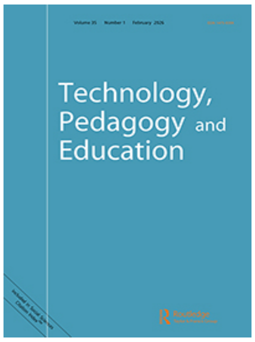

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Introducing AI education in school contexts: a 3D-literacy analysis of the Swedish AI subject

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ABSTRACT

This paper examines how AI literacy is conceptualised in Swedish upper secondary school policy documents that govern a newly introduced AI subject. Drawing on Green's 3D literacy model comprising operational, cultural and critical dimensions, the authors analyse the curriculum and support materials to explore how these dimensions are represented and what this implies for teachers, teacher educators and students. The analysis shows a strong emphasis on operational literacy, some presence of cultural literacy and a limited focus on critical literacy, particularly its agentive dimension. The authors argue that this imbalance may constrain students' opportunities to critically engage with AI as a sociotechnical phenomenon and limit teachers' ability to support such engagement. The study contributes to international discussions on AI education by highlighting the need for a more holistic and critical approach to AI literacy, with implications for curriculum design, teacher preparation and educational policy.

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3D literacy; AI literacy; AI education; critical literacy; teacher education

Introduction

The presence of artificial intelligence (AI) in society is increasingly reflected by human interactions with prediction- and decision-based machine systems, shaping social environments (UNICEF, 2021). This presence has stirred interest in education's role in developing people's AI-related sets of skills and knowledge. These commonly include competencies that allow individuals to critically evaluate and engage with AI technologies, such as recommender systems and large language models (Long & Magerko, 2020). AI education efforts are being developed and framed for school contexts worldwide (Ng et al., 2021; Sperling et al., 2024), either infused with existing subjects or as distinct school subjects (UNESCO, 2022).

One of the countries that has introduced AI as a school subject is Sweden, which is the empirical context of this paper. As an upper-secondary school subject, it includes two elective courses comprising theoretical knowledge, practical use and approaches related to AI. The subject was launched for STEM programmes in 2024, with an all-programmes expansion scheduled for 2025. This wide programme scope is mirrored by the AI subject's

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purpose, which concerns 'AI development primarily from a societal perspective and explores the consequences it may have for daily life' (Swedish National Agency for Education, 2024a, p. 1). The subject aims to develop students' understanding of AI as a 'complex sociotechnical artefact' (Swedish National Agency for Education, 2024b, p. 2). Consequently, AI subject teachers need relevant content and didactic competence to teach about AI informed by a holistic perspective, particularly in the context of generative AI (Kalantzis & Cope, 2025). As stressed by Holmes et al. in a European Union report, 'teaching about AI using simplified technical language is important but teaching about what AI does is incomplete without explanations of "the people, power and political motivations behind' (2022, p. 29). Teachers' fostering of AI-related skills and knowledge thus requires a more comprehensive understanding of AI, which goes beyond the technology behind to include how AI is and can be used in different contexts (Long & Magerko, 2020; Ng et al., 2021).

The introduction of AI-related competencies in school contexts reflects how knowledge and skills beyond traditional reading and writing are increasingly regarded as necessary for young people's participation and work in society, i.e. the development of AI literacy. Whilst no definition of AI literacy has been universally adopted and conceptualisations therefore vary (Ayanwale et al., 2024), the focus has often been on technical skills related to how AI works and its usage. This focus reflects an operational literacy perspective on AI, which predominates in research and policy with an instrumental emphasis on skills and competencies for work and life (Velander et al., 2024). Common examples include AI definitions, practical applications of AI in everyday life, identification and recognition of AI systems, data structures, propositional logic, Python programming, natural language processing, computer vision and machine learning (ML) (Sperling et al., 2024).

A critical and multidimensional understanding could draw attention to, for example, issues of power and control that underpin AI integration in society or emphasise the situatedness of literacy where AI technologies are situated and as such perceived and used differently (Merchant, 2021; cf. Lankshear & Knobel, 1998).

Thus, a key premise of our paper is that different perspectives on AI literacy translate into different teaching and learning activities. In schools, teachers must interpret and operationalise relevant steering documents when teaching the AI subject in different contexts, as must teacher educators training these AI teachers. How these steering documents conceptualise AI literacy therefore has cascading effects. They shape what teacher educators prioritise in AI teacher preparation, influence how teachers understand their role in AI education and ultimately influence what forms of AI literacy students have opportunities to develop. Given AI's growing importance for democratic participation in algorithmically driven societies, these interpretative choices can have substantial consequences for young people's capabilities to critically engage with and shape AI's role in society (cf. Örtegren, 2024; Sperling et al., 2024). Such interpretative choices also reflect Prestridge and Starkey's (2025) emphasis on teachers' AI literacy and how cultivating this can aid interpreting and making informed decisions in relation to education policy.

Aim and research questions

In our paper, we approach AI education from a literacy perspective, examining the Swedish AI subject for upper secondary school. Specifically, we analyse the presence of different dimensions of AI literacy in relevant steering documents to discuss potential implications for teachers, teacher educators and students. With Sweden as an empirical case, our paper contributes knowledge on how AI education steering documents (e.g. curriculum, syllabus, official support materials) can shape both demands on AI literacy for teaching and learning and students' opportunities to develop AI literacy. The following research questions (RQs) guide our study:

- RQ1. What dimensions of AI literacy are present in steering documents governing the Swedish AI subject?
- RQ2. Considering RQ1, what are potential implications for teachers' and teacher educators' AI literacy?

