

MATHEMATICAL LITERACY AND AI LITERACY: A CONCEPTUAL BRIDGE FOR INTERPRETING ALGORITHMIC MODELS

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Abstract

The increasing presence of Artificial Intelligence (AI) in educational and social contexts has intensified the need to clarify what is meant by AI literacy and how it relates to existing forms of literacy. While numerous frameworks describe AI literacy through technical, ethical, or practical dimensions, fewer studies examine its underlying epistemic foundations. At the same time, mathematical literacy, as defined by the OECD/PISA, offers a well-established model of how individuals interpret reality through the formulation, application, and evaluation of formal representations. This paper examines in what sense AI literacy can be theoretically framed as an extension of mathematical literacy, and what shared epistemic structures underpin both constructs. Through a conceptual analysis of established definitions and international frameworks (OECD, UNESCO, and research-based models), which currently remain theoretically disconnected, we compare their core processes, the nature of the models involved, and the role of uncertainty and judgment. The analysis shows that both literacies rely on a common structure of meaning-making: interpreting models, reasoning under uncertainty, and critically evaluating formal outputs in relation to real-world contexts. In AI-mediated contexts, this involves interpreting algorithmic outputs as model-based representations rather than direct reflections of reality. The key distinction lies in the origin of the models. While mathematical literacy engages with human-constructed mathematical representations, AI literacy involves interaction with machine-generated, probabilistic models that mediate knowledge and decision-making. By framing AI literacy as a theoretical extension of mathematical literacy into algorithmic environments, this paper offers a coherent conceptual foundation for future research and the development of integrated literacy frameworks.

Keywords: *AI literacy, mathematical literacy, epistemic structures, algorithmic models, conceptual analysis.*

1. Introduction

Artificial Intelligence (AI) systems increasingly mediate how knowledge is produced, represented, and used in contemporary educational and social contexts. From automated recommendations and predictive analytics to generative models, individuals are now regularly required to engage with outputs that are probabilistic, opaque, and algorithmically generated. As a result, the concept of AI literacy has rapidly emerged as a key educational goal, aiming to equip learners with the capacity to understand, evaluate, and responsibly interact with AI systems (Long & Magerko, 2020; Ng et al., 2021).

Despite the growing interest in AI literacy, existing definitions and frameworks remain conceptually fragmented. Many approaches emphasize technical skills, ethical awareness, or practical competence, focusing on how AI systems function, how they should be used, or what risks they pose (UNESCO, 2024; OECD, 2025). While these dimensions are undoubtedly important, they often leave under-theorized a more fundamental question: what forms of reasoning are required in order to make sense of AI-generated outputs as representations of reality? Beyond knowing how to use AI systems or reflect on their social implications, learners must also develop epistemic capacities for interpreting, evaluating, and judging algorithmic results.

At the same time, the concept of mathematical literacy, particularly as articulated within the OECD/PISA framework, offers a well-established epistemic model of how individuals use formal systems to interpret the world. Mathematical literacy is defined as the capacity to formulate, employ, and interpret mathematics in a variety of real-world contexts, in order to describe, explain, and predict phenomena and to make reasoned decisions (OECD, 2019). Central to this conception is the idea that mathematical meaning does not reside in procedures or formulas themselves, but emerges through a process of model-based

reasoning, in which formal representations are constructed, applied, and critically evaluated in relation to contextual knowledge (Niss & Jablonka, 2014).

This paper argues that the epistemic logic underlying mathematical literacy provides a powerful theoretical lens for rethinking AI literacy. Rather than treating AI literacy as a wholly new or separate competence, we propose that it can be conceptually understood as an extension of mathematical literacy into algorithmic environments. This perspective foregrounds the central role of interpretive judgment in AI-mediated contexts. Both literacies involve engaging with models that mediate understanding of reality, reasoning under conditions of uncertainty, and exercising judgment in order to interpret formal outputs in context. The difference lies not in the structure of reasoning itself, but in the nature of the models involved: in mathematical literacy, models are human-constructed mathematical representations, whereas in AI literacy, they are machine-generated, data-driven, and probabilistic.

