

Towards a Multidimensional Framework for Educational Data Literacy

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Abstract: Educational data literacy (EDL) has become a central concern for European schools as digitalization generates unprecedented volumes of sensitive data on minors, while the GDPR and AI Act impose constitutive constraints on data use. The conceptual landscape, however, remains fragmented: several traditions have proposed competency models, but each foregrounds one dimension while leaving others aside, and the boundary between EDL and adjacent constructs such as assessment literacy is still unresolved. This paper compares the four most influential traditions in the English-language literature: the Data Literacy for Teaching model, the Dutch Data-Based Decision Making tradition, the Learn2Analyze Educational Data Literacy Competence Profile, and the Critical Educational Data Literacy perspective. The comparison uses two axes: a dimensional axis of five facets (Technical, Pedagogical, Organizational, Ethical, Transversal) and a role axis distinguishing teachers from school leaders. The analytical method is a conceptual framework analysis rather than a systematic review, complementing recent empirical syntheses by asking whether the architectures organizing the field are adequate. The findings show that no tradition covers all five dimensions strongly, that role differentiation between teachers and school leaders is systematically lacking, that the organizational dimension is the most neglected, and that teachers' actual data use remains narrower than definitions suggest, with assessment data still dominating practice. From these findings, four design requirements for an integrated framework follow: multidimensional coverage with explicit interdependencies; role differentiation within a unified architecture; contextual adaptability through modular proficiency levels; and governance as institutional infrastructure. The discussion grounds these requirements in the DIKW hierarchy, aligns them with European regulatory and data sovereignty requirements, and draws implications for teacher education, school leadership development, and European policy on professional data competence, translating analytical findings into actionable design parameters.

Keywords: Educational Data Literacy, Competency Framework, Data-Based Decision Making, Data Governance, School Leadership, Data Wisdom

1. Introduction

The digitalization of European schools has generated an unprecedented volume of educational data. School information systems, learning platforms, and standardised testing produce data that could support instructional improvement, equitable resource allocation, and evidence-informed governance. The breadth and sensitivity of the data is often overlooked. Schools collect information far beyond grades and test scores, including behavioural assessments, family circumstances, special educational needs, and confidential records on minors, no less sensitive than health data. European policy reflects both potential and risks: the Digital Education Action Plan 2021-2027 calls for strengthening data literacy among educators (European Commission 2020), and the AI Act sets stringent requirements for high-risk AI systems in education (European Parliament and Council 2024).

Despite this policy momentum, EDL remains under-theorized. A cross-model comparison of twenty data literacy frameworks found widely divergent competency sets, with no single model covering all aspects applicable in a given context (Downes 2023). This fragmentation recurs within the educational sub-domain, where pedagogical, organizational, ethical, and governance considerations add complexity generic models do not address (Schumacher and Ifenthaler 2025). Several scholarly traditions have proposed competency models for EDL but developed largely in isolation, each foregrounding one dimension while leaving others aside. As a result, EDL is still insufficiently distinguished from related concepts such as assessment literacy, and fragmented approaches persist across countries. A cross-country study of five European nations found that no country has a dedicated strategy for data literacy in compulsory education, that curricular integration remains fragmented, and that no shared operational definition exists (Kostas et al. 2025).

The gap is structural, not merely definitional. As schools rely increasingly on commercial platforms, decision-makers without organizational and ethical data literacy cannot adequately assess governance, data ownership,

or the boundary between institutional and third-party data. A systematic comparison of EDL frameworks is therefore needed not to catalogue what exists but to identify where coverage breaks down and what follows.

This paper compares the four most influential EDL traditions along two axes: a dimensional axis (Technical, Pedagogical, Organizational, Ethical, Transversal) and a role axis (teachers, school leaders). Three research questions guide the inquiry:

RQ1: To what extent do existing EDL traditions cover each of the five dimensions?

RQ2: How, and to what degree, do the traditions differentiate the competencies required of teachers from those required of school leaders?

RQ3: What structural gaps emerge from the comparison, and what design requirements follow for an integrated, multidimensional EDL framework?

2. Analytical Method

This study adopts a conceptual framework analysis approach (Jabareen 2009) rather than a systematic review. The goal is not to catalogue empirical findings but to compare the conceptual architectures proposed to define and operationalize EDL. The strategy builds on a cross-model analysis of twenty data literacy definitions (Downes 2023), with two extensions: an explicit dimensional matrix replaces the competency list, and a role axis separates teachers from leaders.

