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Evidence-Based Integration and effective use of ICT and Generative AI in K-12 schools in Spain

May 2026

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Executive summary

"We should not be debating where technology is taking us, but where we are taking it".

Evarist Bartolo
Former Minister for Education and Employment in Malta

BACKGROUND AND EVIDENCE

Is Spain well positioned to harness the complementary potential of ICT and the new wave of AI-driven educational tools? The country has moved beyond the digital access phase, has a regulatory framework that recognises digital competence, and has significant investment underway. Turning these elements into real learning gains, however, depends on shifting the focus to the "how": closing persistent gaps in implementation, teacher training, and pedagogical use.

The evidence accumulated over previous waves of ICT in education is consistent on two points:

- **Personalisation works.** Interventions that use technology to tailor instruction to each pupil's learning level produce robust effects, typically between 0.1 and 0.5 standard deviations. By contrast, programmes that simply expand device access, with no specific pedagogical intent, show effects close to zero.
- **Purpose, guidance, and the right device matter.** Building on the previous point, technology only delivers academic gains when it comes with clear pedagogical intent and teacher mediation. The device also matters: using a desktop or laptop at school is associated with gains of up to 17 points in mathematics relative to no digital use, while unsupervised personal smartphone use is associated with drops of 11 points. And under current conditions of use, more time on technology translates into more learning only up to a point — beyond that threshold, returns turn negative.

The same evidence shows that well-integrated technology adds clear value in three specific dimensions:

1. **It extends reach** where structural conditions make teaching difficult — geographic barriers, shortages of qualified teachers, or logistical constraints — securing access to resources that would otherwise be unfeasible.
2. **It improves higher-order skills,** such as complex mathematical reasoning or problem-solving, when properly integrated.
3. **It supports students who need tailored attention,** especially when instruction and practice can adapt to differences in pace, skill profile, and support needs.

The emerging evidence on AI converges with these earlier learnings. The available causal studies, though still in their infancy, point in three promising directions for productive educational use:

- **Adaptive instruction with pedagogical safeguards** that preserve the student's cognitive effort.
- **Teacher-oriented AI,** which can act as a scaling technology for content production, planning, assessment, and communication, with proportionally greater benefits for less experienced teachers.
- **Large-scale educational analytics,** operating at the student level and deployable system-wide, which allow for the precise identification of critical intervention windows.

By contrast, the evidence warns against the use of generative AI without safeguards or supervision, particularly at younger ages, when executive functions and relational bonds are still developing.

These findings translate into three principles that guide the recommendations of this report. **First, teachers at the centre.** With adequate support, training, time and tools, AI can support teachers in lesson planning, feedback, formative assessment and the early detection of pupils at risk of falling behind or dropping out. **Second, integration must come with purpose, guidance and pedagogical design**: the evidence is consistent that technology delivers learning gains when it is introduced with clear intent, under teacher mediation, and embedded in a coherent pedagogical model. **Third, only once these conditions are met can technology be integrated gradually with pupils**: in primary education, with strong teacher mediation and a focus on consolidating foundational skills and digital literacy; in lower and upper secondary, with growing personalisation and progressive pupil agency.

Building on this evidence and these principles, two linked questions follow from these insights: which **enabling conditions** Spain must meet for technology to function as an effective complement, and in which **specific areas** — by educational stage and by actor — it can deliver real value for learning. The report's three phases respond to this dual agenda.

PHASE 1: ENABLING CONDITIONS

The report identifies three basic conditions Spain must meet to translate the evidence into practice.

Infrastructure and digital equity. Although the initial access phase can be considered complete, significant inequalities remain that limit the viability of the most effective interventions:

- Public schools lag 15 percentage points behind privately managed and charter schools in the availability of digital platforms.
- Differences in digital readiness between autonomous communities exceed 30 percentage points.
- 9.2% of households with children aged 6 to 17 do not have a computer, a proportion that rises to 23% in the lowest income quintile.

Teachers with time, access and capacity. Spanish teachers operate in an environment strained by administrative overload, the need to continuously adapt to curricular changes, and a deteriorating classroom climate. It is precisely in these three sources of stress that Spain stands above the OECD average, with gaps ranging from 13 to 24 percentage points, and with an average of 18 hours per week devoted to non-teaching tasks, primarily lesson preparation and grading (1.65 hours more than the EU average). These are also the areas in which AI appears to offer the greatest potential value for teachers:

- **Reduce planning time, lesson preparation, and administrative workload.** Large-scale representative surveys suggest meaningful time savings: a 2025 Gallup–Walton Family Foundation survey of 2,232 K-12 public school teachers in the United States found that teachers using AI weekly save an estimated 5.9 hours per week, and 81% report time savings on administrative support. In Spain, the National Office of Foresight and Strategy (2025) estimates that AI could free up to a full working day per week—time that could be redirected to teaching, professional development, or student support.
- **Scaling up feedback** to students and the teacher's own teaching practice.

AI adoption among Spanish secondary school teachers (35%) is close to the European average but constrained by a lack of training — cited by three out of four non-users as the main barrier — and concentrated on basic uses such as planning. The gap between stated training needs and training received is wider in AI than in any other area of professional development. The current Reference Framework (MRCDD), approved before the emergence of generative AI, does not include it as a specific competence. The bottleneck therefore lies in institutional support for teachers.

An institutional and regulatory framework that empowers without stifling. Spain has the basic regulatory elements in place (LOMLOE, MRCDD, AI Act) but lacks operational guidelines to advise schools on how to integrate generative AI, and a binding teacher certification system. International comparisons confirm that successful programmes are distinguished by the quality of implementation, not by regulatory ambition or scale of investment: an $850 million programme for adaptive AI textbooks in South Korea was reclassified as "supplementary material" after four months for lack of phased piloting and exclusion of teachers from the design process, while the models in Singapore and Estonia have been built over two and three decades of institutional layers, with teachers at the centre of the process.

PHASE 2: INTEGRATION INTO LEARNING, BY STAGE

Technology adds educational value when it is integrated after basic competences are properly secured. From there, layering digital competence and the pedagogically oriented use of technology on top of basic skills can strengthen critical thinking, self-regulation, and collaboration. This should happen with pedagogical guardrails, introduced gradually, and differentiated by stage.

In primary education, the latest TIMSS and PIRLS data show Spanish performance in mathematics 27 points below the OECD average — equivalent to more than half a year of schooling — and reading comprehension 12 points below it. At this stage, the priority is to consolidate foundational skills; technology should therefore be introduced gradually and carefully, in specific, well-defined moments, under teacher mediation.

→ Large-scale analysis of learning trajectories can accurately identify the critical windows in which gaps emerge, enabling earlier and better-targeted interventions.

→ Adaptive instruction in moderate doses and under teacher supervision can reinforce the acquisition of basic skills during the window of greatest cognitive plasticity, with value for pupils with specific needs or at risk of falling behind early on.

In lower secondary education, Spain continues to record one of the highest grade-repetition rates: 22% of students have repeated at least one grade by the age of 15, the third-highest rate in the EU and the fourth highest in the OECD. Significant gaps also persist. At this stage, technology should be directed primarily to supporting the most fragile educational trajectories and reducing the factors that undermine learning.

→ Early detection systems for students at risk, combined with personalised tutoring, can help to identify and support the most vulnerable students in time.

In post-compulsory secondary education, the early school leaving rate stands at 12.8% — its lowest level on record — but remains above the OECD average, with marked regional disparities (from 3.6% in the Basque Country to 20.6% in Murcia), and a possible post-pandemic rebound on the horizon. The intergenerational transmission of educational attainment also remains high: 75% of young people with at least one parent holding a tertiary qualification go on to attain one themselves, compared with 30% of those whose parents did not complete upper secondary education. AI can add the greatest value here in three areas:

→ Conversational assistants to reduce dropout rates during educational transitions.

→ Augmented academic guidance to improve the quality of career choices, particularly for students with less family support.

→ Skills mapping tools to align training with labour market demands.

PHASE 3: PILOT, EVALUATE, SCALE

Implementation should follow a cycle of piloting, evaluating and scaling up. Experience from previous technology cycles shows that scaling up unevaluated interventions produces insufficient results. The report proposes three actionable priorities for the coming academic year:

- **(i) Update the MRCDD** to incorporate AI as a specific, assessable competence at all levels, aligning teacher accreditation with the competences demanded by the new reality.

- **(ii) Develop operational guidelines** for integrating AI with pedagogical safeguards, differentiated by educational stage, to guide schools on productive uses and human supervision protocols.

- **(iii) Prioritize investment** in public schools and in regions with lower levels of digital readiness, with experimental evaluation protocols in place before scaling any intervention across the system.

This report identifies the specific levers needed to translate AI's potential into real improvements in learning. Consolidating them remains the task ahead, and the condition for this technological wave to fully unfold its potential.

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S1 From ICT to AI: the rise of *edtech* and the evidence base

This report moves from the general and fundamental (this section) to the specific and concrete (section 2): it reviews the available evidence on the impact of ICT and, in particular, AI on the various stakeholders in the education system (with a special emphasis on teachers and students) and, based on this, identifies the conditions that the Spanish education system needs to meet in order to harness the complementary potential of these technologies.

WHERE WE'VE COME FROM: THREE STAGES OF ICT IN EDUCATION IN SPAIN

ICT encompasses the set of technologies, infrastructures and digital tools used to create, process, store and communicate information and knowledge (ENACOM, 2023). In Spain, the expansion of ICT has spanned three stages over some four decades:

01

The digital foundation 1985–2000

The Atenea and Mercurio projects: the first computers in Spanish primary and secondary school classrooms. The start of educational digitisation policies.

02

Connectivity 2000–2015

Internet in schools, the Escuela 2.0 Programme, Wi-Fi in classrooms, learning platforms (Agrega). Broadband in homes and schools (INTEF, 2017).

03

Expansion of devices, platforms and AI 2015–present

Widespread adoption of tablets and *Chromebooks* per pupil; learning platforms (*Google Classroom, Moodle*); + early AI systems.

These three stages have shaped a digital ecosystem with unprecedented transformative potential. Whether that potential is realized depends not on the technology itself, but on who uses it, for what purpose and under what conditions.

Actor	Potential uses of ICT
Students	Content, practice and individualized assessment using adaptive software that adjusts the difficulty to each student's level.
Teachers	Support for lesson planning, assessment and personalization of learning, as well as the automation of administrative tasks.
School leadership teams and system managers	Centralized information and communication systems; usage analytics and predictive early-warning models; tools for monitoring the educational use of digital resources.
Families	Individualized content and practice at home; automated information systems (such as SMS messages) providing personalized data on their children's attendance, performance, and homework and activities.

Two lessons have become clear regarding the interaction between stakeholders over these four decades:

- i) the systems best equipped to integrate educational technology maintained pedagogical continuity, as observed during school closures due to the pandemic (Banco Mundial, 2024).
- At the same time, ii) harnessing the potential of ICT requires an understanding of how much and how it is used, depending on the context and the specific needs of students, teachers and families (Ganimian, Vegas, & Hess, 2020).

AI does not arrive in a neutral system: it is deployed on the infrastructure built in the two previous stages, which accelerates its spread and amplifies its effects. But it is also a technology with distinctive capabilities (it generates content and simulates educational interactions) that set it apart from traditional ICTs. This poses a twofold design risk: treating AI as just another ICT, ignoring what makes it different; or dismissing the evidence accumulated in the previous stages, ignoring what they have in common. To avoid both, it is advisable to start with what research has learned about ICT (the factors inherited from the earlier stages) and, on that basis, examine what changes with AI.

WHAT WE HAVE LEARNT FROM RESEARCH ON ICT IN EDUCATION

Research on ICT in education, when compared with the data available for the Spanish case, converges on four findings. All four remain valid for AI, and all four will reappear (in greater detail) throughout the report.

Lesson 1: The access gap has closed; the usage gaps have not.

The presence of ICT in European education systems has increased steadily over the last two decades. In Spain, the initial access phase can be considered virtually complete.

However, certain gaps remain. Data from PISA 2018 showed that only 52% of Spanish schools had an effective digital platform for online teaching, with differences of more than 30 percentage points among autonomous communities[1] . The analysis also revealed that only 53% of school heads believed their teachers had the technical and pedagogical skills necessary to integrate digital devices into teaching (Zubillaga and Gortazar, 2020).

However, a comparison of data from PISA 2018 and 2022 (Mata et al., 2025) shows that, although access gaps narrowed substantially following the pandemic, gaps in usage and pedagogical readiness persisted. In 2022, state schools remained approximately 15 percentage points behind private schools in terms of platform availability, and pupils from disadvantaged backgrounds faced greater difficulties in the independent use of digital tools.

Added to this is regional heterogeneity. According to PISA 2022, the percentage of students using digital devices in **more than half or almost all** maths and reading **sessions** ranges from 11–13% in Cantabria to 37–46% in the Basque Country, which even exceeds the OECD average.

100%

schools with internet access (2022-23)

(MEFPD, 2024)

96.9%

schools with operational Wi-Fi

(MEFPD, 2024)

1 In Aragon, Asturias, Extremadura, the Valencian Community, Andalusia, Cantabria, Navarre and Castile-La Mancha, more than half of schools lack adequate resources to provide online education.

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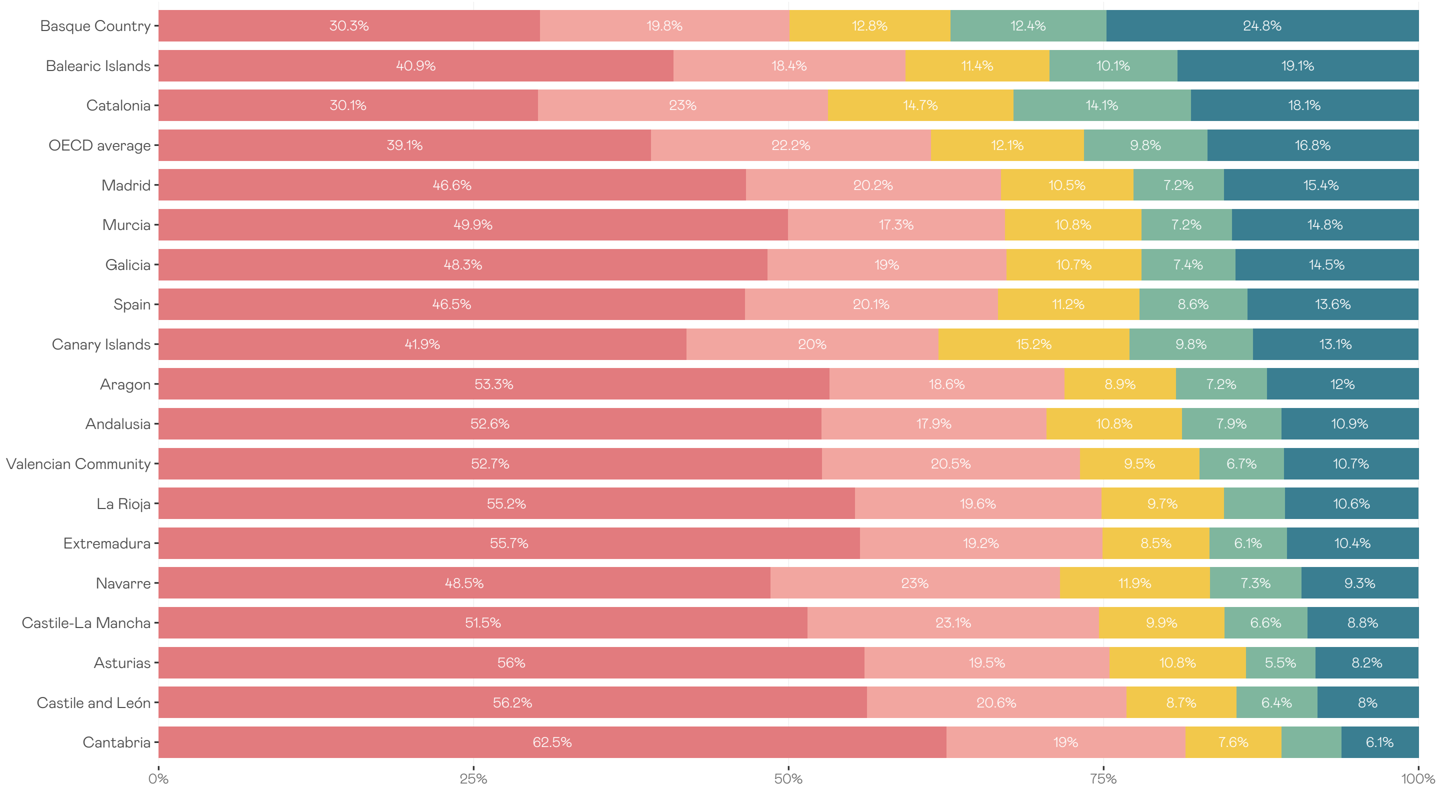
Use of digital devices in mathematics lessons