Accordingly, this paper addresses the following conceptual research question:

- *In what sense can AI literacy be theoretically framed as an extension of mathematical literacy, and what shared epistemic structures underpin both constructs?*

To address this question, the paper adopts a conceptual analysis approach, drawing on established definitions of mathematical literacy (OECD, 2019; Niss & Jablonka, 2014), emerging AI literacy frameworks (UNESCO, 2024; OECD, 2025; Long & Magerko, 2020; Ng et al., 2021), and theoretical literature on modeling and epistemic reasoning (Morgan & Morrison, 1999; Knuuttila, 2011). By aligning these bodies of work, the paper aims to contribute a coherent theoretical foundation for understanding AI literacy as a form of model-based epistemic practice, rather than merely a set of technical or ethical skills.

2. Method: Conceptual analysis

This study adopts a conceptual analysis approach rather than an empirical research design. The aim is not to test hypotheses or measure learning outcomes, but to clarify and theoretically align two key constructs—mathematical literacy and AI literacy—by examining how they are defined, what forms of reasoning they presuppose, and what epistemic assumptions they entail.

Conceptual analysis is particularly appropriate for this purpose, as both constructs are primarily articulated through theoretical frameworks and policy-oriented definitions, rather than through standardized empirical models. In the case of mathematical literacy, the analysis draws mainly on the OECD/PISA framework, which has established a widely accepted conceptualization of literacy as model-based reasoning in real-world contexts (OECD, 2019). In the case of AI literacy, the analysis draws on international frameworks (UNESCO, 2024; OECD, 2025) and influential research-based definitions (Long & Magerko, 2020; Ng et al., 2021), which emphasize critical understanding and evaluation of AI systems.

The analysis proceeds through a systematic comparison of these sources along three analytical dimensions:

- (1) core epistemic processes, such as formulation, interpretation, evaluation, and judgment;
- (2) nature and role of models, focusing on how mathematical and algorithmic models function as mediators between formal representations and reality; and
- (3) treatment of uncertainty and meaning-making, examining how both literacies conceptualize the interpretation of outputs under conditions of approximation, probability, and limited transparency.

Rather than treating the two literacies as separate domains, the analysis seeks to identify structural similarities in their epistemic logic, that is, in how knowledge is constructed, interpreted, and justified. Through this comparative lens, mathematical literacy and AI literacy are not evaluated in terms of curricular content or pedagogical effectiveness, but in terms of their underlying modes of reasoning. This allows for a theoretically grounded alignment of the two constructs and provides the basis for the argument that AI literacy can be understood as an extension of mathematical literacy into algorithmic environments.

3. Mathematical literacy as model-based reasoning

Within the OECD/PISA framework, mathematical literacy is defined as the capacity to formulate, employ, and interpret mathematics in a variety of real-world contexts, in order to describe, explain, and predict phenomena, and to make reasoned decisions (OECD, 2019). This definition marks an important shift from traditional views of mathematics as a collection of abstract procedures toward an epistemic conception of mathematics as a modeling language for interpreting reality.

Central to this conception is the idea that mathematical understanding is not exhausted by the execution of algorithms or the application of formulas. Instead, meaning emerges through a cycle of modeling in which individuals move between real-world situations and formal mathematical representations. This cycle involves (a) translating a contextual problem into mathematical form (formulation), (b) applying mathematical concepts and procedures (employment), and (c) interpreting and

evaluating the results in relation to the original context (interpretation and evaluation). Each stage requires judgment, approximation, and contextual reasoning, rather than mechanical calculation (Niss & Jablonka, 2014).

From this perspective, mathematical literacy is inherently an epistemic competence. It concerns how individuals construct and justify knowledge about the world using mathematical models, rather than how accurately they perform symbolic operations. Real-world phenomena are rarely fully captured by formal representations; as a result, mathematical modeling always involves simplification, assumptions, and uncertainty. Learners must therefore assess the plausibility of results, recognize the limits of models, and reflect on the meaning of mathematical outputs within specific situations.

This epistemic dimension is particularly evident in PISA-type tasks, where students are asked to interpret graphs, evaluate statistical claims, reason with probabilistic information, or make decisions based on quantitative evidence (OECD, 2019). In such contexts, the key challenge is not computational difficulty, but interpretive judgment: understanding what a numerical result represents, how reliable it is, and what implications it has for the real-world problem at hand. Recent empirical research further confirms that mathematical literacy is primarily associated with reasoning, interpretation, and contextual judgment, rather than procedural performance (Nolka & Sofianopoulou, 2025).

