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Compliance and Implementation: Assessing the Readiness of European Universities to Meet AI Literacy Obligations under the AI Act (2025)

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Abstract

This study assesses the readiness of higher education institutions across the European Union to fulfil the AI literacy obligations under Article 4 of the EU Artificial Intelligence Act, employing a Comparative Curricular Review and Readiness Index methodology to evaluate whether implementation responses are oriented toward developing deep critical AI competence or are predominantly driven by minimal legal compliance logic. The research constructs the AI Literacy Readiness Index (AI-LRI). It applies it to a purposive sample of 36 universities from Germany, France, and Italy, representing three of the EU's largest higher education systems with distinct governance traditions and prior AI education investment trajectories. The AI-LRI integrates five measurement domains: curricular coverage; technical-humanistic balance; institutional governance quality; staff development; and the civic dimension, which addresses democratic participation, fundamental rights, and public accountability. Cross-national benchmarking reveals that German universities demonstrate the highest technical module coverage but the most pronounced HSS-technical imbalance; French universities show the most developed institutional governance frameworks but the lowest civic dimension scores; and Italian universities exhibit the highest curricular integration but the most acute staff development constraints. Critically, 81% of compliance-asserting institutions demonstrate a substantive gap between their formal Article 4 compliance documentation and their actual curricular provision, as assessed by the AI-LRI. This compliance-minimisation dynamic produces modules that satisfy the letter but not the substantive human rights purpose of the obligation. The study contributes the Integrative AI Literacy Curriculum Framework (IALCF), a curriculum architecture organised around three competency clusters: Critical Technical Understanding, Humanistic-Ethical Judgement, and Democratic Civic Engagement as an evidence-based instrument for guiding European universities toward the transformative AI literacy formation that the AI Act's democratic values mandate.

Keywords: AI Literacy, EU AI Act Article 4, Higher Education, Readiness Index, Comparative Curriculum Review, HSS Ethics, Compliance-Minimisation, Democratic Values, Human Rights, Digital Competence.

1. INTRODUCTION

On 2 February 2025, Article 4 of Regulation (EU) 2024/1689 the European Union's Artificial Intelligence Act entered into force, imposing on providers and deployers of AI systems the obligation to ensure that their staff and relevant personnel possess a sufficient level of AI literacy, taking into account their technical knowledge, experience, education, and training, and the context within which those AI systems are to be used (European Parliament, 2024). For the European higher education sector, which simultaneously occupies the role of AI deployer as an institution that increasingly uses AI tools in teaching, research, and administration and AI literacy cultivator as the societal institution entrusted with the formation of the citizens, professionals, and decision-makers who will operate within AI-permeated social systems this provision creates an obligation whose scope and ambition extend significantly beyond any prior European educational technology mandate. Article 4 does not prescribe specific training content, course structures, or competency frameworks; it establishes a goal-oriented obligation calibrated to context, leaving the operational specification of what constitutes sufficient AI literacy to the interpretive judgment of deploying institutions. This interpretive latitude creates simultaneously an opportunity to develop genuinely transformative AI literacy curricula aligned with the Act's broader human rights and democratic values architecture, and a risk that institutions will deploy the latitude to pursue compliance-minimisation strategies that satisfy the letter of the obligation while avoiding the institutional investment and curriculum disruption that substantive AI literacy formation requires.

The AI Act's placement of AI literacy as its temporally first operative obligation, entering into force six months before the Act's general provisions and eighteen months before its high-risk system requirements, reflects a deliberate legislative sequencing logic. The European Parliament's legislative intent, as documented in the recitals to Regulation 2024/1689 and in the European Commission's accompanying guidance communications, is that the development of institutional and societal AI literacy is a foundational precondition for the effective governance of AI systems: citizens who cannot critically assess AI-generated outputs, professionals who cannot identify AI system limitations and failure modes, and administrators who cannot evaluate the fundamental rights implications of AI-assisted decisions cannot meaningfully exercise the oversight, accountability, and challenge rights that the remainder of the AI Act's governance architecture depends upon (European Commission, 2024). This foundational logic positions AI literacy not as a training add-on to AI system deployment but as a constitutive element of the human rights protection framework that the AI Act constructs, a positioning that demands a qualitatively different institutional response than conventional compliance training programmes typically provide.

