, and that allows us to present students with the challenges for the construction of new digital solutions. It goes further: it addresses how challenges are being developed step by step, in a pedagogical analysis. Thus, we ensure that inputs on the construction of the space are aligned with educational literacy goals. We suggest the inclusion of some technological and computational equipment to support the afore-mentioned goals applied to the "digital" teaching. The following equipment should include: the 5 components of a PC (Power supply, Motherboard, processor, memories and disks - both Hard & SSD); PCs assembled exposed in their components; Soldering irons, solder, dupont connectors and resistors; Set of Sensors dedicated to educational objectives; Multimeter; SBC (Single Board Computers) with 4-core processors; SD Cards of at least 32 GB; LCD monitors, with multiple video inputs (HDMI, DVI and VGA); Wired and wireless keyboards; Wired and wireless mouse.

A way was found to provide the student with equipment and accountability using that equipment that includes kits with the last five items. Each student or group of students take responsibility for, unpack, check, use and pack up again after work. Although digital items are often designated as 'smart' ('smart watches'; 'smart phones'; 'smart cities'), it does not grant these digital technologies with "magical" powers nor does it make them entities, let alone thinking beings. In the learning space we advocate, it is also relevant to understand the value of each item that will support the pedagogical practice - how and when to place them and with which technology (hardware, software and settings) to pair it. These actions should be aligned with the transversal curriculum and have a yearly update. This will allow us to ensure that the classroom is a space of discovery, passion, and joy, see Figure 3 a and b. The technology supports the action, but the planning, the development, the questioning, and the execution of the educational act must also take part – likely a most significant one - in the pedagogical architecture

AP_PDF. Only when such premises are fulfilled and students are allowed to enter a space that complies with the patterns set to achieve digital and values students' relationship with knowledge can we grant due value to information, tangible, procedures, and behavioural assets.

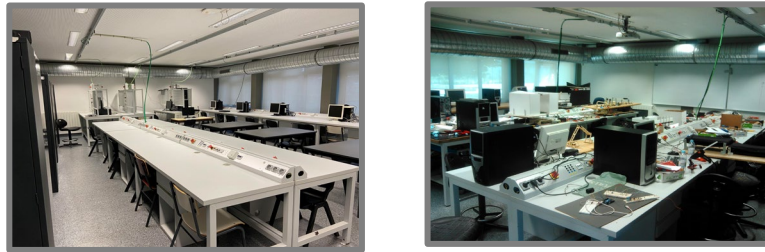


Fig. 3: a) Digital skills classroom and b): Digital immersion space displaying evidence of digital literacy challenges (Fontes Pereira de Melo high school in Porto, Portugal)

4. Educational structure

4.1. What to Teach and How to Teach It

The disruptive architectural space proposed above for the teaching of digital literacy, values conceptual particularities for student challenges, and combines epistemological justification in the design of the pedagogical innovation plan, in the learning spaces, in relationship with knowledge, and in the feedback iterations for improvement. The proposal we advocate identifies with the movements that propose to grant the “power” of computing and digital production to all those interested (digital democracy) [16]. Syllabus and digital base contents should be designed for contemporary teaching and learning spaces, according to AP_PDF, respecting differentiation, and the singular identity of students. The contents and intellectual challenges are aimed at establishing a relationship with knowledge in ten broad, in-depth points, considered structuring in the relationship with Digital knowledge, namely: (AL) Algorithm; (CS) Computational systems; (MLT) Multimedia; (DIK) Data, information, and knowledge; (DD) Design and Development; (EUT) Effective Use of Tools; (CN) Computer Networks; (P) Programming; (SP) Safety and Protection; (IT) Impact of Technology.

This element of the architecture referring to the relationship with knowledge is designed and adapted to 12 years of compulsory education in Portugal. The first years focus mainly on development of dexterity in digital skills, which helps students to understand how those digital devices, such as a keyboard, work, and what happens

when a key is pressed and a letter or a symbol appears on the screen. As students advance in their schooling it will be necessary to introduce the concepts mentioned above. These paths through the pedagogical space of architecture, about what to teach include work in the dimensions of physical devices, in the dimensions of the logical and abstract components, and in the dimensions of their relationships with humans.