Mathematical literacy thus provides a paradigmatic example of model-based reasoning under uncertainty. Knowledge is mediated by formal representations, and understanding depends on the learner's ability to move reflexively between mathematical structures and contextual meaning. This conception will serve as the theoretical baseline for the subsequent analysis of AI literacy, which similarly involves interpreting outputs generated by models—albeit models that are algorithmic, data-driven, and often opaque.

4. AI literacy and algorithmic models

The concept of AI literacy has emerged in response to the increasing presence of artificial intelligence systems in everyday life, education, and decision-making processes. Although definitions vary, most contemporary frameworks converge on the idea that AI literacy involves more than technical familiarity with AI tools. Instead, it encompasses the ability to understand, interpret, and critically evaluate AI systems and their outputs, as well as to recognize their limitations and social implications (Long & Magerko, 2020; Ng et al., 2021; UNESCO, 2024).

Importantly, many recent definitions emphasize that meaningful engagement with AI requires interpretive and epistemic capacities, not merely operational skills. Users are increasingly confronted with algorithmic outputs such as predictions, classifications, rankings, and recommendations, which are often presented as authoritative or objective. However, these outputs are the result of complex computational processes that are typically opaque, probabilistic, and dependent on training data. As a consequence, AI systems function as model-generating mechanisms that mediate how reality is represented and understood.

From an epistemic perspective, AI outputs can be conceptualized as algorithmic models of the world. Machine learning systems infer patterns from data and produce representations that approximate or predict aspects of reality. These representations are not direct reflections of the world, but statistical constructions based on correlations, probabilities, and optimization criteria (Mitchell, 1997; Domingos, 2015). Their epistemic status is therefore inherently uncertain: they provide plausible inferences rather than definitive truths. Recent work on formal mathematical reasoning further shows that large language models often generate seemingly coherent but unverifiable reasoning, making human interpretive judgment epistemically indispensable (Yang et al., 2024).

AI literacy, in this sense, involves the capacity to interpret such algorithmic models as provisional and context-dependent representations, rather than as factual descriptions. This requires users to engage in reflective judgment: assessing the reliability of outputs, considering potential biases in data and models, and situating algorithmic results within broader contextual knowledge (Ng et al., 2021; OECD, 2025). Without such interpretive capacities, users risk either over-trusting AI systems or rejecting them uncritically, both of which undermine informed decision-making.

Crucially, this interpretation-oriented view of AI literacy aligns with broader theoretical accounts of models as epistemic mediators between theory and reality (Morgan & Morrison, 1999; Knuuttila, 2011). Just as scientific models simplify and idealize phenomena in order to make them intelligible, AI models construct representations that enable prediction and classification, while simultaneously obscuring underlying assumptions and uncertainties. Understanding AI, therefore, does not primarily mean understanding code or algorithms, but understanding how model-based knowledge is produced, limited, and interpreted.

AI literacy can thus be conceptualized as a form of algorithmic epistemic reasoning: a competence that enables individuals to make sense of machine-generated representations, to reason under algorithmic uncertainty, and to evaluate the epistemic status of AI outputs in real-world contexts. This characterization provides the basis for aligning AI literacy with mathematical literacy, which similarly centers on the interpretation of model-based representations of reality.

5. Conceptual alignment between mathematical literacy and AI literacy

The preceding analysis suggests that, despite emerging in different historical and technological contexts, mathematical literacy and AI literacy share a common epistemic logic. In both cases, individuals do not engage directly with reality, but with models that mediate understanding. These models function as representational tools that enable the description, explanation, and prediction of phenomena, while simultaneously introducing assumptions, simplifications, and uncertainty (OECD, 2019; Morgan & Morrison, 1999). This alignment is further strengthened by empirical evidence showing that mathematical literacy operates primarily as an epistemic competence grounded in interpretation and judgment (Nolka & Sofianopoulou, 2025), as well as by recent analyses indicating that AI-generated reasoning remains epistemically uncertain and requires human validation (Yang et al., 2024).