To address these RQs, we conducted a document analysis drawing on the 3D literacy model (Green, 1988) as our analytical framework. Our empirical results address RQ1 directly, whilst we answer RQ2 by discussing these results. The paper proceeds by first examining AI education and literacy concepts, then presenting our methodology and empirical results, before discussing implications for teachers' and teacher educators' AI literacy.

Setting the stage

AI education for school contexts

AI is increasingly impacting education through its integration into everyday digital tools and educational technologies, and through how it is conceptualised as a subject for teaching students about AI (Holmes et al., 2022). Whilst countries are responding by introducing AI education in national curricula (Heintz, 2021; UNESCO, 2022), such initiatives remain an under-researched area.

Until recently, many AI education initiatives in school contexts have originated primarily in non-governmental organisations, private companies, and with AI experts rather than educators and educational scientists (Holmes et al., 2022). For example, to develop national guidelines for teaching AI to K-12 students in the United States, the Association for the Advancement of Artificial Intelligence and the Computer Science Teachers Association together produced the Five Big Ideas in AI, which has been important in introducing AI to teachers, parents and students (Touretzky et al., 2019, 2022). Similar efforts in the EU are underway and a review draft of an AI literacy framework was released in May 2025 (OECD, 2025a). This framework with the title 'Empowering Learners for the age of AI – An AI Literacy Framework for Primary and Secondary Education' is a joint initiative by the European Commission and the Organization for Economic Cooperation and Development (OECD) and Code.org. The framework is intended as a support for teachers, educational leaders and policy makers and learning designers in integrating AI education in a cross-curricular manner. It is developed to align with the Programme for International Student Assessment (PISA) 2029 Media & Artificial Intelligence Literacy (MAIL) assessment and analytical framework which is expected to be released in December 2025 and will function as an instrument to measure levels of students' AI literacy (OECD, 2025b). Other examples include the International Society for Technology in Education's partnership with General Motors to develop an AI curriculum for high school students, and Google's $1 million investment in AI4All to develop high school curricula (2019). There are also AI education initiatives, e.g. Canada's Kids Code Jeunesse (Coding for kids, 2013) and massive open online courses open to all ages like Finland's Elements of AI (University of Helsinki, 2025). Some use programming activities (e.g. Long et al., 2021; Tedre et al., 2022) whilst others do not (Druga et al., 2022; Sabuncuoglu, 2020).

Regardless of approach, the goal of these AI education initiatives is generally to offer a comprehensive understanding of established AI techniques and practices. However, echoing patterns observed with other digitally related literacies in school and teacher education contexts (Aagaard et al., 2024; Löfving, 2023), the focus tends to be on technical AI knowledge and abilities (UNESCO, 2022).

Literacy in an AI-mediated world

The examples of AI education initiatives are typically framed as aiming to develop what is broadly termed as AI literacy – AI-related competencies necessary for equal opportunities to participate in society, both within school contexts and among the general public (Casal-Otero et al., 2023; Long & Magerko, 2020; Ng et al., 2021). In these framings, the concept of literacy is often under-theorised and tends to align with an operational perspective (Velander et al., 2024). This perspective emphasises technical knowledge and practical usage (Durrant & Green, 2000; Löfving, 2023; O'Mara, 2006; Sperling et al., 2024; UNESCO, 2019; Velander et al., 2024), such as navigating digital information or making responsible decisions as citizens and consumers (Long & Magerko, 2020; Ng et al., 2021). AI literacy is also positioned as a means of promoting equal opportunities for societal participation (UNESCO, 2019), intended to empower individuals concerning privacy, agency and control in a datafied society. These perspectives often rest on the assumption that acquiring such competencies will lead to increased self-efficacy (Pangrazio & Sefton-Green, 2020). The operational perspective often aligns with broader educational policy discourses, where curriculum reforms are justified in terms of keeping pace with technological development. Such policies are driven by assumptions about the knowledge and skills needed to ensure that both individuals and nations remain competitive in a global, digital economy (Rahm, 2018). A digitally literate population is assumed to contribute to financial growth and social wellbeing in the knowledge society (Lankshear & Knoble, 2006; Rahm, 2018), as well as enabling individuals to navigate contemporary challenges such as filter bubbles, disinformation and conformity to social media norms (Kaluža, 2022). Such framings have contributed to an ongoing pressure for citizens to continually update their literacies, with AI becoming an increasingly central dimension (Kalantzis & Cope, 2025; Rahm, 2018, 2024). Here, literacy is no longer understood solely as a set of discrete technical skills. According to UNESCO (2025), literacy is a lifelong process that involves interpretation, communication and creation in a rapidly changing, digitally mediated world. As digital technologies reshape how individuals access and engage with information, literacy overlaps with digital, media and civic competencies.

Scholars have therefore expanded the understanding of literacy by emphasising inherent relationships with its mediating technologies. From this perspective, literacy involves not only reading and writing the *word*, but also the *world* (Freire & Macedo, 1987;

Merchant, 2020). From ink and paper to digital texts, hypertexts and algorithmically generated language, literacy is shaped by tools of communication (Burnett & Merchant, 2019; Leander & Burriss, 2020; Merchant, 2020). As Merchant (2020, p. 97) argues, the written word itself is 'a powerful technology and a means of enacting influence, control, and exclusion as well as emancipation, enrichment, and enjoyment'.