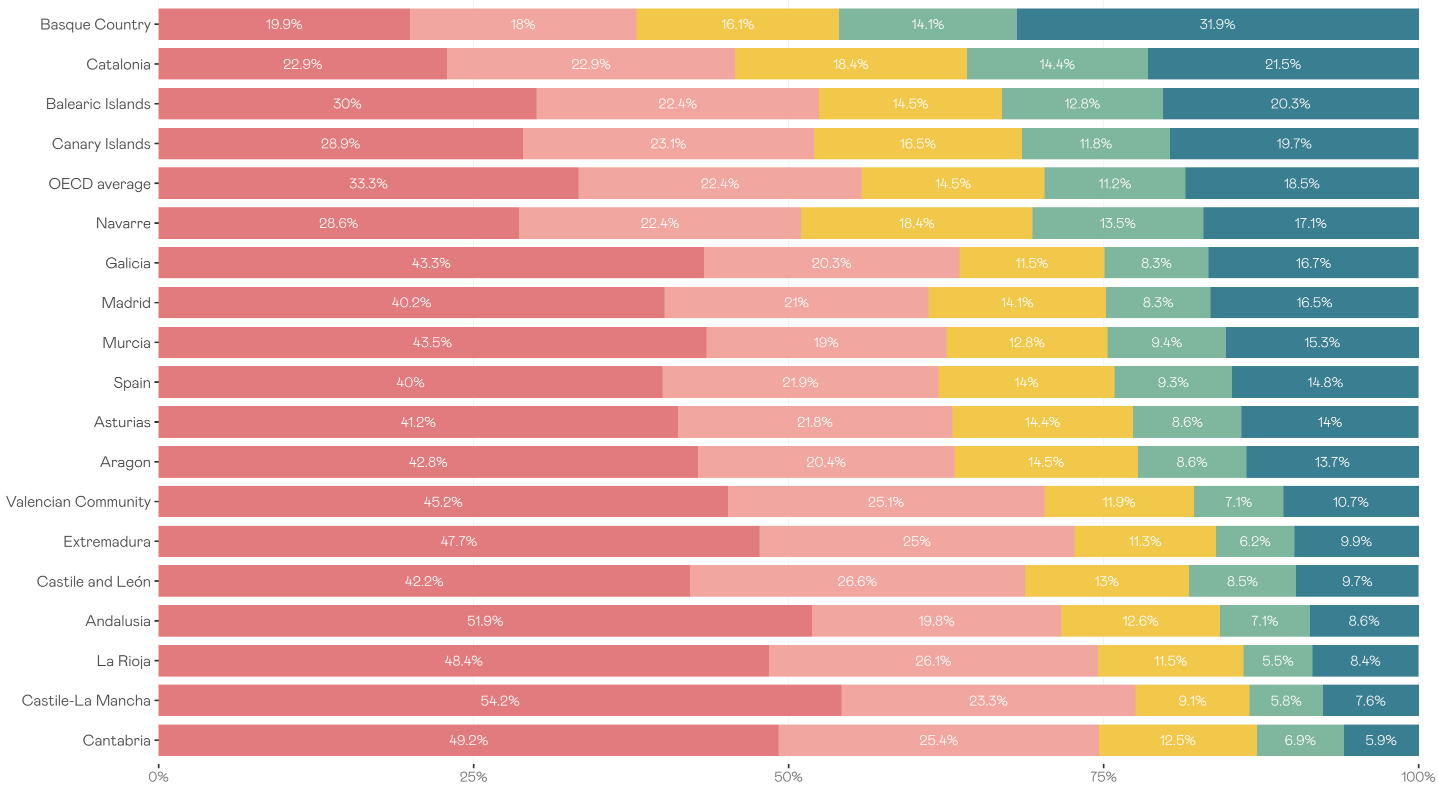
Never or almost never, In less than half of the lessons, In about half of the lessons, In more than half of the lessons, and In every or almost every lesson



Source: Own elaboration based on PISA 2022 (OCDE)

Use of digital devices in language lessons

Never or almost never, In less than half of the lessons, In about half of the lessons, In more than half of the lessons, and In every or almost every lesson



Source: Own elaboration based on PISA 2022 (OCDE)

Lesson 2: Access without pedagogy, insufficient results.

The evidence indicates that mere access to technology does not guarantee improvements in academic performance. A review of 126 studies by J-PAL (2019) concludes that initiatives focused exclusively on expanding access to computers and the internet, without associated pedagogical changes, do not produce systematic improvements in grades or in standardised test results in primary and secondary education. However, these programmes do increase the use of devices and strengthen students' digital skills. Against a backdrop of growing demand for technological skills in the labour market, the development of digital skills constitutes a relevant objective. However, from an academic perspective, access alone is insufficient. This is particularly true when the widespread digitalization of the classroom does not serve a clear pedagogical purpose. In such cases, the issue is not technology per se, but the intention of use, type of activity, the device used, and the extent of teacher guidance.

Not all forms of digital engagement carry the same weight. Gorjón and Osés (2023), using PISA 2018 data for Spain, Estonia and Finland, show that the effect on mathematics scores varies substantially depending on the activity and its frequency: some uses —such as browsing the internet to do schoolwork— are associated with consistent gains, whereas others are associated with penalties that grow with intensity.

On the other hand, evidence shows that when technology is deployed with a clear pedagogical purpose, learning gains can be substantial. For example, Muralidharan, Singh and Ganimian (2019) find that the use of *Mindspark* software —which combined 45 minutes of adaptive software with 45 minutes of supervised group instruction, six days per week— increased student performance by 0,37 standard deviations in mathematics.

Moreover, the type of device also matters. PISA 2022 data show that the use of a PC or laptop at school is positively associated with performance —by as much as 17 points in mathematics relative to students who never use them— suggesting a more productive integration into school learning. Smartphones, by contrast, are associated with an 11-point penalty in mathematics, pointing to the risks of devices that are more easily linked to distraction and less clearly embedded in guided academic tasks.

Lesson 3: Intensity without alignment to purposeful use can backfire.

The previous evidence suggests that technology can improve learning when it is used with a clear pedagogical purpose, embedded in structured instructional models, and supported by appropriate devices, adequate frequency and teacher guidance. When these conditions are not in place, however, the relationship between technology use and student outcomes becomes much more cautionary.

This is what large-scale international assessments appear to capture on average. Both PISA 2022 in secondary-school mathematics and PIRLS 2021 in primary-school reading point in the same direction: an inverted-U pattern, in which moderate use is associated with better outcomes than either very limited or very intensive exposure. This shape reflects the typical conditions under which technology is deployed across systems — often without sufficient targeting, guidance or pedagogical.

This pattern reflects therefore that when technology is deployed in specific, guided, and pedagogically meaningful ways, it can improve learning; when these elements are missing, more intensive use may end up diluting or even outweighing potential benefits.

**Methodological note on interpreting evidence.
How to understand effect sizes in educational research.**

The effects of educational interventions are expressed in standard deviations (sd or SD), a measure that allows results to be compared across studies using different metrics. It reflects how much scores vary from the mean: an effect of 0.20 sd indicates that the treatment group achieved results 0.20 times that standard deviation higher[2].

In an article that has already become a benchmark in the sector, Kraft (2020) proposes evaluating effects by simultaneously considering three dimensions: the magnitude of the effect, the cost per pupil, and the programme's scalability.

Effect size	Cost per pupil			Scalability
	Low (<$500)	Moderate ($500–<$4,000)	High (≥$4,000)	
Small (<0.05)	Small effect / low cost	Small effect / moderate cost	Small effect / high cost	Easy to scale
Medium (0.05–<0.20)	Mod. effect / low cost	Mod. effect / mod. cost	Med. effect / high cost	Reasonably scalable
Large (≥0.20)	Signif. effect / low cost	Large effect / moderate cost	Large imp. / high cost	Difficult to scale

Note: Green and red represent more and less favorable cost-effectiveness ratios, respectively. The effect and cost thresholds provide empirically informed starting points that should be adapted according to the characteristics of each study. Cost should be considered in the context of US public expenditure per pupil, which is higher than in Spain.

Why do these thresholds matter? To put this into perspective: in Year 5, academic performance improves by approximately 0.40 standard deviations over a full school year, and formal schooling accounts for only around 40% of that gain. In other words, a full year of schooling — with over 1,000 hours of instruction and public expenditure exceeding €7,000 per pupil — scarcely exceeds the threshold[3,4] for a large effect in secondary education. Therefore, this framework allows us to contextualize the results presented throughout the report: an effect of 0.10 sd, which might seem modest by conventional standards, is in fact a median result and representative of the typical impact of rigorously evaluated educational interventions.

Source: Kraft, M. A. (2020). Interpreting Effect Sizes of Education Interventions. Educational Researcher, 49(4), 241–253.

2 The thresholds proposed by Jacob Cohen (0.2 = small, 0.5 = medium, 0.8 = large) remain widely used but are inadequate for evaluating educational interventions. These standards are derived from small-scale laboratory experiments in social psychology, a context very different from that of large-scale educational policy evaluations. Cohen himself warned that his thresholds should only be used when no better alternatives existed.

3 In the case of primary education, the annual teaching time is 789 hours and in lower secondary education (ESO) 1,053 hours (INEE, 2025).

4 Public expenditure per pupil in primary education is €6,225 and in lower secondary education €7,603 - data as of 2022 (INEE, 2025).

Lesson 4:
Technology aimed at personalizing instruction does work.

The evidence shows that interventions that merely expand access to devices without changing teaching practice, produce effects close to zero on academic performance, as demonstrated by the *One Laptop Per Child* programmes in Peru (Cueto, Beuermann, Cristia, Malamud, & Pardo, 2025), the distribution of computers to US households (Fairlie & Robinson, 2013) or internet subsidies in state schools (Goolsbee & Guryan, 2006).

In contrast, interventions that use technology to personalize instruction to the student's actual level and complement teacher-led teaching produce substantial effects:

Evidence · Mindspark — adaptive instruction

Muralidharan, Singh & Ganimian (2019) · India, primary and secondary schools · 4.5 months

Software that assesses the student's level and dynamically adjusts the difficulty of the exercises. Students with access to the programme achieved significant improvements in maths and Hindi after just 4.5 months of access.

0.37 sd in maths | 0.23 sd in Hindi

Evidence · Computer-assisted learning with educational games

Banerjee, Cole, Duflo & Linden (2007) · Primary schools, India

Computer-assisted learning programme using educational games. One year after the intervention ended, the impact had settled at a persistent gain of 0.1 sd, both for students of all ability levels and for those who were initially lagging behind.

0.35 sd in year 1 | 0.47 sd year 2 | 0.10 sd persistent gain

Evidence · Global meta-analysis of educational technology

Haßler et al. (2025) · 189 studies synthesised

In countries with high digital literacy, educational technology interventions show a positive impact (sd = 0.4; $p < 0.01$). The effects are greater in secondary school than in primary school, and higher in science than in mathematics or reading. However, the impact on vulnerable pupils is limited when the intervention does not incorporate specific support strategies: the average effect is not statistically significant ($d = 0.05$, $p = 0.21$) and only reaches a moderate magnitude when these students form part of large samples ($d = 0.16$; $p < 0.01$). Therefore, **these findings suggest that technology, on its own, does not address structural inequalities.**

Evidence · SimCalc — advanced mathematical visualization

Roschelle et al. (2010) · Texas, USA · Years 7 and 8

The intervention enabled pupils to manipulate mathematical functions and view animated movements to connect graphical, tabular and algebraic representations, whilst the control group followed standard instruction with high-quality teacher training. Improvements were concentrated in the mastery of advanced mathematical skills without affecting basic learning. These benefits were robust across diverse school settings and demographic profiles, demonstrating that well-integrated technology can level the playing field for access to traditionally difficult mathematical content.

0.63 sd (Year 7) | 0.50 sd (Year 8)

Thus, the reviewed evidence leads to the conclusion that technology demonstrates clear added value in at least two dimensions.

- → It enables access where structural conditions make it difficult: in contexts with geographical barriers, a shortage of qualified teaching staff or logistical constraints, digital tools can ensure access to educational resources that would otherwise be unfeasible.
- → for the development of more advanced skills such as complex mathematical reasoning or problem-solving, well-integrated technology can significantly improve outcomes.

Therefore, **well-designed educational technology is better than its absence**: as a complement that expands access, personalizes instruction and strengthens the education system's capacity to respond to diverse needs.

The decisive factor is not whether technology is present in the classroom, but when, for what purpose and with what pedagogical design it is incorporated.

WHAT CHANGES (AND WHAT DOESN'T) WITH AI

Unlike traditional ICT, AI does not merely automate tasks: it can generate content and simulate educational interactions. This makes it a tool with greater potential for complementarity than its predecessors, but also with a more acute risk of substitution, particularly among younger pupils, whose executive functions are still developing. The question, then, is whether the emerging evidence on AI confirms or qualifies the four findings on ICT. The available causal studies, still in their infancy, point in a clear direction: the same organizing principle remains valid, if anything more pronounced.

AI works when it is a complement.

The causal evidence on AI in education is still limited but growing and points to an organizing principle: **the impact depends on whether AI operates as a complement to cognitive and teaching effort, not as a substitute for it**.

Evidence · Generative AI with and without safeguards

Bastani et al. (2025) · Randomised experiment · Secondary school, mathematics

They compare three conditions during in-class practice sessions: (i) no AI, (ii) access to a genAI-powered chatbot, and (iii) access to a tutor with learning safeguards that avoids giving the full solution and offers step-by-step hints. The results show that access to the chatbot improves marks by 48% and the tutor by 127% compared to the control group. However, when AI is removed, students who used the base chatbot achieve lower results than those who never used AI (≈ 17% drop in exam marks). Nevertheless, this negative effect is mitigated by the tutor: the negative effect disappears, although without generating clear improvements in exam performance. These results highlight what AI can cause when used with minimal adult supervision and guidance, when it replaces rather than enhances thinking, and when students lack adequate preparation for productive use.

Evidence · DytectiveU — Adaptive AI with pedagogical design

Cuevas-Ruiz, Rello, Sanz & Sevilla (2025) · 264 state schools, Community of Madrid
5 academic years (2019–2023) · "Ayuda Dislexia" initiative

Unlike a generative AI chatbot, *DytectiveU* incorporates pedagogical safeguards into its very design: it adapts content to each student's developmental level and performance, avoiding both the frustration arising from excessive difficulty and the replacement of cognitive effort. Furthermore, it does not merely personalize the intervention but is supported by a prior tool for detecting and measuring reading difficulties —*the Dytective Test*— which allows the learning experience to be tailored more precisely from the outset.

The authors estimate that each additional session increases reading progress by 2.4% of a standard deviation. The effect is greater among younger students, who are in the early stages of cognitive development and have greater neural plasticity, confirming the importance of personalization during the initial phases of reading acquisition.

Furthermore, adaptive feedback maintains student engagement across a wide range of sessions, with positive marginal returns up to approximately 154 sessions. When AI is designed to complement the learning process, adapting to the learner without providing the answers, the benefits are sustained over time. The programme operates with minimal reliance on the teacher and at a limited cost, making it a potentially scalable model.

+2.4% SD per session (≈ 1 month of learning)

Evidence · Teacher-oriented AI

Wang et al. (2025), Dennison et al. (2025), Gallup & Walton Family Foundation (2025)

The evidence also shows that AI can enhance the quality of teaching when it is teacher-oriented, rather than learner-oriented. Recent studies document how AI tools integrated into tutoring improve the teaching practices of less experienced tutors, reduce lesson planning time and generate savings equivalent to several weeks a year in administrative tasks.