In mathematical literacy, this mediation takes the form of human-constructed mathematical models—such as equations, graphs, or statistical representations—that translate real-world situations into formal structures. Meaning is produced through the learner’s ability to move between these structures and the original context, interpreting results, assessing plausibility, and exercising judgment (Niss & Jablonka, 2014). The epistemic task is therefore not to obtain a single correct answer, but to construct and evaluate model-based interpretations of reality.

In AI literacy, mediation is achieved through machine-generated, data-driven models that infer patterns from large datasets and produce probabilistic outputs. Although the computational mechanisms differ, the epistemic challenge remains structurally similar. Users must interpret algorithmic representations, reason under conditions of uncertainty, and evaluate outputs in relation to contextual knowledge and practical consequences (Long & Magerko, 2020; Ng et al., 2021). As in mathematical literacy, understanding does not reside in the model itself, but in the human capacity to make sense of its outputs.

This structural similarity allows AI literacy to be theoretically framed as an extension of mathematical literacy into algorithmic environments. The term “extension” here does not imply a linear progression or a hierarchical relationship between the two constructs. Rather, it denotes a shift in the nature of the models involved, from mathematical representations constructed by humans to algorithmic representations generated by machines. The underlying epistemic processes—modeling, interpretation, evaluation, and judgment—remain fundamentally the same.

Both literacies therefore involve (a) engaging with models as mediators of knowledge, (b) reasoning under uncertainty, and (c) critically evaluating formal outputs in real-world contexts. The distinctive feature of AI literacy lies in the opacity and probabilistic character of algorithmic models, which intensifies the need for reflective interpretation and critical judgment (Domingos, 2015; Knuuttila, 2011).

Framing AI literacy in this way shifts the focus of AI education away from narrow technical competencies and toward epistemic practices of meaning-making. AI literacy becomes not a separate or novel form of literacy, but part of a broader continuum of model-based reasoning that has long been central to mathematical and scientific literacy.

6. Discussion and conclusion

This paper sets out to conceptually examine the relationship between mathematical literacy and AI literacy, focusing on how each construct is defined and what kinds of reasoning they presuppose. Rather than treating AI literacy as a novel or unrelated competence, the analysis suggests that both literacies share a common epistemic structure: individuals engage with models that mediate understanding of reality, reason under conditions of uncertainty, and exercise judgment in order to interpret and evaluate formal outputs in context.

By drawing on the OECD/PISA conception of mathematical literacy and contemporary AI literacy frameworks, the paper argued that the core epistemic processes involved in both constructs are structurally similar. In mathematical literacy, these processes revolve around the interpretation of human-constructed mathematical models; in AI literacy, they involve engagement with machine-generated, probabilistic algorithmic models. The key difference, therefore, does not lie in the nature of reasoning itself, but in the origin and opacity of the models that mediate knowledge.

Framing AI literacy as a theoretical extension of mathematical literacy offers an alternative to prevailing skill-based or tool-oriented approaches. It positions AI literacy as an epistemic practice of meaning-making, rather than as a collection of technical competencies or ethical checklists. From this perspective, understanding AI does not primarily mean understanding algorithms or code, but understanding how algorithmic representations are constructed, what kinds of uncertainty they entail, and how their outputs should be interpreted and evaluated in relation to real-world contexts.

This conceptual alignment has several implications for future research. First, it provides a coherent theoretical foundation for the development of AI literacy frameworks that are grounded in established traditions of model-based reasoning. Second, it opens new avenues for empirical studies that examine how learners interpret and reason with algorithmic outputs, drawing on constructs and methodologies from mathematical and scientific literacy research. Finally, it supports the idea of more integrated literacy frameworks, in which mathematical, digital, and AI literacies are not treated as separate domains, but as interconnected forms of epistemic engagement with formal representations of the world.

In an increasingly algorithmic society, the challenge of education is not merely to teach individuals how to use intelligent systems, but to enable them to interpret, evaluate, and critically engage with the models through which such systems represent reality.

This reframing shifts AI literacy from a skill-based construct to an epistemic practice of interpretation under conditions of uncertainty. Understanding AI literacy as an extension of mathematical literacy provides a theoretically grounded and conceptually coherent framework for addressing this challenge.

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