The emergence of AI, particularly generative AI, further complicates this picture. Large language models such as ChatGPT demonstrate how technologies act and interact in communicative environments previously governed by human agency. Human and non-human actors increasingly co-produce word-based artefacts, redistributing agency and reshaping the nature of authorship and communication. In addition to text generation, AI systems produce images, video and sound. AI-generated pictures, for instance, are reshaping practices of communication and cultural production, from deepfakes and manipulated images to creative design and advertising. These multimodal outputs further underline the need for critical AI literacy, as they raise pressing questions of representation, authenticity and disinformation (Vuorikari et al., 2022; cf. Lankshear & Knobel, 1998). Addressing visual and multimodal AI generation is therefore essential for a comprehensive understanding of how AI shapes meaning-making in society. As Leander and Burriss (2020, p. 12) note, '[l]iteracy scholarship can no longer pretend that texts and practices of literacy float free from machines, and especially AI and its computational agents'.

Therefore, scholars increasingly argue for a critical literacy perspective that moves beyond operational skillsets to include reflection on the sociotechnical conditions of AI and its broader implications for society (Leander & Burriss, 2020; Merchant, 2021; Strauß, 2021; Velander et al., 2024). This perspective attends not only to how individuals use AI but also to how AI systems shape communication, knowledge production and social relations. This includes future-oriented approaches that connect with the emancipatory objectives of critical literacy. By understanding past and present AI developments, students can imagine desirable alternative futures, introducing temporal thinking into AI education. Such teaching may include using speculative methods (Costello et al., 2024; Krutka et al., 2021; Lindberg & Haglind, 2024) to imagine alternative futures, which is a stark contrast to policy approaches that often rely on past and present temporalities (Lindberg & Haglind, 2024).

Here, Bill Green's (1988) three interrelated dimensions of literacy: operational, cultural and critical can offer an analytical lens that recognises both the situated nature of literacy and its emancipatory potential (Green, 1988; Lankshear & Knoble, 1999). However, as Pangrazio and Sefton-Green (2021) caution, operational literacy alone does not necessarily lead to greater self-efficacy. A critical approach to AI literacy is necessary to interrogate power, ethics and the sociocultural contexts in which AI is embedded (Rapanta et al., 2025). It is within this tradition that we position the contribution of our paper.

Methodology

Empirical context

Since 2023, Swedish teachers and teacher educators must increasingly navigate digital education policy at the upper secondary school level with limited centralised guidance (Swedish National Agency for Education, 2024a). Previously, a national digital strategy for schools positioned 'adequate digital competence' as a key competence for staff and students (Swedish National Agency for Education, 2017): (a) to have an understanding of how digitalisation impacts society and the individual; (b) understand and be able to use digital media; (c) be able to critically and responsibly relate to digital technology; and (d) be able to actualise these ideas using digital technologies. As inferred by the definition, AI would be a part of this strategy, but a change in government led to its suspension, citing concerns over the effects of digital tools and specifically screens in education (Swedish Parliament, 2024).

These broader Swedish policy developments highlight the importance of teachers' and teacher educators' guidance on engaging with digital technologies and AI at the subject level. In our study, we centre on the AI subject, where it has been introduced in upper secondary school. Upper secondary education in Sweden is non-mandatory, comprising three years where students (typically aged 16–19) follow paths preparing for academic studies, such as social science, economy or natural sciences, or vocational paths, such as childcare or transportation. The AI subject was introduced into STEM programmes and as an elective subject in other programmes. Echoing this, teachers of STEM subjects (maths, technology, programming or web and user interface design) require 15 ECTS of AI studies to be certified to teach the AI subject (approximately equivalent to half a semester of full-time study), whereas other teachers require 60 ECTS.

Empirical materials

Our empirical materials comprise steering documents governing the AI subject produced by SNAE. Specifically, we analysed: (a) the national curriculum for upper secondary school containing the AI course syllabi for both available courses (Swedish National Agency for Education, 2024a) and (b) official commentary materials explaining the syllabi's implementation (Swedish National Agency for Education, 2024b).

These documents were collected on 20 September 2024 from SNAE's website and were publicly accessible. At the time of the study, these represented the complete set of official guidance materials available to AI subject teachers and thus constituted the official framework for governing AI subject teaching in Sweden.

Analytical framework

Given that the Swedish AI subject explicitly aims to develop students' understanding of AI from a societal perspective, including its implications for daily life (Swedish National Agency for Education, 2024a), we required an analytical framework capable of capturing both technical and sociocultural dimensions of literacy. We therefore drew on the 3D literacy model as a heuristic device to guide our analysis as it enables a structure for examining literacy practices and takes a sociocultural perspective on literacy, acknowledging that literacy is always situated in social practices (Durrant & Green, 2000; Green, 1988; O'Mara, 2006). Using the framework as a heuristic allowed us to structure our analysis of different dimensions of AI literacy as represented in the analysed texts, whilst remaining open to refinement and contextual adaptation.

The 3D literacy model conceptualises literacy as comprising three interlinked and equally important dimensions: operational, cultural and critical literacy (Green, 1988). This model has been widely used in educational studies examining the relationship between technology and literacy (Beavis, 2004; O'Mara, 2006, Pangrazio & Sefton-Green, 2020; Tour et al., 2021), making it appropriate for analysing dimensions of AI literacy in educational steering documents. For our analysis of AI literacy, we developed the following working definitions for each dimension.