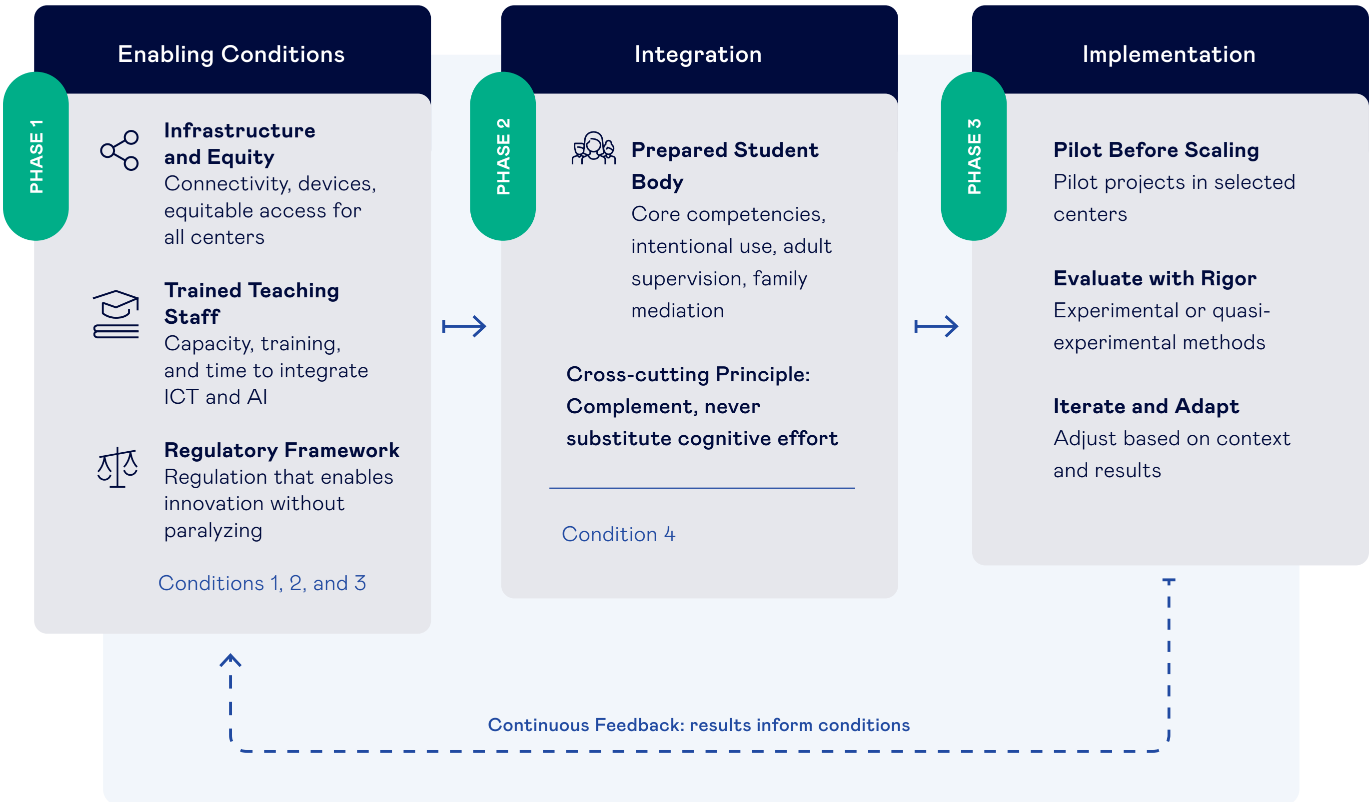
Taken together, the accumulated evidence and emerging experimental findings on AI converge with factors inherited from the previous wave: ICT and AI enhance learning when they complement teaching efforts by increasing reach, quality, personalization and efficiency, but have no effect when this intent is lacking, or even undermine it when they replace the cognitive effort of students or teachers. This risk is greater at younger ages, when executive functions and relational bonds are still developing.

Therefore, success does not depend on the existence of technology per se, but on its design and how it operates within the conditions of the educational ecosystem that receives it. The question that will guide the following sections is: is Spain able to harness the complementary potential of ICT and AI, or are there structural gaps that limit their effective implementation? And, above all: what must it do to close them?

S2 How to incorporate the new wave of *edtech* into the Spanish education system

Given that prioritizing the provision of tools without addressing pedagogical, organizational and institutional conditions leads to insufficient results, this report examines the conditions necessary for effective integration, organized into three phases.

Framework for the Effective Integration of ICT and AI in the Education System



The first phase covers the enabling conditions: digital infrastructure and equitable access, without which no technological intervention is viable; training and time for teachers to integrate ICT and AI in a pedagogically productive way; and a regulatory framework that enables innovation.

The second phase addresses integration into learning: a student body that uses technology purposefully, with the core skills and necessary supervision to ensure that ICT and AI complement their cognitive effort rather than replace it.

The third phase (implementation, evaluation and iteration) recognizes that technological integration is not a one-off deployment but a process that requires piloting, measuring results and adapting.

PHASE 1: ENABLING CONDITIONS FOR ICT AND AI TO FUNCTION

PHASE 1 | Infrastructure and digital equity | Faculty | Regulatory framework

An adaptive learning tool cannot function without reliable connectivity; an AI system can only improve the quality of teaching if there are teachers who are trained and willing to integrate it; and learning safeguards only work if educational institutions establish clear regulatory frameworks.

This section examines these enabling conditions by assessing, in each case, the current situation in Spain and the gaps that remain, to suggest how to close them.

Condition 1: Infrastructure and digital equity

Although the initial phase of access to digital infrastructure is largely behind us in Spain and the ratio of devices per pupil has improved following the pandemic, gaps remain that limit the viability of the most effective interventions.

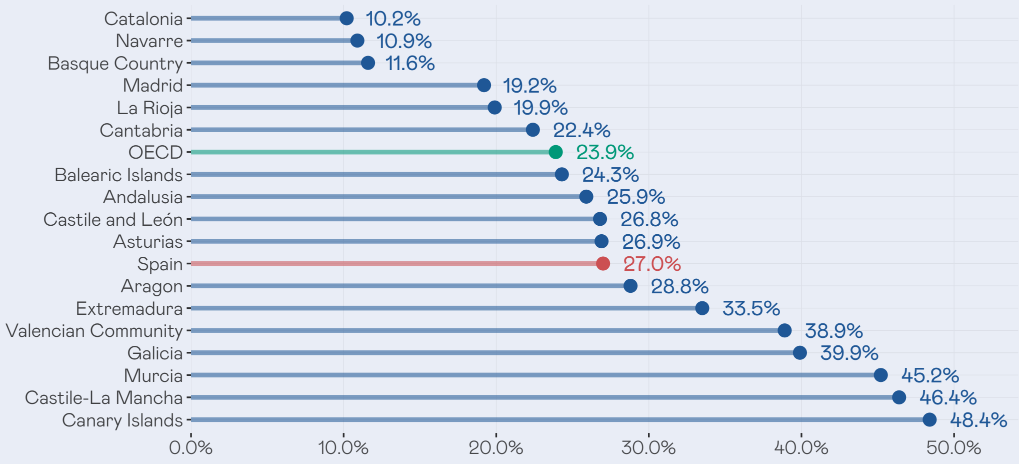
Adaptive learning programmes, which require stable connectivity and functional devices for every pupil, cannot be implemented equitably if infrastructure varies substantially between regions and types of schools. Similarly, teacher-oriented AI tools require a minimum technological foundation to operate.

Context · Some persistent inequalities

According to 2022 data for 15-year-old pupils, state schools remained 15 percentage points behind private schools in terms of the availability of digital platforms for teaching, and the differences between autonomous communities exceeded 30 percentage points in digital readiness (Zubillaga & Gortazar, 2020; Mata, Zubillaga & Gortazar, 2025). Furthermore, pupils from disadvantaged socio-economic backgrounds face greater difficulties in the independent use of digital tools.

These inequalities are also reflected when analyzing various variables at the autonomous community level. 27% of 15-year-old pupils in Spain attend schools whose headteachers report that their ability to deliver teaching is hampered by a lack of digital resources. This figure is higher than the average for OECD countries. Furthermore, seven autonomous communities have percentages above the national average.

Percentage of students in schools reporting that their capacity to deliver instruction is hindered by a lack of digital resources



Source: PISA 2022. Includes respondents who answered ‘to some extent’ or ‘to a large extent’.

These regional differences can be explained by:

1. Public spending per pupil, which varies by up to €3,700 per year between regions (Ivie, 2025). The three autonomous communities with the lowest perceived digital deficit (Catalonia, Navarre and the Basque Country) coincide with those recording the highest educational expenditure per pupil, whilst regions with lower expenditure per pupil have the highest percentages of hindrance.

2. Prioritization of education spending. The differences are not explained solely by the inequality of resources resulting from regional funding, but also by the political decisions of each government (Ivie, 2025): Andalusia, for example, despite having a below-average GDP per capita, allocates nearly 30% of its total resources to education — the highest relative investment in the country alongside Murcia and the Valencian Community — which could contribute to its percentage of schools with perceived digital shortcomings (25.9%) being very close to the national average.

3. The composition of the school network could also influence these figures. The greatest difference in the school digital divide is not found between autonomous communities or according to families' socio-economic status, but rather by the type of school ownership (Mata, Zubillaga, & Gortazar, 2025), which puts state schools at a disadvantage. Even when controlling for socio-economic status, the differences between state-subsidized and private schools persisted.

The key objective is for every group of pupils to have sufficient devices and connectivity to guarantee individual access when required by the activity, without the infrastructure becoming a bottleneck. This can be achieved:

→ By providing devices to those households that cannot obtain them. 9.2% of Spanish households with children aged between 6 and 17 do not have a computer. In regions such as the Andalusia or the Canary Islands, this figure reaches 13%-15%, varying by income quintile: the figure stands at 23% among the lowest-income household quintile. This, together with other factors related to the design and implementation of the educational strategy, leads to the following point.

→ Via devices provided by the school. Following an initial phase of desktop computers, the growing trend towards portability has encouraged this approach: the #DigEdu programme, with a budget of 989 million euros, was primarily aimed at this. Going forward, ensuring that pupil vulnerability —accompanied by effective monitoring mechanisms— remains a central criterion in fund allocation and programme design will be key to preventing the digital transition from widening existing educational inequalities.

Condition 2: Teachers with the time, access and capacity to integrate ICT and AI

PHASE 1 | Infrastructure and digital equity | **Faculty** | Regulatory framework

International evidence shows that AI can function as a technology for scaling up teaching *expertise*, with greater benefits for less experienced teachers (Wang et al., 2025), and that it can significantly reduce the time spent on planning and administrative tasks (Dennison et al., 2025; Gallup and Walton Family Foundation, 2025). The question is therefore twofold: what conditions does the technology require to work effectively with teachers, and do teachers in Spain have these conditions? This section addresses both questions and concludes by identifying three areas where AI can provide concrete value to teachers: reducing the administrative burden, scaling up feedback, and safeguarding the classroom environment.

Context · Overburdened teachers

Today, Spanish teachers operate in an environment that combines administrative overload, constant adaptation to regulatory changes, and a deteriorated classroom climate. Data from TALIS 2024 and PISA 2022 help to illustrate this pressure.

Percentage of teachers who report the following reasons as sources of stress

Results based on teacher responses in Spain, OECD-27 and UE-22

Source: Own elaboration based on TALIS (OECD) 2024 data | EsadeEcPol

Sources of teacher stress (TALIS 2024, lower secondary). Spain ranks above the OECD in the five main reported sources of stress, with especially marked gaps in:

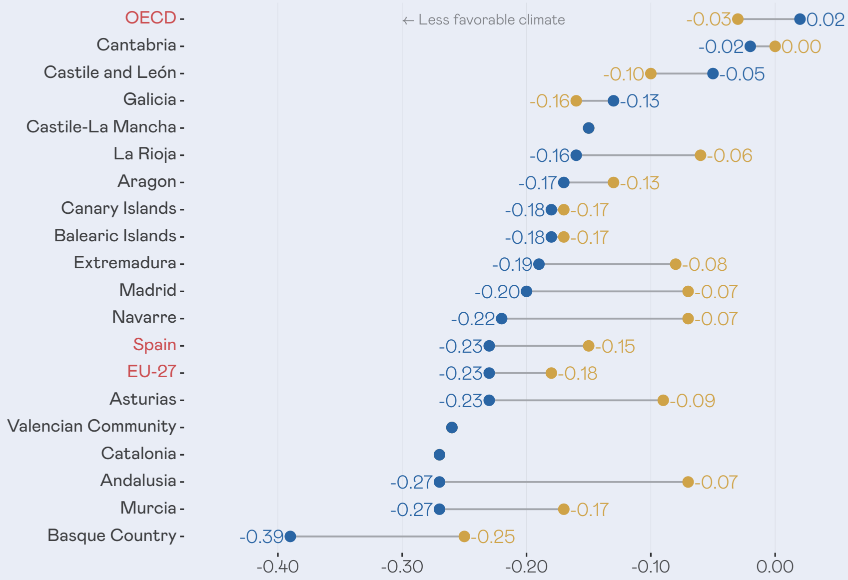
- Administrative workload: 12.6 percentage points above the OECD.
- Adapting to curriculum change: 23.8 percentage points above.
- Meeting requirements from education authorities: 17.3 percentage points above.

The pattern is replicated in primary education, where curriculum change (63.1%), administrative workload (60.1%) and regulatory requirements (52.4%) also top the list of causes of stress.

Time cost. Spanish secondary school teachers spend 18.03 hours per week on non-teaching tasks — planning, marking, administration and communication with families — 1.65 hours more than the EU average.

Classroom atmosphere (PISA 2012–2022). The classroom atmosphere in mathematics has deteriorated more in Spain than in the OECD and the EU-27. The decline is particularly pronounced in Asturias, Andalusia, Catalonia, Murcia and the Basque Country; Galicia and Castile and León are the only regions to have improved over the period. As a behavioral correlate, 38% of Spanish pupils state that their classmates do not listen to the teacher in most lessons (30% in the OECD) and a third report distractions caused by their own or others' digital devices.

Change between 2012 and 2022 in classroom climate: mathematics at age 15 in secondary education



Source: PISA (2012 and 2022) | EsadeEcPol.
Note: The index takes the value zero for the unified 2012 and 2022 OECD sample in PISA.
The index is expressed as a proportion of standard deviations of the whole sample. It was built using a Bayesian Rasch analysis that maximises the likelihood of the responses collected from 5 items of the student questionnaire. Question: How often do these things happen in your mathematics classes?
Response options: [All classes; most classes; some classes; never or hardly ever]
a) Students do not listen to what the teacher says
b) There is noise and disorder
c) The teacher has to wait a long time for students to quiet down
d) Students cannot work well
e) Students do not start working for a long time after the lesson begins

AI is being introduced into a system where teachers' time is already stretched by non-teaching tasks and where classroom atmosphere is degrading. Assessing 'what works requires weighing up, in addition to the pedagogical impact, the effect on these two dimensions.