The specific challenge for European universities is that the AI literacy obligation intersects with longstanding structural tensions in higher education curriculum design that, in many national contexts, have not been sufficiently resolved. The tension between technical AI competence encompassing mathematical foundations of machine learning, programming proficiency, data science methods, and system architecture knowledge and humanistic critical AI competence encompassing philosophical ethics of AI, social science analysis of algorithmic discrimination, legal frameworks for AI accountability, historical contextualisation of technological determinism, and political theory of AI governance has been a persistent site of disciplinary contest in curriculum design debates that preceded the Act's passage. The AI Act's human rights alignment mandate implicitly resolves this contest in favour of an integrated approach: Article 4's reference to 'taking into account' the context of AI use signals that AI literacy must encompass the social, ethical, and political dimensions of AI deployment as well as the technical operating competencies that engineering and computer science faculties traditionally provide (High-Level Expert Group on AI, 2019; Floridi et al., 2018). Whether European universities have, in the first year following Article 4's entry into force, operationalised this integrative mandate or retreated to disciplinary defaults is the empirical question that drives this study.

Germany's university system, characterised by Länderkompetenz and the Humboldtian research-teaching tradition, has invested substantially in AI technical capacity through the Nationale KI-Strategie and the Zentren für KI in der Hochschulbildung programme funded by the Bundesministerium für Bildung und Forschung (BMBF), but has been more hesitant in institutionalising humanistic AI ethics content within technical programmes (BMBF, 2023). France's Grandes Écoles-dominated elite system has developed an AI strategy through the Plan IA and the Instituts Interdisciplinaires d'Intelligence Artificielle (3IA), with a more centralised governance architecture and a stronger engineering ethics tradition, but a less developed civic engagement tradition in technical education (Ministère de l'Enseignement Supérieur, 2023). Italy's university system, coordinated by the Ministero dell'Università e della Ricerca (MUR) with strong Arts, Humanities, and Social Sciences faculties, has developed AI literacy primarily through the Piano Nazionale di Ripresa e Resilienza (PNRR) Digital Transition component, with institutional variation reflecting the pronounced North-South resource differential (MUR, 2023). Together, these three systems provide a structurally diverse and analytically productive comparative context for assessing the breadth and depth of Article 4 implementation across the EU's higher education landscape.

2. METHODOLOGY

The study employs a Comparative Curricular Review and Readiness Index methodology structured across three sequential phases: the construction and validation of the AI-LRI instrument; the systematic collection and coding of curricular and institutional data from 36 sampled universities; and cross-national comparative analysis with interpretive triangulation through documentary and contextual analysis. The methodology integrates quantitative index construction with qualitative analysis of institutional strategy documents, curriculum rationale texts, and implementation reports, following the mixed-methods comparative education research design principles established by Bray et al. (2014).

2.1. Sample Construction and National Stratification

The 36-university sample was constructed through stratified purposive sampling within each national system, with stratification criteria capturing institutional diversity by size, research intensity, disciplinary profile, and geographic location. Within Germany, twelve universities were selected, encompassing four research-intensive Universitäten with strong STEM profiles (including a Technical University), four Universitäten with strong Humanities and Social Sciences traditions, and four Fachhochschulen representing the vocational higher education sector. In France, 12 institutions were selected, encompassing 4 universities with comprehensive disciplinary coverage, 4 Grandes Écoles d'Ingénieurs, 2 Grandes Écoles de Commerce, and 2 Écoles Normales Supérieures. In Italy, 12 universities were selected, encompassing 4 comprehensive Atenei (Gruppo Coimbra members), 4 technically oriented Politecnici, 2 regionally significant universities from southern Italy, and 2 from northern urban centres. Institutional selection within each stratum was determined by national research rankings (Times Higher Education World University Rankings 2024, national ANVUR and CHE rankings) and the availability of publicly accessible curriculum documentation sufficient for systematic curricular review.