The operational dimension focuses on understanding and using AI effectively. This includes technical knowledge of how AI and ML work, understanding data structures, training AI models, distinguishing between different types of ML and interacting with AI-powered tools such as chatbots. Teaching this dimension requires technical knowledge of AI and especially ML, mathematics, statistical concepts and an understanding of programming.

The cultural dimension highlights that AI is not neutral technology in how it is implemented, represents the world or in how its results are interpreted or applied. This dimension focuses on how people interpret and use AI differently depending on social, cultural and professional contexts. Teaching the cultural dimension situates the operational dimension in different contexts, requiring teachers to unpack AI concepts and applications whilst considering the situatedness of data availability and representation.

The critical dimension focuses on reflection and critical engagement with AI's role in shaping society. It includes unpacking biases, questioning who benefits or is excluded and analysing how AI systems reinforce or challenge power structures. Teaching this dimension involves linking societal effects to their technical enablers (operational dimension) and the contexts in which they emerge (cultural dimension), whilst encouraging students to reflect on who is represented in AI systems and actively contribute to rethinking AI systems and their integration in different contexts.

As will be described below, we found during our early analysis that refining the critical dimension was necessary into two sub-dimensions: one that positions the learner as an *observer* (passive) and one that positions the learner as an (active) *agent* (as detailed below). The purpose was to better capture the diversity in how critique and power were represented (or not) in the included steering documents.

Document analysis

Document analysis is well suited for examining how concepts are constructed and represented in policy texts (Bowen, 2009), making it applicable in this study for examining dimensions of AI literacy in steering documents. To analyse the presence of such dimensions in our empirical materials, we followed Bowen's (2009) three-step approach: skimming and initial examination, detailed reading and coding, and interpretation and synthesis.

Beginning with provisional coding (Saldaña, 2015), we employed a deductive coding strategy, using our adapted 3D literacy model (Table 1) as initial codes to identify relevant passages. Each document was read thoroughly, with passages coded according to whether they reflected dimensions of operational, cultural or critical literacy and if there were any areas of potential ambiguity. These were discussed among the authors, leading to iterative refinements of the 3D model's working definitions as patterns and themes emerged.

Table 1. The 3D literacy dimensions initially adapted for AI literacy analysis in this study.

Literacy dimension	Working definition
Operational	Understand and use AI (concepts and applications) to perform tasks efficiently for different purposes.
Cultural	Understand that how people perceive AI (concepts and applications) differs across social contexts, both reflecting and shaping societal values and norms.
Critical	Critically evaluate and engage (questioning, analysing, challenging) with AI (concepts and applications) and its societal implications, including underlying assumptions and power dynamics, reimagining and reconstructing different possibilities, and contribute to the transformation of AI towards more just, inclusive and ethical futures.

Subsequently, with these refined working definitions, we conducted inductive analysis of the coded passages to explore how each AI literacy dimension was represented within the materials. During this phase, we found that the critical dimension, as originally defined in our adopted model, did not fully capture how critique and power were represented. For example, we found text positioning students as critical *observers* (analysing and evaluating AI's implications) but few instances as critical *agents* (challenging assumptions and seeking transformation). Because the critical dimension includes both observing and actively engaging, we refined the critical dimension by dividing it into two sub-dimensions:

- Critical observers: involving analysis and evaluation of societal implications of AI, such as bias, ethics or legal implications
- Critical agents: including critically engaging with underlying assumptions, power relations and possibilities for transformation or resistance.

With this refined critical dimension, we re-coded the materials (Table 2). This formed part of the third and final step of the document analysis, which was condensing the findings and writing up the results.

Throughout the coding and writing process, we employed a collaborative approach to ensure reliability and analytical robustness. Each coding round began with individual analysis, followed by group discussions where divergent interpretations were discussed and consensus reached. In line with Saldaña's (2013) view of coding as an interpretative and context-sensitive act, we emphasised discussion and mutual reflection rather than intercoder reliability metrics. This collaborative approach enabled us to critically engage with how our disciplinary backgrounds shaped our readings, thereby enhancing the transparency and credibility of the analysis.

Results

Document overview

As introductory notes to our analysis, the empirical materials emphasise that students will be assessed on five key areas: demonstrating knowledge of AI applications and

Table 2. The refined 3D literacy dimensions used in the final analysis.

Literacy dimension	Definition	Indicators	Example codes
Operational	Understanding and using AI (concepts and applications) to perform tasks efficiently for different purposes.	Technical concepts, coding practices, algorithmic thinking and tool use	AI functionality, technical knowledge, coding scaffolds
Cultural	Understanding how people perceive AI differs across social contexts, reflecting and shaping societal values and norms.	Social embedding, real-world application, interdisciplinary learning, relevance to student interests	Contextualised learning, AI in daily life, disciplinary integration
Critical – observer	Critically evaluating (questioning, analysing) AI (concepts and applications) and its societal implications.	Ethics, bias, responsibility, law and societal consequences	Ethical reflection, data bias and transparency concerns
Critical – agent	Critically engaging (challenging) with AI (concepts and applications) and its societal implications, including underlying assumptions and power dynamics, reimagining and reconstructing different possibilities and contributing to the transformation of AI towards more just, inclusive and ethical futures.	Questioning, power critique, human vs machine reasoning, knowledge transformation	Challenging assumptions, knowledge critique, AI vs human judgement

techniques; using AI to solve simple problems; comparing human and artificial intelligence; explaining relevant laws and regulations; and reasoning about AI's opportunities, risks and societal consequences (Swedish National Agency for Education, 2024a). These assessment criteria reflect the curriculum's priorities and expectations for student learning in AI education. The materials are structured around three main sections: Artificial Intelligence, Practical Use of AI and Approaches to AI. However, as the support materials emphasise, 'The headings are primarily intended to make the syllabus easier to read, they are not meant to divide the teaching into separate parts. The content often overlaps and runs in parallel throughout the courses' (Swedish National Agency for Education, 2024b, p. 2).