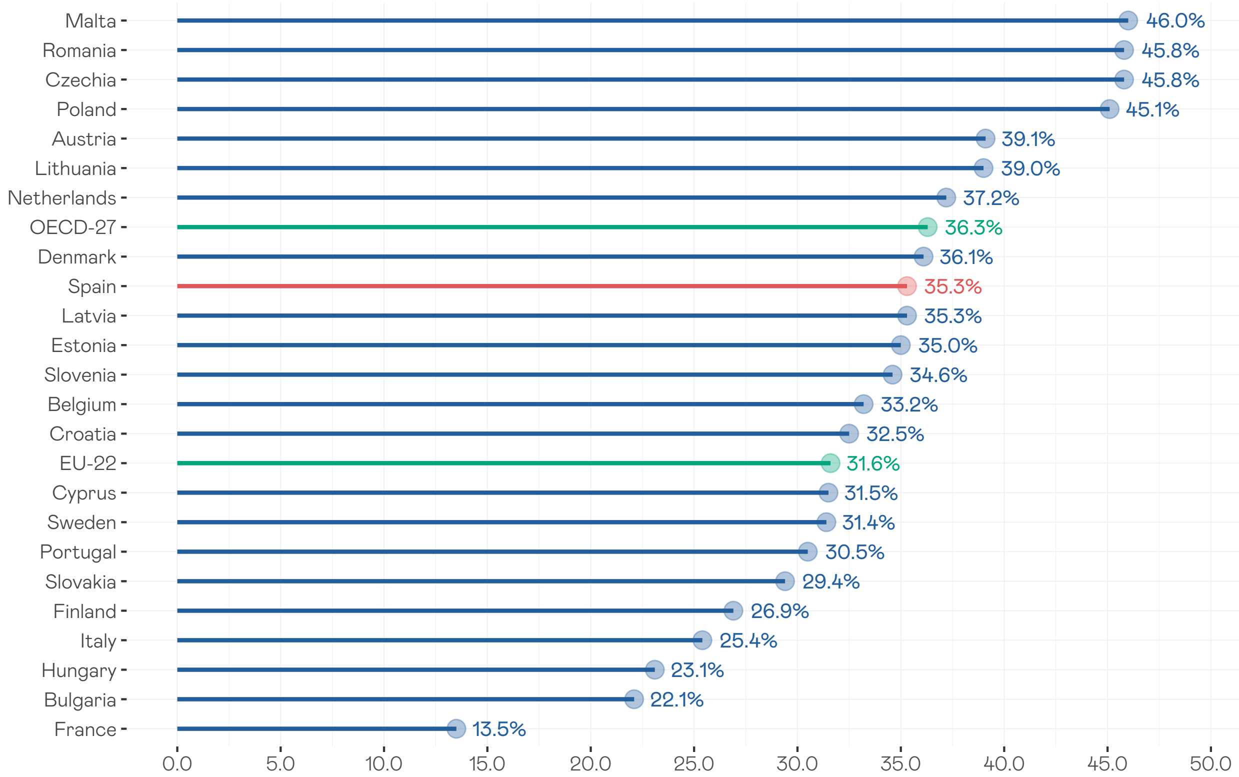
Against this backdrop of overload, the question is how AI has been received by Spanish teachers. The data paint a starting point with three features: adoption comparable to the wider environment, infrastructure like that of the OECD, and a usage profile concentrated on planning.

The adoption of AI is progressing, but with a specific profile

The level of adoption is not particularly low for the region. Data from TALIS 2024 for lower secondary education (equivalent to ESO)[5] show that 35.3% of Spanish teachers report having used artificial intelligence in their work: a proportion higher than the European average (31.6%), although lower than the OECD average (36.3%).

5 TALIS 2024 measures the use of AI in lower secondary education (ISCED 2). The primary education data do not include specific questions on AI adoption.

Percentage of teachers reporting having used AI



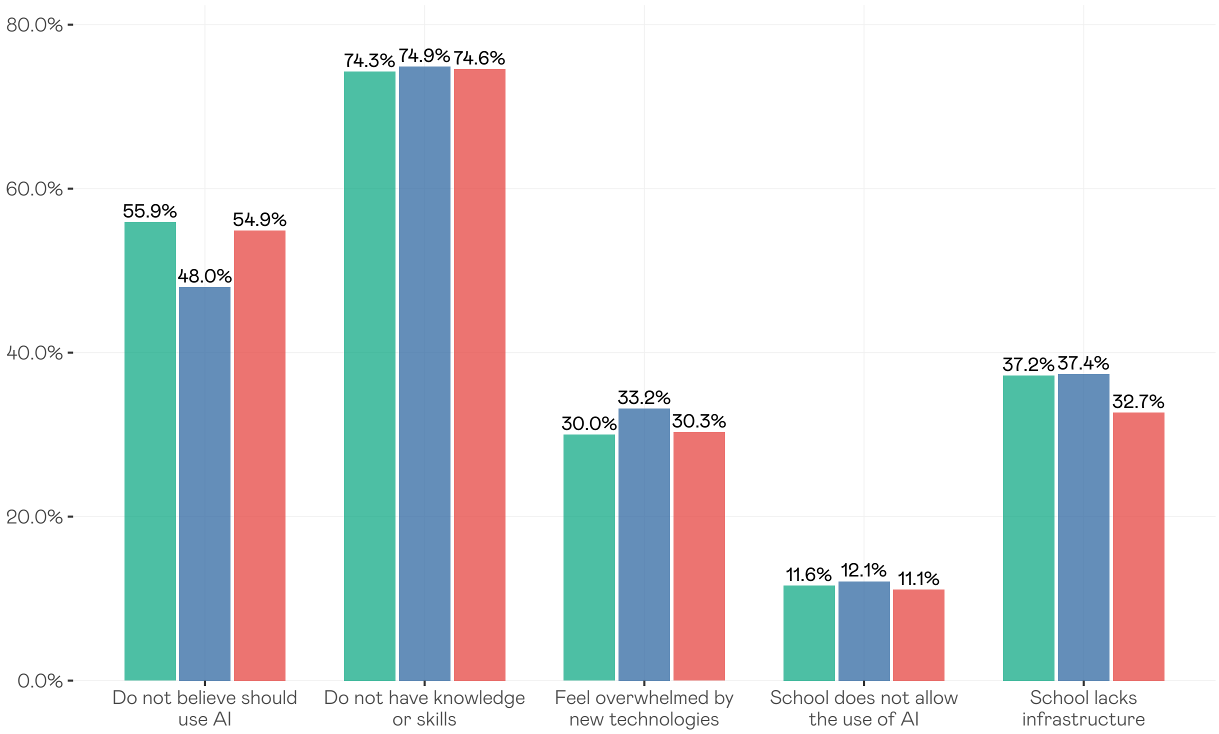
Source: Own elaboration based on TALIS (OCDE) 2024 data | EsadeEcPol

The infrastructure is insufficient, but this is a common challenge across advanced economies. 32.7% of Spanish teachers indicate that their school lacks adequate infrastructure for the use of AI — a barrier directly linked to the institutional and equipment conditions analyzed above. These figures are in line with those for Europe and the OECD, meaning this is not solely a Spanish challenge but one faced by high-income/European countries.

A usage profile concentrated on planning is identified. The most widespread use is the creation of lesson plans or activities (68.8%), a proportion higher than the OECD average (63.7%) and the EU average (63.9%). By contrast, Spain ranks significantly lower in uses linked to information search and synthesis (49.0% compared to approximately 67% in the OECD/EU) and in feedback and monitoring tasks: only 20.7% use AI to draft feedback texts or communications with families (compared to ~31–32% in the OECD/EU) and just 14.7% to review student participation data (~25–26% in the OECD/EU).

Percentage of teachers reporting the following barriers to using AI

Results based on teacher responses in Spain, OCDE-27 and UE-22



Source: Own elaboration based on TALIS (OCDE) 2024 data | EsadeEcPol

Regulatory instability may help explain this: against a backdrop of constant and recent curricular changes (with the implementation of the LOMLOE), teachers concentrate their use of AI where regulatory demands are most intense (curriculum planning, curricular adaptations).

Lack of training: the primary barrier to effective integration

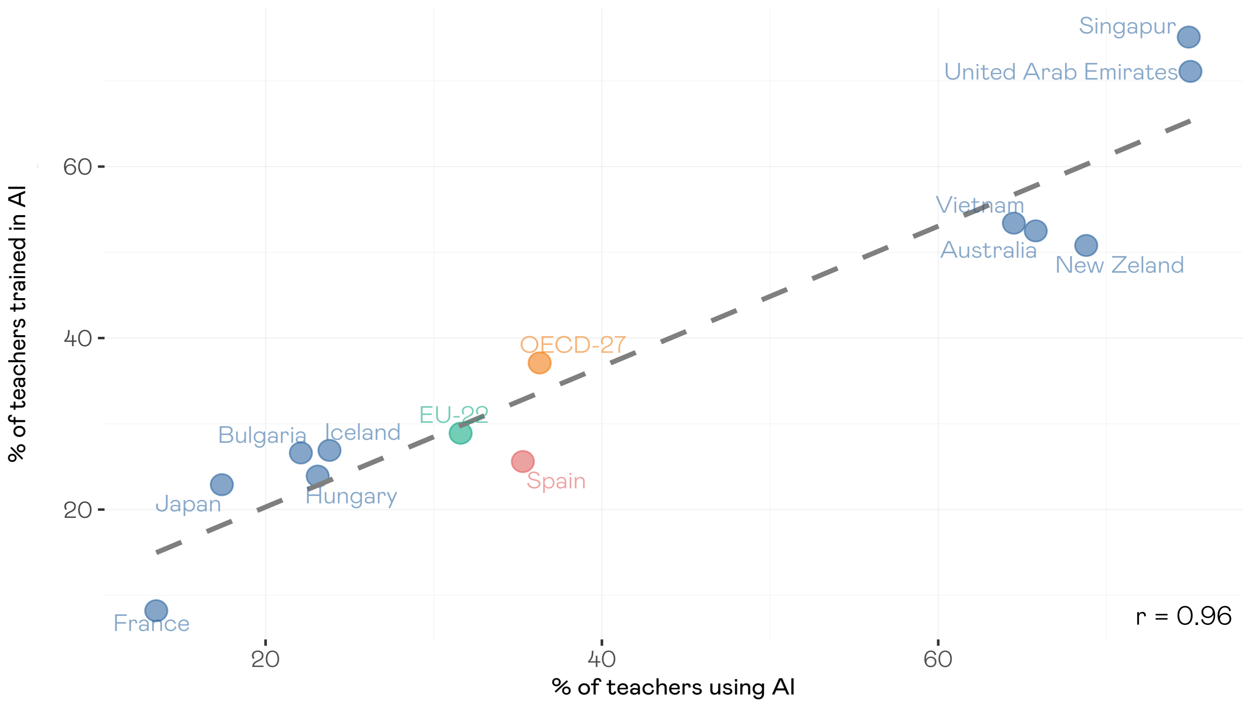
For this progress to continue and expand, the main barrier faced by teachers must be addressed: the lack of both access to and incentives for training. TALIS data show that the main barrier to the use of AI is the lack of specific knowledge or skills to use it properly (74.6% in Spain)[6]. Furthermore, teachers also report uncertainty about whether they should use it and a feeling of being overwhelmed by the introduction of new technologies.

This critical issue is illustrated by the gap between stated training needs and training received. 24.2% of teachers in Spain (18.7% for the OECD average) who reported a 'high level of need' for training in the use of AI for teaching have not participated in related training activities. This gap is wider in the field of AI than in areas such as classroom management (11.9%) or teaching students with special educational needs (16%).

Furthermore, there is a strong positive correlation between the percentage of teachers using AI and the percentage reporting having received training in this area: countries with the highest proportion of teachers using AI are, in general, those where at least 50% of the teaching staff have received training in AI. Spain has more teachers than the average using AI, but, at the same time, fewer who have received training.

6 This percentage rises to 81% in primary education.

Relationship between teacher AI training and adoption



Source: Own elaboration based on TALIS (OCDE) 2024 data | EsadeEcPol

Why training is inaccessible. When analyzing the factors explaining why teachers find it difficult to access training, it is observed that, across OECD countries, the EU and in Spain, the main reasons coincide: lack of time due to other responsibilities, absence of incentives to participate in professional development activities, and conflicts between training and working hours (TALIS, 2024).

However, the lack of incentives to participate in professional development activities stands out particularly as an explanatory factor in Spain. Whilst the OECD average for this factor is 45.7%, in Spain it rises to 70.1%, a considerable difference compared to the other countries analyzed (and this is particularly true for teachers with more than 10 years' experience).

These shortcomings not only limit teachers' ability to integrate AI into more sophisticated tasks but also contribute to their lack of awareness of its potential benefits for teaching.

We therefore see that one of the main barriers to the adoption of AI **is not technological, but human and resource-related: without specific training, institutional support and protected time for pedagogical integration, teachers cannot harness the potential of AI as a complementary tool. Closing the training gap is a necessary condition for ICT and AI to generate real improvements.**

Training without structure is not enough

But closing the training gap is a necessary, but not sufficient, condition. Even if a teacher is trained, the technology will not produce results if the school does not provide the organisational conditions for its sustained use. The most recent evidence clearly demonstrates this.

Evidence · Khan Academy — implementation support

Oreopoulos, Keyes-Krysakowski and Agarwal (2026) · Uttar Pradesh, India · Secondary

In a randomised trial across 83 public boarding secondary schools in Uttar Pradesh (India), the authors assessed whether strengthening the implementation framework could increase the quantity and quality of use of the Khan Academy computer-assisted learning platform. All schools had access to the platform, but treatment schools were assigned a lab supervisor dedicated to ensuring connectivity, safeguarding weekly practice time, monitoring in-class use, coordinating content with teachers, and tracking progress.

The results show a stark contrast. Without structured support, average use of the platform was merely 7.2 minutes per week — practically negligible. With the lab coordinator, usage increased to 47.4 minutes per week. Students in the treatment schools scored between 0.44 and 0.47 standard deviations higher on the end-of-course maths assessment. The result demonstrates that the limiting factor is not the technology or the content, but the presence of organisational structures that ensure sustained instructional use.

Evidence · CoPilot Tutor — AI as teaching support

Wang et al. (2025) · USA · Primary and secondary

Wang et al. (2025) evaluate Tutor CoPilot, an AI system integrated into online maths tutoring that provides immediate pedagogical suggestions to the tutor during interaction with the student. The study involved approximately 900 tutors and 1,800 primary and secondary school students from historically marginalised communities.

The results show a positive effect on short-term learning. On average, students whose tutors used Tutor CoPilot were 4 percentage points more likely to demonstrate mastery of the content compared to the control group ($p<0.01$). The effect is particularly pronounced among tutors with less experience or lower initial performance. Students mentored by novice tutors showed a greater improvement (9 percentage points) compared to their peers in the control group. This pattern suggests that AI can function as an 'expertise scaling' technology, reducing gaps in teaching quality where teaching staff are more heterogeneous.

The study identifies mechanisms consistent with effective teaching practices: by analysing over 550,000 messages, the authors show that CoPilot increases the use of strategies promoting understanding (e.g., asking guiding questions or prompting the student to explain their reasoning) and reduces the tendency to directly reveal answers. Interviews with tutors confirm that the system makes it easier to respond to students' needs in the moment, although they also point out limitations such as recommendations that are sometimes ill-suited to the student's level.

Research by Copur-Gencturk et al. (2024) and Demszky et al. (2023) reinforces these findings by demonstrating that personalized AI feedback enables the scaling up of high-quality teaching practices, significantly benefiting instructors with less prior experience. Overall, the **technology only yields results when specific institutional conditions are in place**: dedicated support staff, protected time for practice, coordination with the existing curriculum, and systematic monitoring of usage.

Teacher training and institutional support structures are, therefore, the two enabling conditions that define the scope for action. Within that scope, the evidence identifies three specific areas where AI can add value for teachers. For each, we summarize below the available evidence, the situation in Spain, and what remains to be done.

Two areas where AI adds value for teachers

1. Administrative overload and curriculum adaptation

What does the evidence say?

There are no randomized trials demonstrating that AI reduces teachers' administrative workload, but large-scale representative surveys (Gallup and Walton Family Foundation, 2025; N=2,232 teachers in US K-12 state schools) show that teachers who use AI weekly estimate they save ~5.9 -hours per week, with 81% reporting time savings thanks to support with administrative tasks. In Spain, the Government's National Office for Foresight and Strategy (2025) estimates that AI could free up to one working day per week, time that teachers could devote to providing more personalized attention to pupils, continuing their professional development or becoming more involved in the management of their schools.

Schools and education ministries in various countries already use tools of this kind for predictive analysis, attendance monitoring or early warning systems, such as *Civitas, PowerSchool or PraxiSchool* (Burns et al., 2026).

Adoption in Spain (TALIS 2024)

In Spain, only 37.1% of secondary school teachers and 43.4% of primary school teachers report using AI to automate administrative tasks.

Outstanding requirements

- Schools should provide specific, well-supported training within working hours on the use of AI for administrative management, including, for example, automating reports, minutes, and timetables through templates and prompts tailored to the school context.