The approach complements existing systematic reviews, which catalogue individual studies: a scoping review of 276 studies on teachers from 2020 to 2024 (Pastore 2026), a review of 95 indicators across 83 studies from 1990 to 2021 (Lee et al. 2024a), and one focused on principals (Lee et al. 2024b). Empirical reviews tell us what has been studied; conceptual analysis asks whether the architectures guiding it are adequate.

Selection of traditions followed three criteria: publication in peer-reviewed outlets or as a validated deliverable of a publicly funded project; explicit focus on data literacy in primary, secondary, or teacher education; and articulation of a structured set of competencies. The selection is not exhaustive. Traditions in other languages or within specific national policy contexts, such as Data Wise (Boudett et al. 2013) or Earl and Katz (2006) on data leadership, may add further perspectives. The selection reflects which bodies of work have most shaped the international scholarly conversation in English.

The analytical matrix has two axes. The dimensional axis comprises five facets derived inductively across the selected traditions: Technical (collecting, managing, processing, visualizing data), Pedagogical (translating insights into instructional decisions), Organizational (embedding data practices in institutional governance), Ethical (privacy, fairness, consent, power), and Transversal (collaborative, communicative, reflective dispositions). The role axis distinguishes teachers from school leaders. The structure differs from the type-based classification adopted in the most comprehensive systematic review (Lee et al. 2024a), which captures what kind of competence is at stake; ours captures in which domain of practice a competence operates, making visible a structural fragmentation that a competence-type classification cannot.

Coverage is coded on a three-level scheme. Strong: the dimension is a core focus, articulated through multiple sub-competencies, supported by dedicated empirical work. Moderate: addressed but not primary. Limited or absent: mentioned peripherally or not as a distinct component. The coding reflects authorial interpretive judgment, an analytical proposition open to scrutiny rather than a definitive measurement.

3. Mapping the Landscape

3.1 The Data Literacy for Teaching (DLFT) Model

The most widely cited contribution to EDL in the English-language literature defines data literacy for teaching as the ability to transform information into instructional knowledge (Mandinach and Gummer 2016). The framework organizes knowledge and skills around the data use cycle: identifying problems, collecting data, transforming data into information, converting information into decisions, and evaluating outcomes. Data-literate teachers must integrate content, pedagogical content, and curriculum knowledge to contextualize data within meaningful instructional frames.

The primary strength is the granular articulation of the pedagogical dimension: data use is explicitly linked to professional judgment, with statistical summaries treated as insufficient without interpretation. Subsequent

work connected teacher data literacy to teaching analytics (Ndukwe and Daniel 2020) and framed DLFT as a meta-construct subsuming assessment literacy as one component (Beck and Nunnaley 2021). A scoping review of 276 studies found that virtually all definitions of teacher data literacy in the literature align with DLFT (Pastore 2026). The limitations are substantial: developed within the US accountability context, the model tends to link data use with standardized test scores; ethical considerations such as algorithmic bias, consent, and the power dynamics embedded in data systems are not foregrounded; the organizational dimension receives only incidental attention; and the framework offers no competency profile for school leaders.

3.2 The Dutch Data-Based Decision Making Tradition

A parallel, largely independent tradition emerged at the University of Twente, organized around Data-Based Decision Making (DBDM). The competency model is a cyclical process: setting a purpose, collecting data, checking quality, analyzing and interpreting it with professional knowledge, and taking instructional action (Kippers et al. 2018). A consequential feature is that the cycle begins with goals, not data, positioning data use as an instrument of school improvement rather than an end. A second feature is the sustained emphasis on collaborative data use within Professional Learning Communities and data teams: data practices are treated as inherently social. A meta-analysis of 27 intervention studies found a medium effect ($g = .41$) on student achievement, with effective interventions marked by collaboration and school-level support (Spiele et al. 2025).

DBDM is the only tradition reviewed here giving sustained attention to school leaders, though within the same programme rather than a separate framework. Research identifies leadership behaviours that support data teams: establishing vision, providing individualized support, creating a safe improvement-focused climate, and using data personally (Schildkamp 2019, Schildkamp et al. 2017). These behaviours are described as enablers of the DBDM process rather than as a distinct competency profile. Ethical considerations remain peripheral, and the organizational dimension is addressed primarily through PLC facilitation rather than institutional governance in a broader sense; recent work also shows that students remain largely passive data sources (Schildkamp et al. 2025).

3.3 The Learn2Analyze Educational Data Literacy Competence Profile

The Learn2Analyze project, funded under Erasmus+, developed the Educational Data Literacy Competence Profile (EDL-CP) through expert consultation and validation with 210 professionals (Papamitsiou et al. 2021). The profile comprises five competence areas: Data Collection, Data Management, Data Analysis, Data Comprehension and Interpretation, and Data Application and Communication. The validation confirmed the dimensions as a foundation for EDL development while revealing that the surveyed professionals were not yet EDL-competent; the framework was later elaborated in a dedicated monograph (Sampson et al. 2022).