This integrated approach in the steering documents is relevant to our analysis, as we examine how AI literacy connects technical, cultural and critical dimensions and the implications this has for teachers' and teacher educators' AI literacy. We therefore present each literacy dimension separately, followed by an analysis of how the materials encourage connections between these dimensions in teaching practice. For each dimension, we identify main themes present in the steering documents, provide empirical examples and include representative quotes (Swedish National Agency for Education, 2024a, 2024b).

Our document analysis shows that the presence of AI literacy dimensions varies considerably across the empirical materials, with operational aspects receiving the most attention. The materials present AI as a technology that affects us as individuals and our society and therefore emphasise that it is important to learn about AI as citizens (Swedish National Agency for Education, 2024b). AI is referred to as data-driven and, in most cases, used interchangeably with ML, consequently with a strong focus on data as an aspect of AI literacy. The term AI is broadly used to refer to both its concepts (e.g. ML, natural language processing, recommender systems) and applications (contexts where concepts are used, e.g. social media applications, certain smart apps). We provide an overview with empirical examples below. (Table 3)

Table 3. Examples of literacy dimensions and commonly coded content.

Literacy dimension	Examples from the analysed materials
Operational	-Students learn AI techniques such as classification, prediction, natural language processing, machine learning and object recognition. - Use of decision trees, regression and supervised/unsupervised learning. - Application of AI in problem-solving, adapted to students' study paths or interests. - Train and test AI models using labelled/unlabelled data. - Use of block programming or existing code for those unfamiliar with programming. - Hands-on use of AI tools and platforms without requiring software installation.
Cultural	- Multiple definitions of AI over time and across institutions. - How the perception of AI evolves (e.g. from the Turing test to generative AI). –AI's integration into everyday life (e.g. streaming, e-commerce, societal institutions). - Demographic shifts and consumption patterns driving AI development. - Reflection on AI vs human abilities (creativity, intuition, moral judgement).
Critical – observer	- Discussions on bias in data and its societal effects (e.g. representation, fairness). - Ethical dilemmas: transparency, responsibility, copyright, AI as a 'black box'. - Effects on democracy, misinformation and access to public services. – AI's influence on social, economic, environmental and legal structures. -Risk analysis: surveillance, automated decision-making, misinterpretations, sustainability. - Reflection on what knowledge remains important for humans in an AI-driven world.
Critical–agent	Not addressed in the analysed materials.

Operational dimension: understanding and using AI in practice

The operational dimension is the literacy dimension with the strongest presence in the analysed materials, encompassing knowledge and practices related to understanding, applying and implementing AI technologies. This dimension appears primarily in the sections 'Artificial intelligence' and 'Practical use of AI', with the latter focusing almost exclusively on operational aspects (Swedish National Agency for Education, 2024a, 2024b).

Definitions and concepts are introduced early in the materials. AI is described as a 'comprehensive field' that engages students with 'not only specific forms of AI, such as generative AI or humanoid robots' (Swedish National Agency for Education, 2024b, p. 3). Throughout the materials, AI is presented as a data-driven concept dependent on data for accurate predictions, with ML as the main enabling technique and often used interchangeably with AI. 'Data is fundamental to AI' (Swedish National Agency for Education, 2024b, p. 3), with model accuracy dependent on data quality and quantity. To avoid biased results, data must be 'balanced, representative and impartial' (Swedish National Agency for Education, 2024b, p. 3).

A range of technical methods is presented throughout the operational dimension. Students are introduced to, for example, neural networks, decision trees, classification algorithms and linear regression. These methods are connected with practical applications and often related to implementation strategies:

> Methods and algorithms are fundamental to solving problems using AI . . . Depending on the students' prior knowledge of mathematics, the teacher can choose some of the following examples of methods: naive Bayesian classifiers, the k-nearest neighbors algorithm, or linear regression. (Swedish National Agency for Education, 2024b, pp. 4–5)

Teaching should include elements of programming, algorithm development and practical coding skills related to AI. As students have varied levels of programming and mathematics, this can be done through block-based or text-based programming. The problem-solving process is described in structured terms, including the stages of data collection, model training, evaluation and deployment: 'When solving problems with AI, a systematic approach and a well-defined problem description are crucial', for example data collection, model selection, training, evaluation and implementation (Swedish National Agency for Education, 2024b, p. 5).

Additional content addresses the use of common libraries and services for problem-solving with AI. Here, students can use 'ready-made programming examples, their own coding with the help of common programming libraries or available services and platforms for AI' (Swedish National Agency for Education, 2024b, p. 5). The support materials also include contrasts between AI and human problem-solving capabilities, concerning aspects such as speed, creativity and judgement:

> Some suggestions for similarities between how AI and humans solve the same problems could be data usage, pattern recognition, use of algorithms and tools. Suggestions for differences that can be highlighted in teaching are speed, creativity and ethical considerations. (Swedish National Agency for Education, 2024b, p. 6)

The comparison between human and machine capabilities appears primarily within the operational dimension but also connects to cultural and critical–observer concerns. For example, aside from performing 'monotonous and repetitive tasks without tiring', 'AI can operate vehicles with more precision and react faster than humans' (Swedish National Agency for Education, 2024b, p. 6). This statement supports operational literacy by illustrating efficiency and functionality. Simultaneously, it invites reflection on epistemic differences between algorithmic and human reasoning, which can be interpreted within both cultural and critical–observer frames, particularly in relation to creativity, judgement and responsibility.