- Before incorporating technological solutions, existing administrative processes must be reviewed to identify those that are unnecessary or redundant, not only for teachers but for the school community. As the OECD points out, at the system level there is often considerable scope to simplify the administrative work generated by bureaucratic and accountability procedures (OECD, 2021). Automating without this prior review risks perpetuating and even amplifying existing inefficiencies. **Workload is, to a large extent, an institutional problem requiring organizational solutions, not just technological ones.**

- Regulatory frameworks are needed to ensure legal certainty and ethical guidelines for the handling of personal data, as well as integrated and interoperable data infrastructure.

2. Correction, grading and feedback

What does the evidence say?

Although the automation of marking is among the most sought-after applications, the available causal evidence focuses on a different but complementary area: automated feedback on teachers' pedagogical practice.

Evidence · M-Powering Teachers — automated feedback to teachers
Demszky et al. (2023) · RCT with 1,136 instructors

Demszky et al. (2023) demonstrate in an RCT involving 1,136 instructors that the M-Powering Teachers tool improved instructors' uptake of students' ideas by 13%, with evidence suggesting improvements in student satisfaction and task completion.

Evidence · AI feedback vs. human feedback
Demszky et al. (2025) and Banihashem et al. (2025) · K-12 and meta-analysis (41 studies, 4,813 students)

Demszky et al. (2025; Computers & Education): RCT in primary and secondary face-to-face classrooms. Automated feedback increased the use of focus questions by 20%, although this did not translate to other instructional practices. A recent meta-analysis (Banihashem et al., 2025; 41 studies, 4,813 students) found no significant differences in performance between students who received AI feedback and those who received human feedback (Hedges' g = 0.25, not significant), suggesting that AI feedback may be as effective as human feedback.

Adoption in Spain (TALIS 2024)

Only 20.7% of Spanish teachers use AI to draft *feedback* or communications with parents (compared to ~31–32% in the OECD/EU). 21.9% use AI to mark pupils' work.

Outstanding requirements

- Training in advanced pedagogical uses of AI[7] beyond lesson planning should be provided within working hours. This training should include not only technical skills, but also criteria for critically evaluating AI-generated outputs and human oversight protocols that preserve teachers' pedagogical agency.

The above data reveal a common pattern: for the first two challenges (administrative overload and feedback), AI can add value if conditions for training, human supervision and adequate regulation are guaranteed, although rigorous causal evidence remains scarce. However, this assessment must be interpreted bearing in mind that the evidence reviewed in this section is based on the first generation of generative AI models deployed in the educational sector. It is reasonable to anticipate that the capabilities of these models will continue to improve at an accelerated pace, with direct implications for the areas analyzed (administrative overload and feedback), as these are precisely the areas where recent technical advances are most pronounced. However, more capable technology alone will not compensate for a system that has not invested in its teachers' ability to use it. If we are to capitalize on the advances yet to come, we must prepare and support teachers today through specific training, protected time and institutional structures that translate technological potential into a real improvement in educational practice.

7 According to the framework proposed by UNESCO (2025), training should progressively cover five dimensions—human-centered mindset, AI ethics, technical foundations, AI pedagogy, and professional administration—guiding teachers from an acquisition level (understanding and using tools) to a creation level (designing learning experiences transformed by AI), aligned with the school context.

Condition 3: An institutional and regulatory framework that enables without stifling

The above conditions (digital infrastructure and a teaching workforce that is willing, prepared and supported) are necessary but not sufficient. For them to function in a coordinated manner, the system requires **a regulatory and institutional framework that must fulfil a dual role: enabling schools to integrate digital tools with pedagogical intent and, at the same time, safeguarding against the inappropriate use of technology.**

This framework is not limited to legislation: it also includes investment, implementation programmes, the actors operating between policy and the classroom (management teams, ICT coordinators, inspectors, trainers) and the coordination and monitoring mechanisms that translate policies into actual practice. The literature on educational governance identifies precisely this gap between formulated policy and implemented policy as one of the main reasons why reforms do not translate into effective improvements in learning (Angrist & Dercon, 2024; Viennet & Pont, 2017).

What do we mean by regulatory framework?

This term refers to the set of binding legal instruments that govern the integration of ICT and AI into the education system. These instruments are not homogeneous: they are arranged in a hierarchy that combines legal rank, speed of adoption, and capacity for adaptation.

High-level regulation. This establishes the structural principles of the system (LOMLOE, MRCDD, AI Act). It provides stability and legal certainty, but its adoption and amendment are slow, as they require broad parliamentary majorities. It can hardly keep pace with a technology that evolves in a matter of months.

Operational instruments. These are mandatory within their sphere of competence, but their adoption and revision are considerably more agile. They make it possible to specify how high-level regulation should be applied in schools, adjust it to technological developments, and adapt it to the territorial context.

This hierarchy is especially relevant in Spain because of the distribution of powers between the State and the Autonomous Communities. The State establishes the minimum core curriculum and common frameworks, while the Autonomous Communities define the curriculum in greater detail, manage schools, regulate teacher training, and implement most public spending. This multilevel architecture, while enriching the diversity of approaches, also introduces an inherent complexity in terms of coordination, which should be considered when assessing the adequacy of the regulatory framework.

Spain has the basic regulatory elements in place: the LOMLOE establishes digital competence as a cross-curricular subject, the MRCDD provides an educational framework, and the Spain Digital Agenda 2026 channels significant investment.

The LOMLOE and digital competence (Organic Law 3/2020)

- **Digital competence as a key competence:** This is specified in five operational descriptors within the student learning outcomes. Digital competence is addressed across the board in all areas and subjects. In secondary education, the subject 'Technology and Digitalization' explicitly includes interaction with emerging technologies such as AI, the Internet of Things (IoT) and *Big Data.*
- **Institutional framework for digitalization:** Article 111 bis stipulates that virtual learning environments must contribute to extending the concept of the classroom in time and space, and that public authorities must establish conditions to eliminate risks arising from ICT. Article 121 requires that each school's educational project incorporate a digital strategy.
- **Mandate for equitable access:** Public authorities shall ensure that all students have access to the necessary digital resources.
- **Investments:** The ENIA and the Spain Digital Agenda 2026 allocated €1.41 billion (2021–2024) for the digitalization of education. In May 2025, the INEE carried out the first pilot assessment of digital competence in Year 6 of primary school.

Note: the LOMLOE was approved before the emergence of generative AI. It contains no specific provisions on the use of AI in the classroom or automated grading.

Complementary frameworks and regional regulations

- **Digitalization and Digital Competences Plan *(#DigEdu):*** As part of the Recovery Plan, it sets out four strands: (1) Improving digital competence in education; (2) digitalization of schools through School Digital Plans; (3) creation of digital educational resources; and (4) advanced methodologies and competences, including AI and personalized learning.
- **Reference Framework for Teachers' Digital Competence (MRCDD, 2022):** Adapts the European DigCompEdu to the Spanish context. It is structured around 6 competence areas and 23 competences, with a progression model comprising 3 stages and 6 levels (A1–C2). It includes personal data protection and digital rights. Developed by INTEF in collaboration with representatives from all the autonomous communities.
- **European AI Regulation (*AI Act,* UE 2024/1689):** In force from August 2025. Education falls into the high-risk category: AI systems used to determine access to educational institutions, assess results, monitor behaviour during exams or adapt the level of teaching are subject to strict requirements regarding transparency, human oversight and data quality. For Spain, this poses a twofold challenge: adapting national regulations and developing operational guidelines for educational institutions.
- **Regional regulation of mobile phones (2024-2025):** Virtually all autonomous communities have regulated the use of mobile phones. Most opt for a ban or restriction. La Rioja, Navarre, the Basque Country and Asturias prefer recommendations and training. Exceptions in primary schools are limited to health or special educational needs; in secondary schools, most allow use for educational purposes. The scope varies: Cantabria, Catalonia and the Basque Country include smartwatches; Madrid extends this to computers and tablets.

However, international experience shows that what determines success is not the ambition of the regulations or the scale of investment, but the quality of implementation: the gradual roll-out, the preparation of intermediary actors and the existence of feedback mechanisms.

Four international cases: lessons on the gap between policy and practice

SOUTH KOREA
Cancelled after 4 months

AI *Digital Textbook* (2023): $850 million on books with adaptive AI for primary and secondary schools. Content errors, recurring technical faults, protests from families over screen overexposure and data protection. Reclassified as "supplementary materials".

Lesson: No phased roll-out. Teachers excluded from the design process.

SINGAPORE
Successful roll-out

EdTech Masterplan 2030 + Ethical framework for AI in education based on agency, inclusivity, equity and safety. AI tools[8] with safeguards in *Student Learning Space (SLS):*[9] *Teaching, Feedback and Learning Assistants + Adaptive Learning System.*

Lesson: 23 years of institutional development. Teachers at the heart of the process.

FRANCE
Operational framework underway

AI framework in education (June 2025). Mandatory Pix certification with an AI pathway for pupils and teachers. *P2IA alliance for the development of national EdTech with digital sovereignty. European AI4T project for teacher training.*[10] [11]

Lesson: AI integrated into existing certification (Pix/DigComp).

ESTONIA
Mature ecosystem

AI Leap (2025): 20,000 students + 3,000 teachers using AI apps. Teacher training BEFORE roll-out. Participatory curriculum design. Digital infrastructure: *eKool* (90% of the school network) on *X-Road.*[12] Digital literacy compulsory since 2014.

Lesson: 30 years of institutional layers. Experimental and adaptive approach.

8 These include *Teaching Assistants* (support for teaching practice), *Feedback Assistants* (automated feedback with human supervision), *Learning Assistant* (guiding students through questions in different roles) and *Adaptive Learning System* (generating personalized learning pathways based on each student's level).

9 *Student Learning Space (SLS)* is the national online learning platform.

10 Alliance for Innovation in AI *(P2IA)*: this public procurement programme aims to support the development of French AI-based *EdTech* solutions, in line with digital sovereignty and data security requirements.

11 The *AI4T (Artificial Intelligence for and by Teachers)* project was designed by France, Slovenia, Italy, Ireland and Luxembourg to contribute to AI training in education, aimed at teachers and school leaders.

12 *eKool* is a school management system covering 90% of the school network and connecting pupils, families, teachers and school authorities. It operates on X-Road, the national data exchange platform, and allows access via a national digital identity. Its use covers grades, attendance, homework, communication and real-time monitoring of academic progress.

What distinguishes Singapore and Estonia from South Korea is not investment or ambition but having first built the actors and processes that turn policy into practice: teacher training prior to roll-out, digital coordinators in every school, gradual piloting with feedback. Viewed from this perspective, the Spanish ecosystem has two key shortcomings: in teacher accreditation and in the intermediary actors operating between policy and the classroom.

Shortcomings in teacher accreditation

The main objective of the *#DigEdu Plan* was to accredit 80% of the approximately 700,000 non-university teachers by the end of 2024. According to INTEF (April 2024), the *#CompDigEdu* programme managed to accredit 407,006 teachers (72% of the target). These figures are supported by TALIS 2024: 74% of secondary school teachers consider themselves digitally competent. However, if 75% of teachers who do not use AI cite a lack of training as the main reason (Condition 2), the question is why the accreditation system does not provide it. The limitations of Spanish teachers documented in the previous condition (low specific training in AI, lack of incentives to train) are reflected in structural limitations of the framework itself:

→ **An accreditation framework predating generative AI.** The MRCDD (approved in March 2022) does not include AI as a specific competence. AI appears sporadically, primarily in data protection and at advanced levels (C1-C2). Given that most accreditations are concentrated at A1-B1, the training does not address the competences demanded by the new reality.

→ **Accreditations concentrated at basic levels.** The national accreditation regulations were not approved until July 2023 (Order EFP/823/2023). Higher levels (B2, C1, C2) require assessment based on evidence and observation of classroom performance — processes that are not yet widespread. It is likely that a significant proportion corresponds to basic levels, sufficient for the quantitative indicator but insufficient for a qualitative transformation.

→ **Accreditation does not guarantee use.** Digital empowerment also requires motivation, comfort and an institutional environment (Cortés Jiménez, 2024). Female teachers show less initiative in using technology (59.8% vs. 61.9%); teachers aged 56–65 have up to 7.4 percentage points lower digital empowerment; lower secondary education (ESO) emerges as the level requiring the most support.

Intermediary actors: between policy and the classroom

→ **ICT Coordinators / Educational Digital Transformation (EDT) Coordinators:** Each school must appoint a coordinator responsible for promoting digital competence, facilitating internal mentoring, disseminating reference frameworks and exercising delegated leadership in digital matters. However, the allocation of hours and resources vary substantially between autonomous communities, and there is no register to indicate how many schools have an operational EDT coordinator.

→ **Educational Inspectorate:** The LOMLOE assigns to the Inspectorate the supervision of management functions (Art. 151.b) and the evaluation of schools. Inspectors are well-positioned to verify whether School Digital Plans are implemented in practice, but their training in digital matters and their operational protocols have not been systematically updated at a national level.

→ **Teacher training centers and advisers:** Teacher training in digital skills is managed in a decentralized manner (CEP, CTIF, CFR depending on the autonomous community). The intensity, quality and coverage vary considerably between regions, with no mechanism for comparative evaluation.

The lack of aggregated data on these stakeholders constitutes a significant gap in itself: it is not possible to manage what is not measured.

Gaps to be closed between the regulatory framework and the conditions for effective integration

An analysis of the Spanish regulatory framework, compared with international standards and the state of the implementation ecosystem, identifies four gaps that limit the education system's ability to harness the potential of ICT and AI as a pedagogical complement:

1. **Lack of operational guidelines on AI in compulsory education.** Spain lacks specific guidelines to advise schools on how to integrate generative AI tools into teaching practice, assessment and classroom management. As noted at the beginning of this section, the high-level regulatory framework (LOMLOE, MRCDD, AI Act) is already in place; what the system needs is to strengthen the operational instruments—orders, circulars, and instructions—that specify how schools should integrate AI with the necessary pedagogical safeguards. In addition, these instruments are binding within their territorial scope and are quicker to adopt and revise than higher-ranking legislation, which allows them to keep pace more effectively with the speed at which technology evolves. The creation of the Spanish AI Supervisory Agency envisaged in the ENIA could address this shortcoming, but its current mandate does not explicitly include the non-university education sector.

2. **Disconnect between restriction policy and technology integration policy.** The wave of regional regulations in 2024–2025 has focused on banning personal mobile devices, but without establishing a complementary framework defining how schools should integrate digital technologies with pedagogical safeguards.

3. **Teacher training in ICT/AI without binding certification or assessment of outcomes.** The MRCDD establishes a robust competency framework, but its implementation lacks a mandatory certification system comparable to the French *Pix*. Teacher training in digital skills is managed in a decentralized manner by each autonomous community, with varying levels of intensity and quality, and there is no evaluation mechanism to measure teachers' digital competence at a national level. The MRCDD itself recognizes AI among its achievement indicators, but this has not translated into widespread specific training programmes.

4. **Dedicated time.** Training and accreditation are necessary but insufficient conditions if teachers do not have time within their working hours to practice with new tools, receive support and apply what they have learnt in the classroom. **In Spain, this aspect is not regulated at national level**: there is no common standard guaranteeing dedicated time for training and technology integration within teachers' working hours. Allocation depends on each autonomous community and the internal organization of each school, resulting in a highly uneven distribution. Systems that have integrated technology with the best results — such as Singapore, which reduces the teaching load of novice teachers so that they have time for learning and mentoring — regulate this allocation, safeguarding teachers' non-teaching time (OECD, 2021). In the absence of such regulation, technological integration competes for time that, as documented in the previous section, is already scarce.

PHASE 2: PREPARING STUDENTS FOR THE SUCCESSFUL INTEGRATION OF ICT AND AI INTO LEARNING

PHASE 2 — Prepared Student Body

Infrastructure, trained teaching staff and an enabling regulatory framework are necessary, but not sufficient, conditions to ensure that ICT and AI support learning. This section addresses the conditions on the student side: first, what skills students need *to acquire before incorporating digital tools* so that technology functions as a complement rather than a substitute. And, secondly, an assessment and specific proposals for each stage of education.