The L2A-EDL-CP stands out for its attention to the full data lifecycle, including storage, curation, and quality assurance other traditions overlook; its technical dimension is the most thoroughly articulated of the four, and it includes learning analytics competencies relevant to digitally mediated environments. Its limitations concern scope: data protection is mentioned but the broader terrain of fairness, consent, power, and epistemic justice is not systematically addressed; governance is not treated as a distinct dimension; and although extended from instructional designers to K-12 teachers (Sampson et al. 2022), it does not differentiate competencies by professional role.

3.4 The Critical Educational Data Literacy Perspective

A fundamentally different approach has emerged from critical data studies, data feminism, and critical digital literacy. Early contributions argued for moving beyond DigComp to address the specificities of EDL for educational professionals (Raffaghelli 2017, 2019), developed into a socio-political repositioning of EDL (Raffaghelli and Stewart 2020): data systems are not neutral instruments but embody power relations, institutional logics, and epistemic hierarchies that shape whose knowledge counts. The most recent articulation proposes a multidimensional model that includes technical and interpretive skills alongside critical awareness, ethical positioning, and what is termed data activism, the capacity to challenge or refuse data practices that undermine educational values (Raffaghelli et al. 2020). This tradition makes the most developed contribution to the ethical dimension and corrects the instrumentalism of earlier models.

The limitations mirror the strengths. The pedagogical dimension receives less granular treatment than in DLFT or DBDM: the critical perspective explains why data practices should be questioned but offers limited guidance

on how teachers might use data constructively. The organizational dimension, addressed through institutional data cultures, is not operationalized into competency statements. The framework remains primarily theoretical: unlike DBDM, it has not been validated through school-based work, and its adoption in professional development or policy documents has been limited. This gap is itself a finding: conceptually important traditions may remain marginal to practice if they do not translate insights into operational tools.

4. Comparative Analysis

Table 1 synthesizes the coverage of each tradition across the five dimensions and two professional roles. A three-level scheme is used: strong coverage (●), moderate coverage (◐), and limited or absent coverage (○).

Table 1: Coverage of EDL traditions across five dimensions and two professional roles

Dimension	DLFT	DBDM	L2A-EDL-CP	Critical EDL
Technical	○ Implicit; assessment data focus	◐ Moderate; quality checks, basic analysis	● Strong; full lifecycle incl. LA	○ Limited; deconstructive rather than applied
Pedagogical	● Strong; instructional decision-making	● Strong; action-oriented cycle	◐ Moderate; present but not school-specific	○ Limited; not central
Organizational	○ Peripheral	◐ Moderate; PLC structures, data teams, leadership as enabler	○ Peripheral	◐ Moderate; data cultures discussed
Ethical	○ Minimal	○ Minimal	○ Limited; data protection mentioned	● Strong; power, fairness, activism
Transversal	◐ Moderate; knowledge integration	● Strong; PLC collaboration, sensemaking	◐ Moderate; communication skills	● Strong; reflexivity, agency
Role: Teacher	● Primary target	● Primary target	◐ Generic educator	◐ Generic educator
Role: School Leader	○ Not addressed	◐ Addressed as enabler; no distinct profile	○ Not differentiated	○ Not differentiated

Regarding **RQ1**, no tradition covers all five dimensions strongly. DLFT and DBDM are well developed pedagogically but neglect ethics; the critical perspective offers the deepest ethical analysis but underdevelops pedagogy and organization; L2A-EDL-CP is technically the most comprehensive but lacks organizational and ethical depth. The pattern confirms what has been observed in the broader data literacy domain: each model reflects the context in which it was derived, and none covers the full spectrum (Downes 2023). The spread of 95 indicators across 83 empirical studies (Lee et al. 2024a) suggests the field has generated granularity at the component level while lacking integrative structure.

Regarding **RQ2**, differentiation is systematically lacking. DLFT and L2A-EDL-CP target teachers or generic educators. The critical perspective addresses a generic educator. DBDM has given the most sustained attention to leadership, but school leaders are treated as enablers of the data use process rather than as holders of a distinct profile (Schildkamp 2019, Schildkamp et al. 2017). A recent systematic review of principals' data literacy confirms that most studies on school leader data use employ the DLFT definition, designed for teachers, rather than a leadership-specific model (Lee et al. 2024b). The role-defined approach proposed in the broader data literacy field (Downes 2023) has not been taken up in education.