The operational dimension thus establishes a comprehensive technical foundation, emphasising systematic approaches to AI implementation whilst accommodating diverse student backgrounds through differentiated learning pathways. This dimension positions students as users and implementers of AI technologies, focusing on developing practical competencies for working with AI systems.

Cultural dimension: contextual and situated understanding of AI

The cultural literacy dimension is found mainly in the 'Approaches to AI' section but also to some extent in 'Practical use of AI' (Swedish National Agency for Education, 2024a, 2024b). The materials emphasise AI in social contexts, the social embedding of AI and perceptions of AI.

Historical framings are used to introduce different conceptualisations of AI. For example,

> Although AI has a shorter history compared to many other technologies, a historical perspective on how AI has developed can still be important to address . . . such as the Turing Test and expert systems, and highlighting notable historical and current events that have had an impact in the media. (Swedish National Agency for Education, 2024b, p. 3)

The materials include sector-based examples, particularly from healthcare and environmental monitoring, where AI is shown to interact with practical societal challenges. 'Through case studies, where students can analyse real-life examples, teaching can highlight instances where AI has outperformed humans or vice versa' (Swedish National Agency for Education, 2024b, p. 6).

The materials also mention that definitions of AI evolve over time and across social groups. Teaching includes 'providing an opportunity to explore how perceptions of AI change over time, as well as the boundaries of what is considered AI' (Swedish National Agency for Education, 2024b, p. 3). This highlights the socially constructed nature of AI definitions and encourages an understanding of AI as a concept evolving across time and contexts.

Students are also encouraged to explore AI applications in everyday life and across different subject areas, with scope for individual interests, career goals and prior experiences to shape learning. For instance, 'In teaching, there is an opportunity to relate to previous situations where students have encountered and worked with problem-solving, for example, in design or mathematics' (Swedish National Agency for Education, 2024b, p. 5). This approach emphasises situating AI learning within students' existing knowledge and interests rather than treating it as an isolated technical subject. More broadly, these examples demonstrate the tendency in the materials to situate AI in contexts relevant to the student, engaging in the AI process from data collection to evaluation of outcomes and implications.

The cultural dimension thus positions AI as a socially embedded and historically evolving concept, encouraging students to understand how AI technologies vary across contexts and connect to their own experiences. However, whilst demonstrating how AI is situated in relation to societal domains and cultural shifts, the dimension focuses primarily on situating AI use rather than examining how AI shapes cultural norms and practices.

Critical (observer)

The observer component of the critical dimension is addressed through references to ethical considerations, fairness, transparency and the societal implications of AI. These topics are typically introduced as areas for reflection and discussion, where the individual is positioned as a critical observer (Swedish National Agency for Education, 2024a, 2024b).

For example, issues of bias in data and algorithms are noted in the 'Artificial intelligence' section:

> The selection of data is crucial for quality and therefore needs to be balanced, representative, and impartial, i.e. not contain bias. Here, there are interesting ethical questions to discuss in the classroom. What effects does biased data have on us as recipients of messages and information? (Swedish National Agency for Education, 2024b, p. 3)

This example demonstrates how ethical considerations are framed as discussion topics for students to explore. Discussions around data selection and algorithmic bias span the operational and critical – observer dimensions. However, this overlap is not explicitly expressed in the materials.

Other examples refer to concerns about the opacity of certain AI systems. In teaching, 'examples of ethical issues that can be addressed include the lack of transparency, AI as a black box, and who carries responsibility when AI acts in a way that could not have been predicted?' (Swedish National Agency for Education, 2024b, p. 7). These examples position students as observers who recognise and analyse ethical problems in AI systems.

The materials also raise questions about the societal impact of AI-generated content. For example, whilst 'The flow of information is affected by increased opportunities for strengthened news production', it is also affected by 'sensationalist news and disinformation' with democratic implications, for example, through troll factories and alt-news websites (Swedish National Agency for Education, 2024b, p. 8). AI-driven decisions ultimately have 'social and economic consequences for the individual citizen' (Swedish National Agency for Education, 2024b, p. 8). This highlights how students are expected to understand AI's broader societal implications.Environmental sustainability is included within this dimension. Specifically,

> AI is used in several ways to obtain secure and swift compilations, models, and analyses. Automatic damage assessment, energy savings, and real-time monitoring of climate systems are some examples where AI is a great asset for informed decisions. At the same time, the use of AI itself is energy-intensive and storing data requires large data centres. (Swedish National Agency for Education, 2024b, p. 8)

This example also illustrates some overlapping content across the cultural and critical – observer dimensions, with indirect links to the operational dimension through reference to large-scale computing infrastructures. Whilst framed as a factual observation, this example situates AI within broader cultural debates about environmental impact and introduces ethical questions related to resource use and energy consumption. The operational implications (e.g. model size, infrastructure needs) are not explicitly elaborated but remain relevant to understanding environmental trade-offs in AI development.