What pupils need before AI

The emergence of generative AI does not change the role of schools, but it does make clearer what that role should be. Current models produce texts, solve problems and combine ideas with a fluency that, until recently, we considered distinctly human. This means that the value of what a student can do for themselves can no longer be taken for granted: it depends on whether they have acquired the skills that allow them to use these tools as a complement to their own thinking, rather than as a shortcut that replaces it. Therefore, school cannot be viewed solely as a space for the transmission of knowledge. It is also a key space for a deep understanding of that knowledge, and where the skills enabling students to interact productively with technology must be developed; these encompass four dimensions:

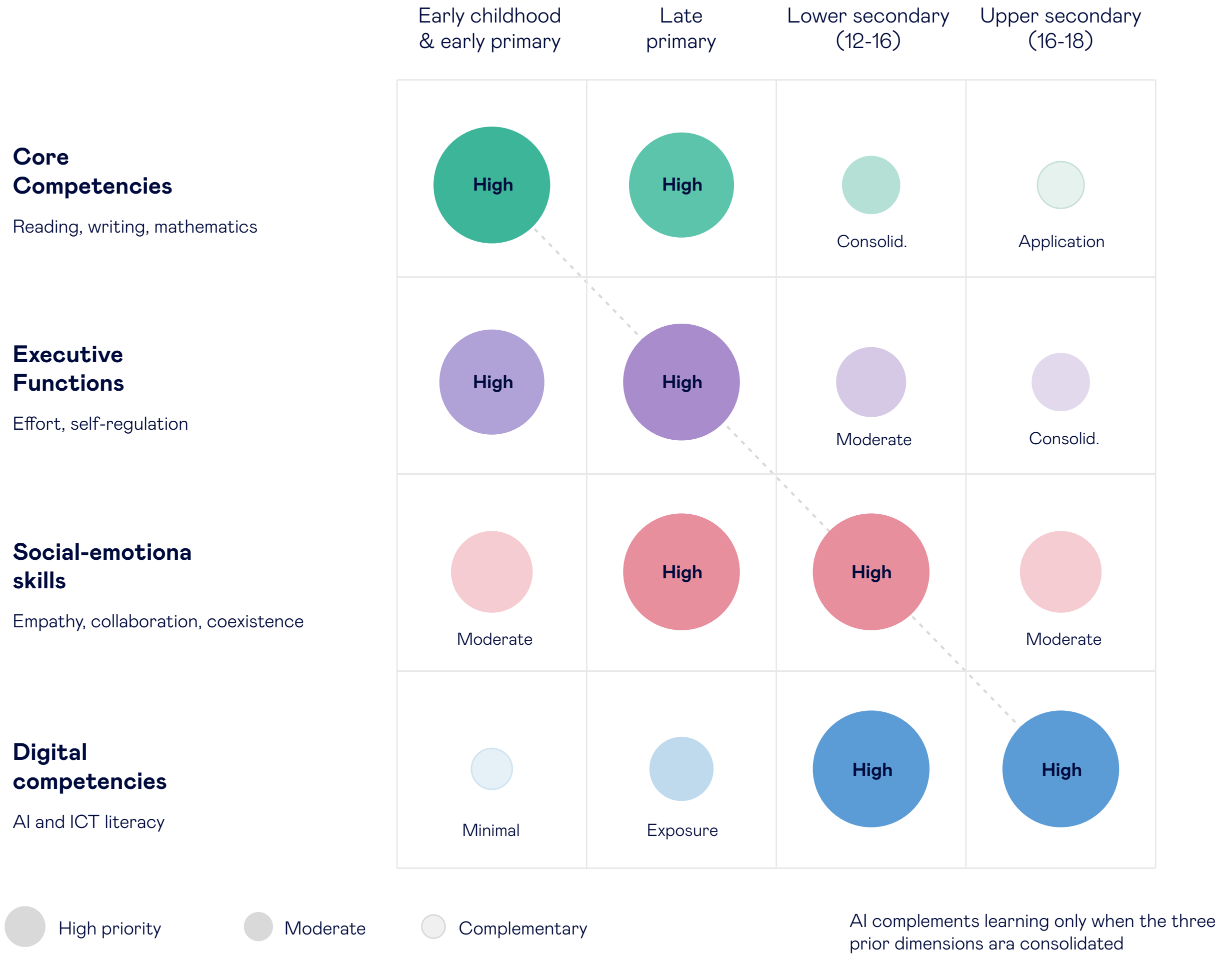
D1. Prioritising the acquisition of fundamental basic skills: reading, writing and mathematics (and in particular critical thinking and reflection on these subjects) form the foundation without which no technological tool can be productive. Complex cognitive skills (such as deep reading, critical thinking and advanced writing) may be undermined by the incorporation of digital technologies without a well-defined pedagogical purpose backed by evidence.

D2. Executive functions, effort and learning abilities: In an environment where ICT and AI offer immediate answers, students' ability to resist instant gratification, maintain sustained concentration, self-regulate and adapt their thinking to new information is more critical than ever. These skills can and must be actively developed in schools, from early years through to secondary education, using teaching strategies that promote productive effort, reflection and self-regulation (Diamond and Lee, 2011; Zelazo, Blair, & Willoughby, 2016). As Rebecca Winthrop states, 'schools must teach children to do difficult things before they start interacting with AI'.

D3. Social and emotional skills: collaboration, empathy, emotional regulation, tolerance and civic mindedness are skills whose development benefits particularly from face-to-face interaction. In a world of increasing polarization of discourse and online interactions, school is one of the most prevalent social institutions where pupils can meet other people in person (outside their family and neighborhood) and constitutes a fundamental counterbalance for developing the skills necessary for coexistence (Burns et al., 2026).

D4. Digital and technological skills: these skills are only effective when built upon the three previous dimensions. The World Economic Forum has noted that AI literacy will be one of the defining skills of the 21st century, comparable to what basic literacy was in the 20th century (WEF, 2025). Adding digital competence and the pedagogically oriented use of tech on top of basic skills would add to critical thinking, self-regulation, and collaboration. However, digital competence without critical thinking, self-regulation and the ability to collaborate turns students into passive users of tools they do not understand, unable to make the most of them or evaluate them.

The relative priority of each dimension varies according to the stage of education and must be integrated in parallel and in coordination with all the digital tools incorporated into each stage. The following figure summarizes this relationship: basic skills and executive functions are a prerequisite for digital skills to be productive, rather than merely a substitute.



Source: Own elaboration | EsadeEcPol

Building on this framework, the following sections examine the actual situation of Spanish pupils at each stage of education, identifying where technology can add the most value and where the risks of inappropriate implementation are highest.

Differentiated integration of technology for each stage of education

It is not only pupils' basic abilities that evolve with age: so too do the pedagogical challenges of the system and, with them, the type of technology that can add value. In primary education, the central challenge is to consolidate basic skills at a time of high cognitive plasticity; in secondary education, to sustain learning pathways that are beginning to diverge; and in post-compulsory education, to support increasingly significant decisions.

Levels of technological sophistication in education

The literature distinguishes four levels of educational technology, whose conclusions regarding effectiveness are not transferable between them:

- **Basic ICT:** access to devices, connectivity and static digital content (videos, digital whiteboards). Necessary infrastructure, but the mere provision of which, without associated pedagogical design, does not produce systematic improvements in academic outcomes (J-PAL, 2019).
- **Interactive digital platforms:** tools featuring exercises, immediate feedback, progress tracking dashboards for the teacher and, occasionally, gamification elements, but without automatic adaptation of content to the individual student's level. All students work on the same exercises; personalization depends on human intervention by the teacher or an external coordinator.
- **Computer-assisted learning (CAL):** platforms that automatically adjust the difficulty, sequence and type of exercises based on the student's individual performance, without manual intervention by the teacher to make such adjustments.
- **Artificial intelligence applied to education:** systems that use *machine learning* models or natural language processing to personalize learning in real time in ways that predefined algorithms cannot. This includes both AI applied in the classroom (teacher assistants, *chatbots*, AI-powered CAL) and system-level analytics (early detection, aggregated trajectories, supply-demand alignment).

Positive outcomes can emerge at different levels of technological sophistication, provided certain implementation conditions are met.

Using these four levels as a framework, the three stages that follow are addressed using the same structure: specific context, where technology can add value, and key recommendations.

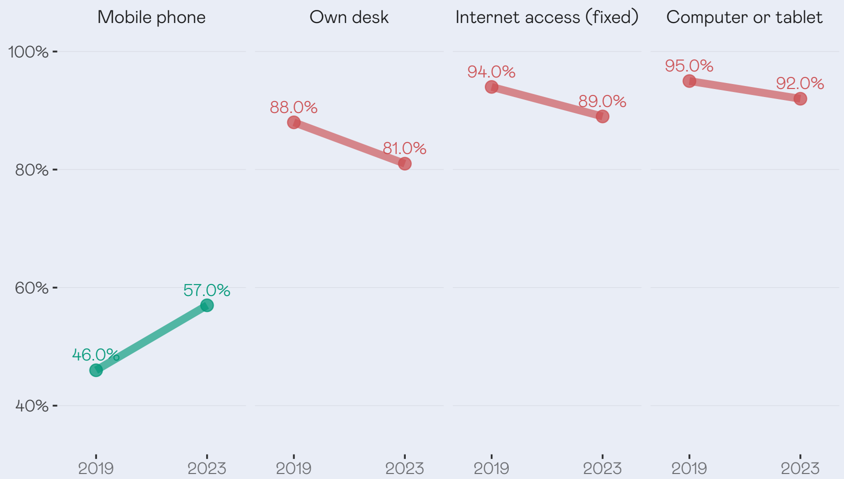
6-12 · Primary education

Context · Basic skills in difficulty: outcomes and associated factors

Basic skills (reading and mathematics). The results of the 2023 TIMSS show that Spain performed poorly in the Year 4 mathematics tests compared with the OECD countries taking part in the survey. Spain scored 498 points in mathematics, compared to the OECD average of 525 and the EU average of 514, representing a 27-point gap with the OECD — equivalent to more than half a year of schooling. Among the participating autonomous communities, Castile and León, the Principality of Asturias, the Community of Madrid and the Community of Navarre are the regions with the highest scores (between 522 and 517 points), all of which are above the EU average and close to the OECD average. In contrast, Catalonia, the Canary Islands and the Balearic Islands fell below the national average; in the case of the Balearic Islands, their average lies on the border between low and intermediate performance levels (MEFPD, 2024). The results of the 2021 PIRLS test show that Spanish Year 4 primary school pupils achieved an average of 521 points in reading literacy, compared to the OECD average of 533 and the EU average of 528, a 12-point difference from the OECD average, which is smaller than that observed in mathematics with TIMSS. Asturias (550), the Community of Madrid (539) and Castile and León (538) achieved scores significantly higher than the national average, whilst the Canary Islands (510), Catalonia (507), Melilla (499) and Ceuta (498) were significantly below it (MEFPD, 2023).
Factors associated with the decline. Microdata analysis (Gortazar & Cahu, 2025) identifies three main factors.

1. The deterioration of children's social conditions: problems relating to nutrition and food security increased by 50% in Spain between 2019 and 2023, with an estimated negative impact of almost 3 points.
2. The growing language gap: only just over half of primary school pupils are fully familiar with the language of instruction, and the proportion who never speak it at home rose from 8.6% to 12.4% between 2019 and 2023.
3. The decline in household items that facilitate study: the presence in the home of devices most conducive to the effective use of technology for learning is declining

Percentage of 4th-grade students who have the following goods at home



Source: Own elaboration based on TIMSS 2019 and 2023 data | EsadeEcPol

- **Observation of learning patterns.** Large-scale standardized assessment systems, combined with longitudinal analytics, enable the identification of aggregate patterns within the system that reveal when and where interventions may be most effective in primary education. This information cannot be detected through one-off or disaggregated assessments.

  For example, Martinot et al. (2025) utilize the French national EvalAide programme, implemented by the Ministry of Education (DEPP), to systematically assess all pupils in Years 1 and 2 of primary school at three points during the academic year, and conduct a longitudinal analysis of 2,653,082 children across four consecutive cohorts (2018–2021). The analysis shows that, despite starting with virtually identical scores, girls and boys develop a math's gap in favor of boys within just four months of schooling, reaching an effect size of 0.20 by the end of the first year and replicating year after year regardless of family type, classroom, school or socioeconomic status. By exploiting the quasi-orthogonal variation between age and school exposure, the authors also demonstrate that the gap widens with schooling (not with maturation), which allows for the precise identification of the point at which intervention resources should be concentrated.

- **Digital platforms.** Araya, et al. (2025) use an RCT to evaluate the integration of a digital math's learning platform into the regular school timetable for Year 4 pupils. The programme included an external coordinator who assisted teachers in integrating the platform into classroom sessions. The students who benefited scored 0.27 standard deviations higher than the control group in the national standardized test.

- **Computer-assisted learning (CAL) in mathematics.** Oreopoulos, et al. (2024), in a randomized controlled trial involving pupils in Years 3 to 6 in the Arlington school district, Texas (United States), evaluated the impact of integrating *Khan Academy* into mathematics instruction with the support of teacher training. Pupils in Years 3 to 6 whose teachers participated in the programme scored between 0.12 and 0.17 standard deviations higher on the state standardized mathematics assessment (*STAAR*). A key finding of the study is that, when analyzing variation within the treatment group, the effects were only evident in classrooms where pupils practiced for at least 35 minutes per week, whereas no effect was detected in classrooms with less than 5 minutes of practice. Furthermore, the authors show that variation in practice time depended largely on teacher commitment: teachers with the best results planned specific weekly routines for practice, incorporated the digital learning platform as a compulsory part of their curriculum, actively monitored each pupil's progress, and intervened when they detected stagnation. This suggests that the effectiveness of educational technology does not lie in the platform itself, but in the quality of the accompanying teacher implementation, and that the optimal intensity of use appears to be of moderate duration (more than 35 minutes per week).

- **Artificial intelligence as a new tool.** The systematic review by Yim and Su (2025), which analyses 25 studies on AI in primary school contexts published between 2019 and 2024, provides evidence on the outcomes that AI can produce at these ages. Of these, 15 reported positive outcomes across three dimensions (academic, affective and behavioral), including improvements in computational thinking, creativity, problem-solving and motivation to learn. The most effective pedagogical strategies identified were project-based learning, programming and human-agent interaction with collaborative learning, supported by age-appropriate tools such as *Scratch, MIT App Inventor or Google Teachable Machine*. The authors also conclude that learning outcomes in AI are significantly influenced by students' prior experience with computers and programming, reinforcing the idea that educational technology does not operate in a vacuum, but builds upon previously acquired digital skills.

Furthermore, the review conducted by (Boulhrir & Hamash, 2025) of 80 studies published between 2013 and 2023 shows that the areas where research in primary education has been most concentrated are precisely personalized and adaptive education, intelligent tutoring systems (ITS), literacy and mathematics. The review highlights that ITS, conversational agents and other adaptive tools can tailor content to the pupil's level, adjust the difficulty of tasks and provide immediate feedback, which is particularly useful for pupils with diverse learning profiles or specific educational needs. It also concludes that the most promising results are seen in reading and mathematics, although it cautions that the evidence remains mixed and that significant limitations persist, such as small sample sizes, non-standardized tests and a lack of longitudinal studies.

However, these benefits are neither automatic nor risk-free. Yim y Su (2025) caution that the current literature focuses on technical skills and neglects the ethical and social implications of AI, and they advocate placing ethics at the centre of the curriculum rather than as a secondary add-on. This suggests a coherent pedagogical progression throughout primary education: in the early years, the focus should be on developing basic digital skills and the responsible use of devices, whilst in the later years, when AI tools are introduced, it is essential to accompany their use with the explicit teaching of ethical principles such as algorithmic bias, privacy, data fairness and user responsibility.

✱✱ **AI + CAL: a combination with potential.** Furthermore, Cuevas-Ruiz, Rello, Sanz y Sevilla (2025) evaluate *DytectiveU*, an AI-powered computer-assisted learning programme implemented by the Community of Madrid to strengthen reading skills in primary education. The study analyses data from 34,607 pupils across 264 state schools in Madrid over five academic years. The results show that each additional session of the programme improves progress in reading skills by 2.4% of a standard deviation, equivalent to one month of learning. The study also identifies two key mechanisms behind these effects: content personalization, which adapts exercises to the student's age, usage history and previous performance; and real-time adaptive *feedback*, which dynamically adjusts the difficulty of tasks. The benefits are particularly evident among younger pupils, suggesting that personalization is especially valuable in the early stages of reading acquisition.