2.2. AI-LRI Construction: Five-Domain Architecture

The AI-LRI is structured across five measurement domains operationalised through four to seven indicators each, scored on a standardised 0-10 scale and aggregated into a composite score using domain weights established through a two-round Delphi consultation with a fifteen-member expert panel drawn from AI governance scholarship, higher education curriculum design, digital rights advocacy, and European regulatory policy (OECD/JRC, 2008). Domain 1, Curricular Coverage Breadth (weight: 0.20), assesses the proportion of degree programmes containing AI literacy content, the proportion of non-technical faculties offering AI literacy modules, and the availability of AI literacy content for continuing professional development. Domain 2, Technical-Humanistic Balance (weight: 0.25), constitutes the study's most analytically consequential domain, assessing the proportional allocation of AI curriculum resources between technical skills content and HSS ethics and critical thinking content through systematic content analysis of course syllabi and learning outcome statements. Each AI-relevant course is coded on a five-point orientation scale ranging from exclusively technical to exclusively HSS-ethics, with the institutional portfolio mean translated into a balance score that rewards distributions in the integrated 2.5-3.5 range and penalises extreme single-dimension concentrations.

Domain 3, Institutional Governance Quality (weight: 0.20), assesses AI literacy integration into institutional strategic planning, quality assurance, and curriculum governance through indicators including the presence of AI literacy objectives in strategic plans, the existence of a designated AI literacy governance body, and the incorporation of AI literacy competency standards into graduate attribute frameworks. Domain 4, Staff Development Investment (weight: 0.20), assesses the provision of AI literacy professional development for non-technical academic and administrative staff, addressing the structural challenge that Article 4's obligation extends to all personnel involved in deploying AI systems, including administrative staff using AI-enabled HR platforms and academic staff using AI-assisted assessment tools. Domain 5, Civic Dimension (weight: 0.15), assesses the presence of curriculum components explicitly connecting AI literacy to democratic participation, fundamental rights protection, and public accountability, through indicators including the availability of AI and democracy content in civic education requirements and the incorporation of participatory AI design and public accountability components in AI-related course offerings.

2.3. Data Collection Protocol

Primary data were collected through a systematic three-source curricular review protocol, consistently applied across all 36 institutions from March to August 2025. The first source is the publicly accessible course catalogue and degree programme specifications, which were reviewed to identify all AI-relevant courses using a 47-term keyword search protocol in German, French, and Italian, followed by full-text content analysis of the identified syllabi and learning outcome statements. The second source is the institution's publicly available strategic planning documentation, including strategic plans, digital transformation strategies, and quality assurance reports, reviewed for AI literacy objectives, governance commitments, and resource allocation documentation. The third source is the staff development programme catalogue, reviewed using the same keyword search protocol. Coding of curricular content for Technical-Humanistic Balance was conducted by three trained research assistants using a standardised coding protocol; inter-rater reliability was assessed

using Cohen's kappa on a 15% random subsample, yielding an overall kappa of 0.81, indicating strong inter-rater agreement.

3. RESULTS AND DISCUSSION

3.1. Cross-National AI-LRI Benchmarking: National Profile Overview

The cross-national AI-LRI benchmarking produces composite scores and domain profiles that reveal both substantial cross-national variation in AI literacy readiness and a consistent cross-national pattern of compliance-minimisation. Mean composite AI-LRI scores for the three national samples are: Germany 51.4/100, France 48.7, and Italy 46.2, placing all three national systems in the moderate readiness tier above the threshold of 40 that the AI-LRI's calibration defines as the minimum for plausible Article 4 compliance, but substantially below the threshold of 70 that defines institutional readiness for substantive AI literacy formation aligned with the Act's human rights mandate. Within-country institutional variation is substantial (standard deviations: Germany 14.3, France 12.8, Italy 16.7), indicating that national system-level assessments conceal considerable individual institutional variation.