Several examples of case studies present AI technologies in domains such as healthcare, environmental monitoring and transportation. These examples often link operational, cultural and critical – observer dimensions. For instance, 'In healthcare, the use of AI has provided faster and many times safer diagnoses … How significant is the risk of misdiagnosis and can a robot replace human contact?' (Swedish National Agency for Education, 2024b, p. 8) This excerpt introduces technical applications (operational), situates them in a specific professional context (cultural) and raises concerns about diagnostic accuracy and the role of human interaction and accountability (critical – observer). Such case-based integration may provide a platform for cross-dimensional learning, though explicit instructional alignment across the dimensions is not always evident.

These examples indicate an emphasis on identifying and understanding the ethical and societal dimensions of AI, with attention to the effects of systems on individuals and society at large. The critical observer dimension positions students as reflective analysts who seek to recognise AI's implications, but without necessarily encouraging them to challenge or transform existing AI systems.

Critical (agent)

Despite the inclusion of ethical themes and societal reflection, the analysed materials lack elements associated with the critical agent dimension. Nowhere are students explicitly encouraged to challenge dominant narratives, question power relations or reimagine alternative sociotechnical arrangements. For example, whilst students are asked to reflect on when AI might be appropriate or effective, they are not asked to critically interrogate why certain AI systems exist, who benefits from their implementation, or how AI development might reproduce or challenge inequality.

The critical agent dimension is thus absent from the analysed materials. This absence further positions students as informed observers rather than active agents of change regarding AI systems.

Discussion

The purpose of our paper was to examine AI education from a literacy perspective, focusing on the presence of different dimensions of AI literacy in educational steering documents for an independent AI school subject. We did this using an adapted version of the 3D literacy model, with the Swedish AI subject for upper secondary school as an empirical case. Our results contribute knowledge about what students are expected to know about AI, but also implicitly about the dimensions of AI literacy that teachers and teacher educators need for course delivery and teacher preparation, respectively. We first discuss the results in relation to RQ1 and, based on these, the implications for RQ2.

Dimensions of AI literacy present in the Swedish AI subject

For RQ1, we found that there is a strong presence of the operational dimension of AI literacy. We also found that there is a focus on understanding the role of data in contemporary AI. This predominant focus on technical knowledge and practical usage in national curricula and related educational resources is unsurprising and has been observed elsewhere (Druga et al., 2022; Durrant & Green, 2000; Löfving, 2023; O'Mara, 2006; Sperling et al., 2024; UNESCO, 2019; Velander et al., 2024).

The operational dimension's dominance has important implications for how students are positioned within AI education. Such a technical-practical focus tends to position the individual as a passive user or consumer of AI, where AI and the way it is implemented in different contexts are not challenged but rather viewed as an unstoppable force that we have to adapt to (Rapanta et al., 2025; Sperling et al., 2024; Velander et al., 2024). These technologically deterministic underpinnings frame AI development as following a predetermined trajectory that education must accommodate rather than critically engage with. The operational dimension also reflects the idea of literacy as something that underpins a nation's development and knowledge advancement, thereby fostering a flexible workforce capable of competing in a globalised and technologically advanced world (Sperling et al., 2024; Velander et al., 2024). This instrumentalist framing risks reducing AI literacy to technical competence in teaching and learning activities, potentially undermining students' opportunities to develop skills and knowledge to critically engage with AI technologies (Örtegren, 2024).

The materials also place a substantial emphasis on developing the cultural dimension of students' AI literacy, which highlights that AI depends on social, cultural and professional contexts and means different things for different people. Students are encouraged to understand AI as socially embedded, context-dependent and evolving historically. Examples such as AI's use in social media, public institutions and different professions situate the operational dimension in everyday contexts, but a critical gap remains regarding the cultural dimension in its insufficient emphasis on the fact that AI is not neutral. AI is not only shaped by cultural and societal norms, but also the other way around, our cultural and societal norms are simultaneously shaped by AI (Leander & Burriss, 2020; Merchant, 2021). This is a critical conceptual limitation regarding the cultural dimension. Whilst the materials acknowledge AI's social embeddedness, they do not address the mutually co-constitutive nature of sociotechnical systems, which may influence students' understanding of their own agency in shaping sociotechnical futures (Lindberg & Haglind, 2024; Örtegren, 2024).

In contrast, the critical dimension of AI literacy is only partially present. Whilst the analysed materials contain elements of what we have labelled the critical observer dimension, such as ethical considerations, legal implications and risks related to bias and surveillance, the critical agent dimension is virtually absent. Students are not encouraged, at least explicitly, to challenge dominant narratives around AI in societal contexts where it is embedded, related power dynamics or imagine alternative sociotechnical futures. This absence is problematic given AI's role for democracy and social justice (Innerarity, 2024; Rapanta et al., 2025). Our results are therefore consistent with previous critiques of digital literacy education that highlight a lack of emphasis on critique and transformation (Burnett & Merchant, 2019; Pangrazio & Sefton-Green, 2021).

Moreover, this framing reflects what Johnson and Verdicchio describe as 'sociotechnical blindness' (2017, p. 2268): understanding technology based solely on its attributes whilst omitting the extensive human work required to make these attributes emerge. In the context of AI education, this blindness is evident in teaching students to understand AI systems without encouraging them to examine the social, political and economic forces that shape these systems' development and deployment. Consequently, students are primarily positioned as informed users or responsible citizens, rather than as active agents of change with regard to AI and its role in society.

Implications for teachers and teacher educators' AI literacy

Addressing RQ2, we discuss in this section the potential implications of our results for teachers' and teacher educators' AI literacy. With an uneven presence of AI literacy dimensions in AI subjects, we argue that teachers and teacher educators are implicitly guided to prioritise certain subject content, which in the Swedish case is technical and contextual knowledge rather than critical engagement. This has several implications that extend beyond individual teacher competence to structural issues in AI education, impacting both schools and teacher education.