Key recommendations

→ **Introduce technology progressively:** gradually introduce digital practice through CAL (Computer - Assisted - Learning) in punctuated, well-defined moments — whether individualised or through supervised collaborative work. The integration should be progressive, allowing learners to familiarise themselves with digital tools step by step as foundational skills are consolidated.

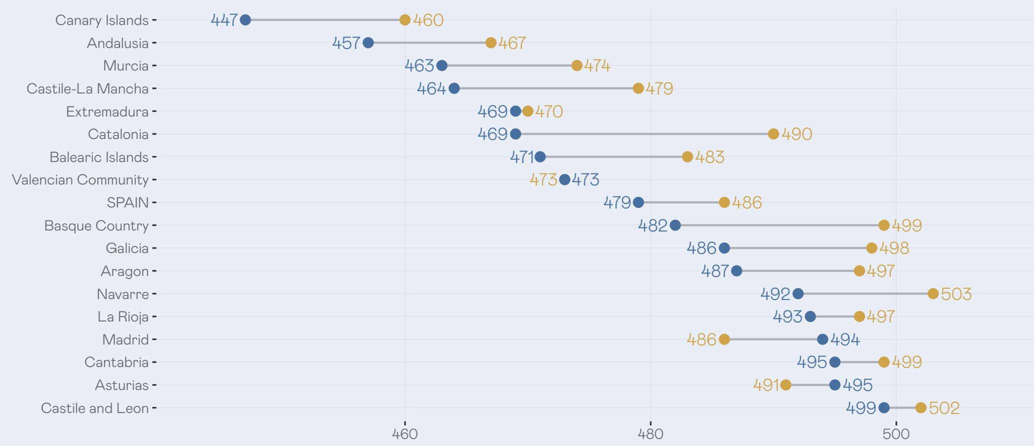
→ **In Years 5 and 6, combine the use of AI with ethical literacy:** integrate the teaching of principles such as algorithmic bias, privacy, data fairness and user responsibility, to prevent misuse of technology.

Context · A system under pressure: repetition, gaps and fragmented attention

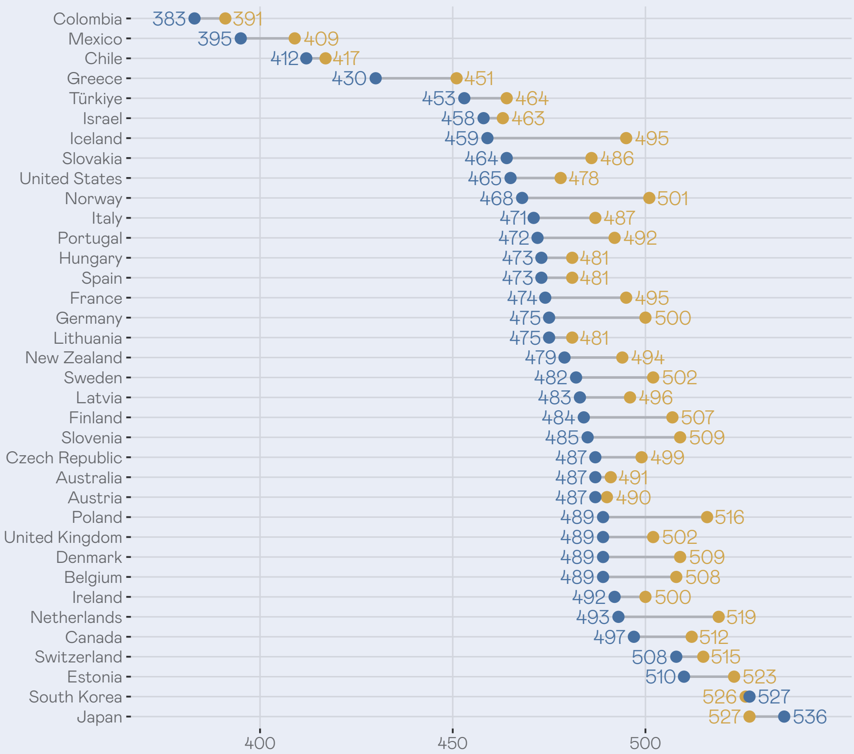
Basic skills (reading and mathematics)

The PISA 2022 results show a 15-point drop in the OECD average score for mathematics. In Spain, scores fell from 481 to 473 points. At regional level, Castile and León, Asturias and Cantabria reported the highest performance (with levels comparable to Canada or the Netherlands), whilst the Canary Islands and Andalusia recorded the lowest levels. The sharpest decline occurred in Catalonia, the Basque Country and Castile-La Mancha, in all three cases by more than 15 points, and only Asturias and Madrid improved their results between 2018 and 2022 (Cobreros and Gortazar, 2023).

PISA mathematics results: 2018 and 2022 , by autonomous community



By Country



Source: Own elaboration based on PISA microdata (2018, 2022) | EsadeEcPol

The PISA 2022 context questionnaires allow us to delve deeper into the factors behind this decline. At least three stand out.

1. **Repeating a year.** Spain ranks among the OECD countries with the highest repetition rates, which carries with it a higher risk of early school leaving. In PISA 2022, Spain remains the fourth OECD country and third EU-27 country to make the most use of this practice: 22% of pupils have repeated a year at least once by the age of 15. This figure reflects a specific moment in the system (marked by the exceptional measures adopted during the pandemic), which calls for caution regarding its evolution in future PISA cycles. Furthermore, the data show that, for the same level of performance, 25% of students from lower socioeconomic backgrounds are almost four times more likely to repeat a year than the 25% from higher socioeconomic backgrounds (Cobreros and Gortazar, 2023). In response to this, the European Commission recommends the early identification of students at risk of underachievement and the provision of specific, individualized support. The evidence highlights the effectiveness of regular tutoring, either one-to-one or in small groups, delivered by trained tutors during the school day.

2. **Socio-economic and gender gaps.** PISA 2022 shows that, in Spain, students in the highest socio-economic quartile score 86 points higher in mathematics than those in the lowest quartile, and that socio-economic status accounts for around 16% of the variation in performance in this skill. Although these gaps are not particularly large for Spain compared to its peers, analysis by autonomous community reveals that Asturias and the Basque Country exhibit lower equity in learning, whilst in Cantabria and Galicia the proportion of variation explained by socio-economic status is lower, placing them among the most equitable communities in this regard.

   In addition, the data also show a gender gap in mathematics: in Spain, boys score 10 points higher than girls, a difference slightly above the OECD average (8.9 points)[13]. Furthermore, this gap has widened in most autonomous communities between 2018 and 2022. The extent of this gap varies considerably between regions: the differences are particularly high in Cantabria and the Community of Madrid, whilst in regions such as Catalonia and the Basque Country the observed gaps are smaller.

3. **Classroom atmosphere.** In the context of secondary education, PISA 2022 data point to a significant deterioration of the classroom climate in Spain, particularly in mathematics, where the decline has been sharper than the OECD and EU-27 averages. This worsening also shows a clear territorial dimension: it is especially pronounced in Asturias, Andalusia, Catalonia, Murcia and the Basque Country, while Galicia and Castile and León stand out as the only regions to have improved over the period.

Behavioural indicators reinforce this picture. In 2022, about 22% of students in Spain reported that they cannot work well in most or all lessons (OECD average: 23%); while 38% of students reported that their classmates do not listen to what the teacher says (OECD average: 30%).

13 The OECD also notes that this pattern is reversed in reading, where girls outperform boys by 25 points.

Empirical evidence on the use of AI in secondary education is still in its infancy, but points to three mechanisms with potential: early identification of students at risk, personalized tutoring and narrowing the gender gap.

* **Understanding learning trajectories and early identification of at-risk pupils.** The use of technology and data analytics can serve two complementary purposes. On the one hand, as already noted in primary education, Martinot et al. (2025) demonstrate how large-scale longitudinal analytics enables the identification of the learning trajectories of the entire student body, which factors are associated with greater academic growth, and at what points interventions are most effective. On the other hand, *machine learning* algorithms allow for a more accurate prediction of which students are at risk of repeating a year or dropping out, by incorporating complex factors such as motivation or mental health, which enhance the effectiveness of predictive models.

  For example, Psyridou et al. (2024) use 13 years of longitudinal data—including academic skills, motivation, behavior and well-being—from 2,000 students in four municipalities in Finland to demonstrate that predictive models can accurately identify the risk of dropping out in upper secondary school as early as the end of primary school (Year 6), with only a slight decrease in accuracy compared to predictions made at the end of lower secondary education. This finding suggests that the risk factors leading to dropout in upper secondary school are detectable during lower secondary education.

** **Personalised support.** Evidence on the personalization of learning through technology has been accumulating over the last decade, from computer-assisted learning (CAL) systems to the latest tools based on generative AI. An early reference is provided by the RCT by Roschelle et al. (2016), which evaluated the *ASSISTments* platform with 2,850 Year 7 pupils in 43 schools in the state of Maine (USA). The tool offers pupils immediate *feedback* and hints as they solve math's problems assigned as homework. After a full academic year of implementation, the treatment group achieved significantly higher scores on the standardized test, with an effect size of 0.18 standard deviations compared to the control group.[14]

  Similarly, the research by Muralidharan et al. (2019) showed significant gains in math's and language through personalized computer-based instruction, and, furthermore, the relative effects for the most underachieving pupils were greater.

  In the European context, Vanzo et al. (2024) conducted an RCT at a secondary school in Verona (Italy) that replaced traditional English homework with interactive sessions using a *genAI-powered* chatbot over 8 weeks, involving 76 secondary school students across four classes. Although the students responded positively to the AI and reported positive experiences in the short term, learning progress did not differ significantly between groups. However, those who started at a lower initial level did benefit more from the tutoring.

* **AI as a tool for reducing the gender gap.** The report by the OECD and Fondazione Agnelli (2025) notes that several of the factors contributing to girls' lower performance in mathematics interact in a cumulative manner. For example, early anxiety and the threat of stereotyping can reduce participation in class; lower participation can limit the choice of advanced courses; and reduced exposure to these courses can negatively affect both competence and confidence. From this perspective, the report explores how AI could help mitigate these dynamics. Although the evidence remains limited, the available findings point in two promising directions. The first is the use of AI to expand opportunities for digital mentoring, with the aim of boosting girls' confidence, participation and persistence in STEM pathways. The second is the use of AI to support teachers, through tools capable of detecting less equitable patterns of interaction in the classroom.

14 These effects correspond, respectively, to an advantage of 8.84 points over the control group (0.18 sd), and of 13.35 points (0.29 sd) and 5.84 points (0.12 sd) in the subgroups with lower and higher prior achievement.

The OECD cites TeachFX, an application that analyses classroom dialogue in real time and identifies, among other things, potential gender disparities in teacher-student interactions. Pilot studies suggest that it can promote more equitable participation by alerting teachers to unconscious biases.

Meanwhile, an example of digital mentoring is *CyberMentor*, a German programme aimed at secondary school girls interested in STEM. The platform pairs pupils with mentors who are studying or working in these fields through an interest-based matching system and incorporates weekly communication and *networking* opportunities. The long-term follow-up study analyses 410 former participants and compares them both with women from the same age cohort and with 71 girls who registered for the programme but did not end up participating; for this second comparison, the authors use propensity score matching. The results show a higher probability of choosing STEM studies or career paths among the participants: (Stoeger et al., 2023).

Key recommendations

→ **Build a pathway analytics infrastructure that enables an understanding of how students learn and identifies those at risk:** data analytics allows us to understand how the student body as a whole is progressing, which factors are associated with greater academic growth, and at what points interventions are most effective; Furthermore, *machine learning* models can accurately identify students at risk of repeating a year or dropping out, incorporating factors that go beyond grades. Spain has the necessary data to move in this direction (PISA context questionnaires, regional diagnostic assessments, academic records), but these are currently used in a fragmented manner. Investing in integrating them under common frameworks with clear privacy safeguards would enable the autonomous communities to shift from a reactive approach (detecting underachievement once it has already taken hold) to a preventive one.

→ **Direct investment in educational technology and AI towards tools with evidence of a differential impact in favor of students with the greatest difficulties, to reduce achievement gaps:** The studies reviewed in this section show that the greatest benefits are concentrated among students with the lowest prior performance. This makes these tools a particularly relevant instrument for addressing the gaps documented by PISA 2022 in Spain.

→ **Establish clear frameworks on when technology[15] adds value and when its use should be restricted, recognizing that the problem is not the technology itself but its unguided use:** A coherent policy on educational technology must recognize that the evidence points in two seemingly contradictory but compatible directions: when used well, technology can improve learning and reduce gaps; when used poorly, it undermines the classroom atmosphere and can negatively affect learning. It is therefore important to clearly distinguish the moments and tasks in which technology fulfils a clear pedagogical function.

15 Or what types of devices and/or technologies.

12-18 · Post-compulsory education

Context · Fragile pathways: retention, pathways and links to employment

Given its aim of sustaining student retention in the system, supporting increasingly important academic and vocational decisions, and providing effective preparation for higher education or entry into the labor market, it is particularly important to analyze educational and career pathways. Three dimensions encapsulate the main challenges of this stage.

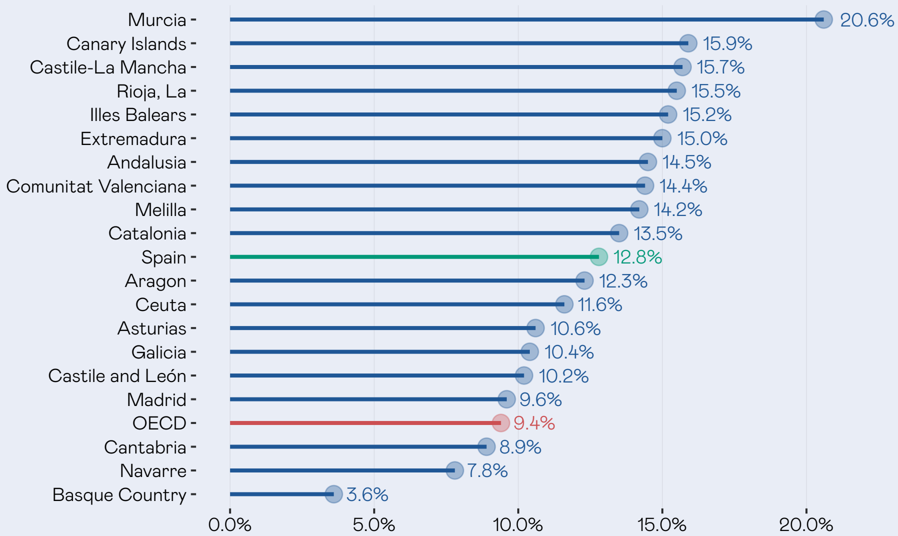
1. Retention in the system and early leaving. The latest data from the MEFPD show that early leaving from education[16] and training stood at 12.8% in 2025, its lowest level in the historical series. Even so, this figure is above the OECD average, with significant regional disparities.

Data by autonomous community show significant variation, with differences of more than 15 percentage points between the extremes. Furthermore, in communities such as Castilla-La Mancha, Extremadura and Cantabria, the figures observed in 2025 are higher than those recorded in 2024, suggesting that the overall improvement at national level is not distributed evenly across regions.

This pattern highlights the system's difficulty in sustaining full educational pathways and preventing early school leavers, thereby reducing education's capacity to improve labor market integration and reduce inequalities.

Early leavers from education and training

By autonomous community



Source: Own elaboration based on MEFPD (2025) data | EsadeEcPol

16 Definition of early leavers from education and training: Percentage of the population aged 18 to 24 who have not completed upper secondary education and are not in any form of education or training.