Regarding teaching methodologies, we propose conceptual adaptable spaces. Considering that digital literacy is a relatively recent subject in the curriculum, there is little specific scientific-pedagogical work able to illustrate teaching approaches. Given that lack of in-depth pedagogical studies in the area, we propose ten pedagogical principles for teaching digital literacy: Leading with concepts; Leading with error; Real-world activities; Collaborative work; Priority in reading and code exploration; Creation of projects; Physical connections (Hands on); Dismantling misconceptions; Writing texts; Adding variety to activities and challenges.

4.2. The Equipment - Designed to Teach

In this space of architecture, we should mention that a recent piece of equipment has been made available to the educational community - a trend for those who want to develop the relationship with digital knowledge [17]. This equipment is referred to as SBC (Single Board Computer), and is very similar to regular computers. It has, however, a significant physical difference, as this computer has the physical dimensions of a credit card. This equipment allows internet navigation, sending an email, or using any MS Office tool such as a word processor. It is possible to go further as the equipment allows establishing a physical link to electrical or electronic devices, via forty metallic pins included on the SBC board. The device can be programmed to provide or receive electrical impulses. This opens a universe of computational and construction possibilities not available on other desktop, laptop, or tablet computational devices. The low cost (around 70€) device was designed from scratch to teach digital production to youngsters. The SBC works as desktop or laptop, runs on a free and open operating system, and uses a memory card like those in digital cameras or mobile phones. A 'USB' charger of a mobile phone can power the SBC, it can be connected to a 'USB' mouse and keyboard and to a TV or monitor desktop. At school, this equipment can be an asset to teaching and learning, coding, and can help in dozens of other multi-disciplinary activities like science and music, for example.

To validate the viability of the digital literacy pedagogical architecture proposed, we designed and implemented a workshop for teacher training at the Porto Polytechnic Faculty of Education. The workshop design included: the reasons behind the relevance of the workshop (disruption); the target-audience; goals; contents; methods; and assessment. The workshop produced meaningful results – a multitude of strategies to the discovery and implementation of pedagogical approaches.

5. Conclusions

The paper begins with a clarification of the term “digital” to seek broad-acceptance terminology and to dismiss ambiguity. The proposed pedagogical architecture uses dedicated equipment designed for teaching, pedagogical strategies in syntony with prior epistemological assertions, empirical classroom experience in the creation of activities, curriculums mapping, plans, and support materials for teaching digital literacy.

The new ICT classroom proposed is now designed for teaching digital literacy. The current agenda for teaching digital literacy is embodied in a digital transformation policy that seeks greater digital empowerment. This digital empowerment should be achievable by combining digital skills with digital literacy to create a conscious relationship with the digital world. The AP_PDF addresses digital literacy by trying to deepen digital proficiency and awareness by teaching how technology works and not simply how to make use of it.

A disruptive pedagogical architecture might be the solution to achieve the goals set for 21st century digital literacy and break the patterns of traditional secondary education in Portugal. Our approach analysed current pedagogical trends and the contemporary pedagogical paradigm on digital literacy teaching tools and methods. The former paradigm is based on prior learning digital skills as instruments, procedures and attitudes culturally and contextually accepted. We have also analysed how digital literacy training follows a different path as it respects the relationship between form and function of the digital skills, in the teaching and learning process. Disruption of the paradigm emerged on the first stage of the design framework, which revealed that intensive repeated usage does not create knowledge, nor new digital assets, regardless of how new forms of training are adopted, or even how correct they are. Thus, we can assume this as an opportunity to propose the use of the term “digital” as a replacement to ICT, training for digital literacies instead of for digital skills. This opportunity is relevant in primary and secondary education. Considering literacy as an educational objective, the particularities of digital literacy must be considered - how digital reality appeared and how it was built, why was it built, what difficulties it had to assert itself, its successes and failure, challenges and evolution that have taken place. The paradigm disruption for digital literacy can be conveyed from early education by designing adequate learning environments for digital awareness, pedagogical methodologies, and ‘feedback’ structures that ensure that trial and error are developed in the process.

This pedagogical architecture was designed to generate disruption in the Portuguese ITC teaching culture and induce the migration to the teaching of digital literacy. Digital empowerment requires training students to become digital entrepreneurs instead of digital consumers. By providing disruption in the teaching and learning environments, inducing diversity, nurturing experimentation within the respect for epistemology, our

pedagogical architecture proposal for digital literacy education can foster meaningful relationships with the digital society, to enable awareness of both concepts and tools, and a conscious relationship with digital knowledge. Though disruptive indeed, this is a path likely to aggregate digital awareness, technological awareness, and combine both with digital skills to achieve digital literacy.

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