Regarding **RQ3**, four structural gaps stand out. First, the organizational dimension is the most neglected. DBDM addresses it through PLC structures but does not extend to institutional governance in a broader sense. Schools without organizational data competence become vulnerable to outsourcing decisions made without capacity to evaluate governance implications, with data sovereignty transferred to actors whose incentives may not align with educational values. Individual data literacy, however strong, has limited protective effect without supportive institutional infrastructure (Schildkamp 2019, Schildkamp et al. 2017). Second, the relationship between the ethical and technical dimensions remains unresolved: the critical perspective positions ethics as a lens through which all data practices should be evaluated, while L2A-EDL-CP treats data protection as a subsidiary technical concern.

Third, the translation from conceptual breadth to practice is incomplete: although DLFT encompasses diverse data sources, teachers overwhelmingly rely on assessment data (Pastore 2026), and a survey of 658 education professionals across five European countries confirms data use is primarily administrative and oriented toward external reporting (Kostas et al. 2025). Qualitative sources often provide more actionable insight than achievement data alone (Kippers et al. 2018, Schildkamp 2019). Fourth, no tradition addresses all five dimensions at multiple proficiency levels within a role-differentiated structure, so no model can guide a comprehensive, role-adapted professional development pathway.

5. Discussion

The four traditions were not designed to be complementary: they emerged from different disciplinary contexts (educational psychology, learning analytics, critical pedagogy) and policy environments (US accountability, Dutch school improvement, European digital competence policy). The result is incommensurability: different ontologies of competence, levels of granularity, and assumptions about who the data-literate professional is.

Theoretically, the field lacks a shared vocabulary. The boundary with assessment literacy in particular remains unresolved: although the two are claimed distinct (Beck and Nunnaley 2021), the data teachers actually engage with remain overwhelmingly assessment-centred (Pastore 2026), and across five European countries teachers were largely unable to distinguish data literacy from digital, AI, or statistical literacy (Kostas et al. 2025). Practically, the absence of an integrated model fragments professional development: a DLFT-grounded programme may produce educators who interpret assessment data but cannot navigate GDPR or join data governance, while a DBDM-informed one may cultivate collaborative inquiry without the ethical competencies needed to evaluate the tools and dashboards teams adopt. The fragmentation also narrows the goals data use serves: equity, wellbeing, safety, inclusion, and civic participation fall outside professional competence when frameworks are anchored to instructional decision-making and assessment data.

5.1 Design Requirements for an Integrated Framework

5.1.1 *Multidimensional Coverage with Explicit Interdependencies*

All five dimensions must be addressed as equally important and interdependent. Data use in schools mobilizes technical, pedagogical, ethical, organizational, and transversal competencies at once, and a teacher reading a learning analytics dashboard exemplifies this co-activation. An integrated framework should make these interdependencies explicit through cross-dimensional descriptors and operationalize the full range of competence types, including the dispositions and behaviours that empirical evidence identifies as central to teacher data literacy (Lee et al. 2024a). Frameworks defining competencies only as what teachers should know and do are structurally incomplete.

5.1.2 *Role Differentiation Within a Unified Architecture*

Teachers and school leaders interact with data in fundamentally different ways: teachers' practices are oriented toward classroom decisions, while leaders operate at institutional level on planning, resource allocation, and conditions for data use. A role-defined approach (Downes 2023), proposed in the broader domain but not yet applied to education, could specify complementary profiles within a single dimensional structure, sharing the five dimensions but instantiating them according to scope and authority. Student agency in relation to data, given that students remain largely passive data sources (Schildkamp et al. 2025), should be considered a transversal principle that operates across both profiles.

5.1.3 *Contextual Adaptability Through Modular Proficiency Levels*

European education systems differ in governance structures, data infrastructure maturity, and professional cultures, and recent projects address this through co-creation with national stakeholders (Kostas et al. 2025). An integrated framework should be modular, defining core competencies that apply across contexts while allowing localization, with proficiency levels from emergent to strategic that allow schools to locate themselves and identify next steps. A precedent exists in DLFT, where a continuum from novice to expert has been proposed (Beck and Nunnaley 2021); extending it to a multidimensional, role-differentiated framework requires specifying levels across all five dimensions simultaneously.