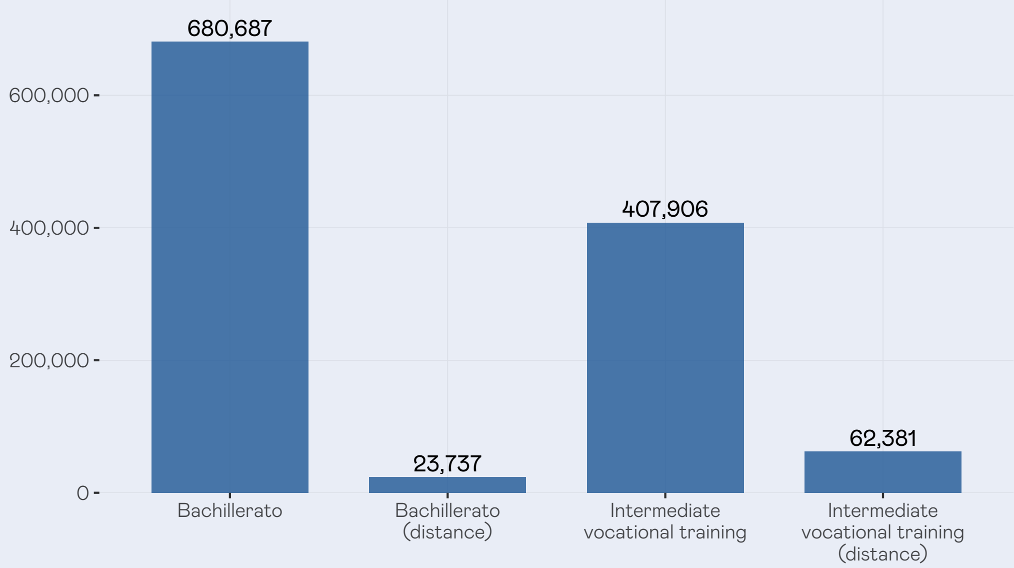
For this reason, the OECD recommends strengthening early risk identification, improving guidance and providing more personalized support during transitional periods, particularly after lower secondary education.

2. Inequality in the choice of pathways. The choice between A-levels and vocational training does not take place on a level playing field: students reach this point with advantages and disadvantages accumulated throughout their compulsory schooling, which influence both the pathway chosen and the likelihood of successfully completing it. Student profiles differ significantly: Expósito-Casas et al. (2024) show that repeating a year is one of the main predictors of a move towards the vocational pathway.

At the national level, OECD data confirm that Spain is one of the countries with the lowest proportion of young adults holding an upper secondary vocational qualification (10.6%, compared to the OECD average), reflecting both a problem in attracting students to this pathway and in retaining them within it (OECD, 2025). Furthermore, nearly 30% of upper secondary students in Spain are enrolled in programmes which, although they award a full qualification, do not provide direct access to tertiary education, thereby limiting the progression options for vocational education and training (VET) students.

Student enrolled in upper-secondary education

Academic year 2024-2025 (national total)



Source: Own elaboration based on MEFPD (2025) data | EsadeEcPol

This choice is not solely determined by differences in academic performance or career preferences: it is also influenced by the quality of the guidance received, family expectations and access to information about the various educational options – resources that are distributed unevenly according to a household's socio-economic status. In fact, data from *Education at a Glance 2025* for Spain show that 75% of young people aged 25–34 with at least one parent with tertiary education also obtain a tertiary qualification, compared with only 30% of those whose parents did not complete upper secondary education (OECD, 2025).

3. Disconnect between the education system and the demands of the labor market. The third challenge is to ensure that those who complete upper secondary education or vocational training acquire skills that facilitate effective entry into the labor market, a link that the data suggest is weak. Among young people aged 25–34 with upper secondary or post-secondary non-tertiary education, the unemployment rate in Spain stands at 13.7%, which is double the OECD average (6.9%). Similarly, data from the European Commission (2025) show that the employment rate for recent graduates of intermediate-level vocational training (68.6%) is well below the European average (80.0%).

Added to this is the fact that in Spain, 42% of the adult population has a high-level qualification and 35.1% a low-level qualification, but only 22.9% has an intermediate-level qualification (European Commission, 2025). This shortfall at the intermediate level coexists with high rates of overqualification: 35% of people aged 20 to 64 with tertiary education work in low-skilled jobs, compared to an EU average of 21.9%, making Spain the country with the highest rate in the EU. All of this suggests a displacement effect, whereby university graduates end up occupying positions that do not require their level of education, thereby reducing job opportunities for those with fewer qualifications.

Added to this polarization is a shortage in strategic areas. Demand for STEM and ICT professionals is growing faster than the supply of graduates, but enrolment in STEM subjects in intermediate-level vocational training (28.3%) is below the European average (36.3%) and falls far short of the European target of 45% by 2030 (European Commission, 2025).

→ Where can technology support students in post-compulsory education

Although experimental evidence on the use of AI in post-compulsory education is still in its infancy, available studies point to three mechanisms with potential: personalized support via *chatbots* during educational transitions, AI-enhanced academic guidance, and AI-based curriculum alignment.

- **AI-powered *chatbots* to reduce dropout rates.** Transitions between stages are particularly vulnerable times for students, who must navigate complex administrative processes: enrolment, scholarship applications, subject selection, and registration for guidance sessions. In this context, Page y Gehlbach (2017)[17] used an RCT to evaluate the effectiveness of a virtual assistant with conversational AI in supporting students admitted to a US university during the summer prior to the start of their university studies. The system, based on text messaging, was integrated with the university's information systems to personalize the contact: it only sent messages regarding tasks that each student had not yet completed and automatically responded to students' queries thanks to a machine learning algorithm that progressively expanded its knowledge base.

  The experiment involved 7,489 admitted students, randomly assigned to either receive or not receive contact from *the chatbot*. The results show that, among students who had already committed to enrolling, those assigned to the treatment group were 3.3% more likely to enroll, equivalent to a 21% reduction in dropout rates during the transition.

17 As far as evidence can be gathered, there is as yet no RCT that strictly replicates the design of Page & Gehlbach (2017) using generative LLMs. The most recent experimental evidence on post-secondary guidance *chatbots* continues to come, to a large extent, from the same team (Page, Gehlbach, Meyer, Lee) and from pre-generative AI architectures.

- **AI-enhanced academic guidance: support in choosing study pathways.** A second mechanism concerns the use of AI to enhance the quality and scope of guidance when choosing between different educational pathways. Lekan and Pardos (2025) analyzed the feasibility of using a *genAI-powered* chatbot to support academic guidance and found that its recommendations were rated favorably by guidance counsellors and matched their own in 33% of cases[18].

- **Curriculum alignment and labor market guidance through AI.** The third mechanism refers to the use of AI to improve the connection between educational provision and the demands of the labor market. In simple terms, AI can analyze the relationship between subjects, educational programmes, skills and professional profiles to better identify which learning outcomes lead to which job opportunities. This makes it possible to detect mismatches, gaps or redundancies in training pathways and, thereby, better tailor the guidance, content and progression of students. Although these applications have been developed primarily in higher education, they could also be transferred to upper secondary education (OECD, 2026).

  From a labor market perspective, evidence also shows that AI can improve training planning by identifying in-demand skills more accurately and linking them to individual profiles and job opportunities. The OECD report (2023) explains that the European Centre for the Development of Vocational Training (Cedefop) processes over 100 million online job vacancies from 28 European countries to build *Skills-OVATE*, a tool that provides more granular and up-to-date information than traditional sources on the skills required by employers. On this basis, AI can be used to build individual skills profiles based on education, work experience and direct or indirect assessments, and compare them with the requirements of available jobs. Examples such as *Competence-Seeker* and *Jobbereik*, developed by the Flemish public employment service (VDAB), illustrate this potential: the former helps to enrich CVs with skills that the individual likely possesses but has not mentioned, and the latter suggests transitions to occupations with similar skills profiles, as well as recommending specific training programmes to facilitate these transitions (OECD, 2023).

Key recommendations

→ **Deploying AI-powered conversational assistants at key transition points, starting with enrolment in sixth form and vocational training:** The study by Page and Gehlbach (2017) shows that a *chatbot* with conversational AI, integrated with institutional information systems and capable of personalizing messages according to each student's pending tasks, can reduce dropout rates during an educational transition by 21%. The case refers to the transition to university in the US, but the mechanism — providing proactive and context-sensitive support during a phase of high uncertainty — is transferable to the transition from lower secondary education to sixth form or vocational training.

→ **Use AI to align training provision with the real demands of the labour market, reducing the structural disconnect between education and employment:** Spain can draw on existing European infrastructure such as Cedefop's *Skills-OVATE* to identify training programmes with the greatest mismatches relative to actual demand and prioritize their review.

18 The results suggest that AI can help personalize guidance based on students' interests and aspirations, but they also reveal significant limitations: several guidance counsellors noted that the AI's responses lacked nuance and that a good guidance process requires asking follow-up questions before recommending an option. Furthermore, when demographic variables were incorporated, the recommendations changed in 10 out of 33 cases, pointing both to their potential for refining personalization and to the risk of reproducing biases. Overall, the study suggests that AI can enhance guidance at decision-making moments, but as a complement to, rather than a substitute for, human judgement.

HASE 3: IMPLEMENT, EVALUATE AND ITERATE

PHASE 3 Implementation

The two previous phases have identified the enabling conditions, and, on that basis, the skills required of students and the areas where ICT and AI can add value. This third phase addresses the question: how can we move from evidence to practice without repeating the mistakes of previous technological cycles? There is a systematic gap between education policy and its effective implementation, and improving outcomes requires paying as much attention to implementation as to policy design (Angrist and Dercon, 2024; Viennet and Pont, 2017). The international comparison reviewed in the institutional analysis carried out at the end of Phase 1 illustrates this clearly: South Korea failed not due to a lack of investment but a lack of gradual piloting; Singapore and Estonia succeeded because they had built institutional capacity before scaling up. Therefore, the implementation of AI in the Spanish education system should follow a three-step cycle: pilot, evaluate and scale up, a cycle in which each phase builds on the previous one.

	What does this entail?	Conditions
01	**Pilot** Testing AI tools in a limited number of schools, using an experimental design, for a minimum duration of one academic year, with rigorous measurement of results.	Diverse selection of schools. Specific pre-training for participating teachers. Student data protection protocol.
02	**Evaluate** Measure the impact using standardized tests, analyze heterogeneous effects by student profile (gender, socio-economic status, prior performance) and gather feedback on the teaching experience.	External and independent evaluation of the technology provider. Tests that measure knowledge transfer, not just immediate performance. Analyse whether the tool widens or narrows existing gaps.
03	**Scaling** Gradually expand only those interventions that have demonstrated a positive and equitable impact to more centers, adapting the design based on lessons learnt from the pilot.	Do not scale up interventions that have not been evaluated. Maintain teacher training and pedagogical supervision. Allocate resources for ongoing evaluation.

The cycle is self-reinforcing: the results of the scaled-up evaluation inform new pilot schemes

Conclusions and recommendations

Is Spain positioned to harness the complementary potential of ICT and AI, or are there structural gaps that limit their effective implementation? **The answer is "yes, but only partially".** Spain has moved beyond the digital access phase, has a regulatory framework that recognizes digital competence, and has made significant investment. However, gaps remain in the quality of pedagogical use, teacher training in AI, the operational framework and student preparedness. We must also be aware of the mistakes being made in the use of ICT and AI for students, particularly in compulsory education.

The analysis reveals that basic **access** to digital infrastructure can be considered a thing of the past: 100% of schools have an internet connection and 96.9% have operational Wi-Fi. However, some inequalities persist. State schools lag 15 percentage points behind independent schools in terms of the availability of digital platforms for teaching, and the differences between autonomous communities exceed 30 percentage points in terms of digital readiness. Furthermore, pupils from disadvantaged socio-economic backgrounds face greater difficulties in using digital tools independently.

These gaps are significant because they affect both the use of technology and AI in the classroom and the scalability of future technological interventions.

As for **teachers**, only 35% of secondary school teachers report using AI, and among those who do not, three out of four cite a lack of training as the main reason. The training gap in AI is the widest among all dimensions of professional development, and the current accreditation framework (MRCDD) does not recognize it as a specific competence. The evidence is clear on this point: technology requires a teaching support structure to function effectively. The greatest benefits of AI are realized precisely when geared towards teachers—improving their teaching practices and reducing planning time—but this requires sustained training and institutional conditions that are not currently guaranteed.

At the regulatory level, Spain has the basic elements in place but lacks the operational mechanisms to put them into practice: guidelines on how to incorporate generative AI, binding teacher certification and systematic evaluation. International comparisons confirm that success depends not on regulatory ambition or scale of investment, but on quality of implementation: South Korea's experience—an $850 million programme cancelled after four months due to insufficient piloting and teacher exclusion—contrasts with Singapore and Estonia, where models were built on decades of institutional foundations and teacher training before roll-out.

Finally, data from TIMSS, PIRLS and PISA reveal significant challenges in the basic skills of Spanish pupils, exacerbated by the deterioration of children's social conditions, a growing language gap and worsening distraction and classroom ambiance (including negative effects of unstructured smartphone use). The evidence reviewed shows that technology can add value at every stage of education—adaptive instruction in primary education in small doses, early detection and personalized tutoring in lower secondary education, vocational guidance and reduced dropout rates in post-compulsory education—when it operates as a complement to teaching and pupils possess the necessary basic skills and supervision.

PHASE 1

ENABLING CONDITIONS

1. **Bridging the infrastructure gap**
   Infrastructure is no longer the main barrier, but access inequalities limit the viability of the most effective interventions. Adaptive learning programmes require stable connectivity and functional devices.

   → Prioritize investment in state schools and regions with lower levels of digital readiness, ensuring that infrastructure gaps do not become gaps in educational opportunity.

2. **Teacher training in AI**
   As noted by the OECD and Fondazione Agnelli (2025), teachers must be involved in decisions regarding the design and adoption of AI, and training must precede deployment, not accompany it.

   → Update the MRCDD to incorporate AI as a specific, assessable competence at all levels (not just C1–C2), aligning accreditation with the competences demanded by the new reality.

   → Design training as sustained support within the school, with supervised classroom practice, peer mentoring and learning communities.

3. **Operational guidelines on the pedagogically intentional integration of AI**

   → Develop guidelines to advise schools on the use of generative AI in teaching practice, assessment and classroom management, following the principle of pedagogical intent.

PHASE 2

INTEGRATION INTO LEARNING

AI with pedagogical safeguards, differentiated by stage and targeted at specific problems.

Spain faces specific challenges at each stage—gaps in basic skills in primary education, repetition and distraction in lower secondary education, and dropout and disengagement in post-compulsory education—that require differentiated responses.

→ **In primary education:** gradually introduce digital practice through CAL (Computer-Assisted Learning) in punctuated, well-defined moments — whether individualised or through supervised collaborative work. The integration should be progressive, allowing learners to familiarise themselves with digital tools step by step as foundational skills are consolidated. In Years 5 and 6, combine the use of AI with ethical literacy: integrate the teaching of principles such as algorithmic bias, privacy, data justice and user responsibility, to prevent the misuse of technology.

- **In secondary education:** i) build a learning pathway analytics infrastructure that enables an understanding of how students learn and identifies those at risk; (ii) direct investment in technology and educational AI towards tools with evidence of differential impact in favor of students facing the greatest difficulties, to reduce gaps; and (iii) establish clear frameworks on when technology adds value and when its use should be restricted, recognizing that the problem is not the technology itself but its unguided use.
- **In post-compulsory education:** i) pilot AI-powered conversational assistants at key transition points, starting with enrolment in sixth form and vocational training; and (ii) use AI to align training provision with the real demands of the labor market, reducing the structural disconnect between education and employment.

PHASE 3

IMPLEMENT, EVALUATE AND ITERATE

Improving outcomes requires paying as much attention to implementation as to design.

Therefore, the implementation of AI in the Spanish education system should follow a three-step cycle: pilot, evaluate and scale.

- **Pilot before rolling out:** Any AI tool proposed for use in schools should first be tested in a limited number of schools using an experimental design, lasting at least one academic year, and involving diverse contexts. Teacher training must precede the pilot, not accompany it.
- **Evaluate independently and rigorously:** the evaluation must be external and independent. It is not enough to measure immediate performance: analyses must include knowledge transfer, heterogeneous effects by student profile, and whether the tool widens or narrows attainment gaps. Teaching experience —what worked, what did not, what conditions were lacking— is also a source of evidence.
- **Scale up only what works:** do not extend interventions that have not been evaluated to more schools. Scaling up must be gradual, with maintained teacher training and pedagogical supervision, and resources for ongoing evaluation.
- **Create a public repository of evaluations:** to document which technological interventions have been piloted, in what contexts, with what results, and under what conditions.

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