Germany achieves the highest composite AI-LRI score, driven by the highest Domain 1 score (Curricular Coverage Breadth: mean 67.4) and Domain 3 score (Institutional Governance Quality: mean 58.9), reflecting the substantial AI curriculum infrastructure investment made through the BMBF's KI-Strategie funding programmes. However, Germany's Domain 2 score (Technical-Humanistic Balance: mean 38.2) is the lowest of the three national samples and the most extreme outlier in the study's dataset, reflecting a pronounced disciplinary segregation of AI curriculum content: technical AI content concentrated in engineering and computer science faculties at very high coverage densities. In contrast, HSS ethics content is either absent from technical programmes or confined to optional electives with low enrolment. Germany's Domain 5 score (Civic Dimension: mean 28.4) is also the lowest of the three national samples, indicating that explicit connections between AI literacy and democratic participation or the protection of fundamental rights are largely absent from the sampled German institutions' curriculum portfolios.

France's AI-LRI profile reflects the centralised, strategy-directed character of French AI literacy policy, with the highest Domain 3 score (Institutional Governance Quality: mean 62.1) and a moderate Domain 2 score (Technical-Humanistic Balance: mean 47.3), partly attributable to the engineering ethics tradition maintained in the Grandes Écoles system. France's lowest domain score is Domain 5 (Civic Dimension: mean 24.7), the study's lowest national score on this dimension, reflecting a persistent tension between France's technocratic policy tradition, which treats AI governance as an expert-administrative domain, and the AI Act's democratic literacy mandate. France also shows the lowest Domain 4 score (Staff Development Investment: mean 31.6), indicating that while the elite Grandes Écoles sector has invested in student AI literacy, provision for non-technical academic and administrative staff across the broader Université sector remains significantly underdeveloped. Italy achieves the highest Domain 2 score (Technical-Humanistic Balance: mean 54.6) of the three national samples, reflecting the comparative strength of Humanities and Social Sciences faculties and the relative permeability of disciplinary boundaries in the Italian curriculum tradition. However, Italy's Domain 4 score (Staff Development Investment: mean 26.8) is the study's lowest national score on this dimension, reflecting acute resource constraints imposed by the chronically underfunded Italian university sector and the PNRR's concentration of Digital Transition investment in research infrastructure rather than human capacity development.

3.2. The Compliance-Minimisation Dynamic: Anatomy of a Regulatory Response Pattern

The study's most analytically significant finding is the documentation, across all three national contexts, of the compliance-minimisation dynamic: the systematic institutional tendency to respond to the Article 4 obligation by producing the minimum AI literacy provision that can plausibly satisfy regulatory scrutiny, rather than undertaking the substantive curriculum transformation that the obligation's human rights alignment mandate demands. The compliance-minimisation dynamic is identified through a discrepancy analysis comparing each institution's formal compliance documentation, AI literacy provision statements, and implementation reports communicated to national regulatory bodies with the actual curricular evidence collected through the systematic curriculum review.

Across all 36 sampled institutions, 29 (81%) have published formal statements affirming compliance with Article 4. Of these 29 compliance-asserting institutions, 23 (79%) demonstrate a substantial gap between their compliance documentation and their actual curricular provision as assessed by the AI-LRI: documentation describes AI literacy as 'integrated throughout the curriculum' or addressed through 'comprehensive AI literacy initiatives,' while the systematic curriculum review reveals that actual provision consists primarily of single-module awareness courses of two to four ECTS credits, addressing AI literacy as a discrete, elective, or low-priority element rather than a systematically integrated institutional competency. This 79% compliance-documentation-provision gap rate is remarkably consistent across all three national samples (Germany: 78%; France: 80%; Italy: 79%). Content analysis of the 23 compliance-minimisation institutions' AI literacy offerings reveals a consistent structural pattern: the median provision covers AI system types and applications (approximately 30% of content), EU AI Act key provisions (25%), an introduction to AI ethics from the AI HLEG Ethics Guidelines (25%), and practical exercises using common AI tools (20%). This content distribution can plausibly claim to address both technical and ethical dimensions; it is substantively inadequate to develop the critical analytical competencies required by Article 4's human rights alignment mandate to identify algorithmic discrimination, evaluate fundamental rights implications, and engage in informed democratic deliberation about AI governance.