5.1.4 Governance as Institutional Infrastructure

Governance is treated by the frameworks reviewed, when at all, as a set of policies. The dynamics of data use in schools suggest governance is better understood as infrastructure: embedded, participatory mechanisms that operate continuously rather than episodically. When governance is treated as an afterthought, decisions are made by default rather than design, with commercial platforms filling gaps that institutional capacity has left open. An integrated framework should position governance as the architecture within which all other competencies operate, including, at the organizational level, competencies in procurement and vendor assessment, data ownership, and the boundary between institutional and third-party platforms. A related concern is reconciling accountability and improvement (Earl and Katz 2006, Ehren and Swanborn 2012, Schildkamp et al. 2014); DBDM has shown that external evaluation can serve as input for internal data use cycles when embedded within a culture of trust rather than blame (Schildkamp 2019, Schildkamp et al. 2017), and an integrated framework should build in the competencies to navigate this tension and resist the narrowing effects high-stakes accountability has on the goals data use serves.

5.2 Alignment with the European Regulatory and Institutional Landscape

A contemporary EDL framework must internalize the regulatory landscape as a structural design parameter. The GDPR (European Parliament and Council 2016) and the AI Act (European Parliament and Council 2024) create a legal environment in which educational data use is subject to transparency, data minimization, purpose limitation, and human oversight. These are constitutive constraints, not external add-ons. DigComp 2.2 (Vuorikari et al. 2022) and DigCompEdu (Redecker 2017) provide European scaffolding but lack the granularity an integrated EDL framework requires; parallel work in higher education shows the field moving toward models with explicit progression levels (Echtenbruck et al. 2025).

The intersection of data and AI literacy is an emerging frontier. As AI-powered tools enter schools, educators must evaluate transparency and explainability, the representativeness of training data, and possible bias in AI-generated recommendations. These competencies sit at the intersection of the technical and ethical dimensions, and the AI Act makes their integration legally necessary.

The DIKW hierarchy (Ackoff 1989) offers an epistemic scaffold for integration. Applied to EDL, progression from raw data through contextualized interpretation to evidence-informed practice and, ultimately, principled data governance requires the simultaneous activation of all five dimensions at increasing levels of sophistication. The highest level, Wisdom, is the capacity to ask not only what data tools can do but whether and how they should be used: the Know Why that enables teachers and leaders to assess power asymmetries, protect learners' rights, and resist inappropriate data mandates. This is precisely where the European Common Data Space for Education and Skills, premised on educational data remaining within European governance frameworks, makes integration a practical horizon: an EDL framework that does not equip school leaders to assess whether a platform aligns with these requirements falls short of what the policy environment demands.

5.3 Implications for Practice

For teacher educators, the persistence of assessment-centred training suggests programme design should move beyond standalone data courses toward integration across the curriculum: fewer than four in ten educators surveyed across five European countries had received formal data literacy training (Kostas et al. 2025). For school leaders, the absence of a dedicated competency profile is both a gap and an opportunity, with the design requirements above pointing to competencies in governance, procurement, team facilitation, and the mediation of accountability. For policy-makers, anchoring professional standards to a single tradition risks neglecting the ethical and organizational dimensions GDPR and the AI Act now require; a policy framework for EDL should be multidimensional by design and accompanied by differentiated pathways for teachers and school leaders.

6. Conclusion

This paper has mapped and compared four traditions that define the current landscape of EDL. Each makes a distinctive contribution, but none provides the comprehensive, role-differentiated, contextually adaptable model European education systems now require. The contributions are threefold. First, the five-dimension analytical matrix offers a reusable lens for evaluating EDL traditions as new models emerge. Second, the comparative analysis specifies where coverage breaks down and why the organizational and ethical gaps carry particular practical weight as schools rely on commercial platforms. Third, the four design requirements

(multidimensional coverage with interdependencies, role differentiation within a unified architecture, contextual adaptability through proficiency levels, and governance as institutional infrastructure) translate analytical findings into actionable parameters, grounded in the DIKW hierarchy and aligned with European regulatory and data sovereignty requirements.

The analysis has limitations. The selection of four traditions may not capture every relevant contribution; models such as Data Wise (Boudett et al. 2013) or Earl and Katz (2006) may offer complementary perspectives. The dimensional matrix is an inductive construct, and the three-level coding reflects authorial interpretive judgment without inter-rater reliability checks. Conceptual architectures are evaluated rather than empirical outcomes. Future research should prioritize empirical validation through school-based interventions across diverse European contexts, assessment instruments measuring EDL across all five dimensions and proficiency levels, and investigation of how organizational conditions mediate the link between individual data literacy and institutional outcomes. Meta-analytic evidence shows that data use professional development positively affects student achievement ($g = .41$), with heterogeneity better explained by school-level implementation conditions than by intervention design (Spiele et al. 2025); understanding these conditions is the next frontier.

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Ethics Declaration

Ethical clearance was not required.

AI Declaration

Generative AI was used only for final language editing and formatting, while all conceptual, analytical, and interpretive work was carried out by the authors.

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