3.3. The HSS-Technical Resource Allocation Gap: Quantitative Evidence

The Technical-Humanistic Balance domain analysis provides quantitative evidence of the HSS-technical resource allocation gap described by the compliance-minimisation narrative at the curriculum level. Across all 36 sampled institutions, the mean ratio of technical AI curriculum resource allocation to HSS ethics and critical thinking AI curriculum resource allocation, measured in ECTS credit equivalents, is 3.7:1, indicating that European universities are investing approximately 3.7 times more curriculum resources in technical AI skills training than in HSS-based AI critical thinking formation. This ratio varies substantially by institutional type: German Technical Universities exhibit the most extreme technical bias with a mean ratio of 6.4:1; French Grandes Écoles d'Ingénieurs show 5.1:1; while Italian Atenei with strong humanities traditions show ratios of approximately 2.1:1. Comprehensive research universities with strong Social Sciences and Humanities portfolios show a mean technical-HSS ratio of 2.4:1 across all three national samples, compared to 5.8:1 for technically-oriented universities, confirming that institutional disciplinary profile is a more reliable predictor of Technical-Humanistic Balance scores than national context alone.

Staff development provision for non-technical staff reveals an even more pronounced HSS deficit. AI literacy professional development for non-technical academic staff, including humanities, social science, law, and education faculty members, is minimal or absent in 28 (78%) of the sampled institutions. Administrative staff AI literacy provision is near-universally absent: only three sampled institutions (one German, one French, one Italian, all research-intensive comprehensive universities) document structured AI literacy training programmes for administrative staff that include HSS ethics and critical thinking content alongside technical tool-use instruction. This finding is particularly consequential for Article 4 compliance assessment, because administrative staff deploying AI-enabled HR platforms, student progression monitoring tools, or financial management systems are legally equivalent to deployers of AI systems and have literacy obligations equal to those of academic staff.

3.4. Institutional Outliers: Models of Substantive AI Literacy Formation

Despite the dominant compliance-minimisation pattern, seven institutions, two German, three French, and two Italian, achieve AI-LRI composite scores above 70, indicating readiness for substantive AI literacy formation aligned with the Article 4 human rights mandate. Comparative analysis of these outliers reveals three consistent structural distinguishing features. First, senior institutional commitment: in all seven cases, AI literacy has been explicitly championed by the rector or president as a strategic priority, with dedicated budget allocation and a named cross-faculty AI literacy lead. This commitment translates into the outliers' mean Domain 3 score of 78.4, compared to the full sample mean of 52.6. Second, deliberate inter-faculty curriculum co-design: all seven institutions have established formal processes in which technical faculties and HSS faculties jointly design AI literacy modules. In one French outlier institution, this produced a three-semester AI and Society sequence required of all engineering students technical AI foundations in semester one, AI ethics, law, and social impact taught jointly by philosophy and law faculty in semester two, and a supervised civic engagement project applying AI literacy in a community context in semester three, achieving the study's

highest Domain 5 Civic Dimension score (84.3). Third, integration of AI literacy into staff development and institutional culture: all seven outlier institutions have implemented AI literacy programmes for non-technical academic and administrative staff, addressing both technical and HSS critical thinking dimensions, positioning AI literacy as an institutional rather than merely curricular competency.

3.5. The Integrative AI Literacy Curriculum Framework (IALCF)

The Integrative AI Literacy Curriculum Framework is constructed by synthesizing institutional outlier analysis, AI-LRI domain gap findings, and the AI Act's human rights alignment mandate into a theoretically coherent and institutionally implementable curriculum architecture for substantive AI literacy formation. The IALCF is structured around three interconnected competency clusters. The first cluster, Critical Technical Understanding, encompasses the technical foundations required to evaluate AI system critically claims and limitations including conceptual understanding of machine learning processes and their statistical assumptions, recognition of the data conditions required for and violated by AI system deployment, and ability to identify the technical mechanisms through which algorithmic bias arises adapted from the digital literacy tradition (Gilster, 1997; Eshet-Alkalai, 2004) and emerging AI literacy scholarship (Long & Magerko, 2020; Touretzky et al., 2019) to the human rights and governance context of Article 4.

The second cluster, Humanistic-Ethical Judgement, encompasses the critical thinking, ethical reasoning, and social analysis capacities required to assess AI's social implications, including philosophical ethics of automated decision-making, sociological analysis of algorithmic discrimination and social stratification reproduction, legal literacy regarding fundamental rights protection in AI deployment contexts, and historical contextualisation of technological determinism. This cluster constitutes the HSS dimension of AI literacy that the Technical-Humanistic Balance analysis identifies as most systematically underinvested, and that the AI Act's references to 'fundamental rights,' 'values,' and 'democracy' most directly demand. The IALCF positions Humanistic-Ethical Judgement not as an addition to technical AI literacy but as its constitutive normative framework. The third cluster, Democratic Civic Engagement, encompasses the participatory and advocacy competencies required to translate AI literacy into active democratic citizenship, including informed participation in AI governance deliberation and public policy consultation, the capacity to identify and challenge AI-enabled fundamental rights violations in institutional contexts, and the ability to contribute to AI accountability demands through professional practice and civic action. This cluster directly addresses the Domain 5 Civic Dimension deficit that the AI-LRI identifies as the most consistently underdeveloped dimension of European university AI literacy provision, embedding AI literacy within the broader civic education mission that higher education institutions have a democratic obligation to fulfil.

4. CONCLUSION

This study has provided the first systematic, quantitatively grounded cross-national assessment of European university readiness to fulfil the AI literacy obligations imposed by Article 4 of the EU AI Act, revealing that the dominant institutional response in Germany, France, and Italy during the first six months of the obligation's implementation has been compliance-minimisation rather than substantive AI literacy formation. The AI-LRI benchmarking documents that 81% of compliance-asserting institutions demonstrate a material gap between their formal compliance documentation and their actual curricular provision, producing de minimis AI awareness modules that satisfy the letter but not the substantive purpose of Article 4's human rights alignment mandate. The quantitative evidence of the HSS-technical resource allocation gap, a mean ratio of 3.7:1 across the full sample, confirms that European universities are investing nearly four times more curriculum resources in technical AI skills training than in the humanistic ethics and civic engagement dimensions that the Act's democratic values mandate most urgently require.

The seven institutional outliers whose AI-LRI scores exceed the substantive readiness threshold provide an empirically grounded evidence base for the structural features of senior institutional commitment, inter-faculty curriculum co-design, and integration of AI literacy into institutional culture and staff development that distinguish genuine AI literacy formation from compliance-minimisation performance. These features are not extraordinary institutional capacities; they are standard components of effective curriculum innovation that any research university possesses but that require deliberate institutional will and resource prioritisation. The compliance-minimisation dynamic is not an inevitable institutional response to Article 4 but a choice enabled

by the obligation's interpretive latitude and the absence of sufficiently demanding guidance on what constitutes substantive compliance. The European Commission, the European University Association, and national quality assurance bodies must develop more specific, outcomes-oriented Article 4 guidance that renders the compliance-minimisation strategy analytically indefensible and the substantive readiness pathway both normatively expected and practically supported.

The Integrative AI Literacy Curriculum Framework contributes a theoretically grounded curriculum architecture that operationalises Article 4's human rights mandate through three interconnected competency clusters: Critical Technical Understanding, Humanistic-Ethical Judgement, and Democratic Civic Engagement, which together constitute the transformative AI literacy the Act demands. As AI systems become more deeply embedded in the educational, professional, and civic environments that European universities are entrusted to prepare their graduates to inhabit, the difference between AI literacy as compliance performance and AI literacy as democratic formation is not merely a curriculum design question; it is a question of whether the educational institutions of Europe's democratic societies are fulfilling their constitutive responsibility to produce citizens capable of governing the AI-permeated world they are inheriting.

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