First, teachers lack guidance and support to develop competence across all three AI literacy dimensions, considering the aims and goals of these AI courses regarding technical and societal perspectives. Many teachers may already feel confident in relation to an operational dimension of AI literacy, particularly those with STEM backgrounds, whilst fewer are likely to be prepared to support students in developing cultural and especially critical dimensions. The overall emphasis on operational literacy creates substantial technical demands for teachers, who must master foundational AI knowledge, ML principles, algorithmic processes and practical skills, including coding, data handling and platform usage. Whilst the materials accommodate varied student backgrounds through differentiated pathways, allowing techniques to be 'presented at a conceptual and overarching level' with 'room for specialisation' (Swedish National Agency for Education, 2024b, p. 4), this technical focus may leave teachers inadequately prepared to address cultural and critical dimensions. The operational dimension is also extensive, which risks putting the cultural and critical dimensions in the background despite the AI subject's stated societal goals.

This is accentuated by the differing Swedish certification requirements for teaching the AI subject: STEM teachers require 15 ECTS of AI courses, whereas other teachers require 60 ECTS. This disparity raises important questions about equity and preparedness across teachers from different backgrounds, particularly related to addressing the societal perspectives emphasised in the analysed materials. Considering research on digital competence in schools and teacher education (Örtegren & Olofsson, 2024; Scherer et al., 2018; Tondeur et al., 2019), a likely scenario is that teachers' backgrounds and beliefs about digital technologies, including AI, will shape course delivery, i.e. students' opportunities to develop holistic AI literacy in line with policy expectations.

Second, the absence of active critical literacy may discourage teachers from exploring AI's political, ethical and societal entanglements in depth, both in school and teacher education contexts. Without clear curricular support or examples, there is a risk that such teaching will be marginalised or omitted in favour of content with clear grading criteria and guidelines. Teachers and teacher educators may struggle to justify allocating time for all AI literacy dimensions. This may ultimately influence teachers' engagement with pedagogical strategies, such as speculative methods (Lindberg & Haglind, 2024), that can help students discuss and imagine alternative futures and power structures (Rapanta et al., 2025).

This absence reflects a broader challenge in international education policy, where AI education is framed in terms of workforce readiness and digital economy rather than democratic participation and citizenship (Rahm, 2018; UNESCO, 2019). As a result, teachers may experience pressure to focus on specific, measurable outcomes, rather than more open-ended and critical explorations inherent in democratic processes. Other implications include how teachers and teacher educators understand their role. Teachers may, for example, lean towards providing students with technical skills and knowledge for the digital economy rather than fostering critical democratic engagement, given current policy.

The analysed materials explicitly position AI literacy as essential for societal participation, stating that 'knowledge about AI is essential for participating in many aspects of society and for comprehending technological advancements' and that students need 'opportunities to learn about AI as citizens' (Swedish National Agency for Education, 2024b, p. 1). However, this civic framing creates tensions. Whilst the stated purpose emphasises citizenship and societal participation, the actual content prioritises technical competencies over the critical thinking skills necessary for democratic engagement with AI systems. This disconnect between stated goals and curricular emphasis may leave teachers and teacher educators uncertain about how to balance technical instruction with the aspects of societal participation stressed in the curriculum.

The analysed materials provide few instances where literacy dimensions overlap or where teachers are encouraged and guided to connect these dimensions. This has implications for teacher education and professional development programmes that seek to prioritise such teaching. The materials' limited guidance on connecting dimensions may also affect expectations for teachers to develop sufficient knowledge, enabling them to provide teaching that bridges operational, cultural and critical AI literacy dimensions. Where overlaps are presented, they often lack explicit instructional alignment across dimensions, leaving teachers with the task of interpreting, prioritising and facilitating such integrated learning.

These implications, therefore, extend to teacher education and professional development programmes, both from the perspective of teachers and teacher educators. Such programmes need to go beyond programming and data to include ethical inquiry, cultural perspectives and future-oriented thinking, ensuring that teachers of the AI subject are equipped to take a holistic perspective on AI. Otherwise, the absence of critical literacy in key steering documents, which is a crucial dimension of AI literacy (cf. Pangrazio & Sefton-Green, 2021; Rapanta et al., 2025), risks having consequences for course delivery in classrooms, resulting in a more technical-instrumental perspective on AI. This points to structural challenges in schools and teacher education that policymakers and key stakeholders need to address.

Limitations

Our study is limited by its exclusive focus on steering documents governing the upper-secondary school AI subject in Sweden. Comparative studies across different national contexts would strengthen understanding of how AI literacy is conceptualised in educational policy internationally. Furthermore, whilst document analysis provides important insights into how AI literacy is formally conceptualised, it does not capture how teachers, teacher educators, or students interpret and enact these documents in practice. Our claims to validity should therefore be understood as confined to the discursive level of educational policy. Further empirical research is needed to investigate how operational, cultural and critical dimensions are taken up in classrooms and teacher education, including how these are balanced in practice.

Conclusions

The present study identifies imbalances in how AI literacy is conceptualised within educational policy, with implications that are relevant beyond specific national contexts. Whilst introducing AI as a subject in upper secondary school represents a timely response to AI's growing role in society, our analysis of the Swedish case demonstrates that AI literacy in educational steering documents risks prioritising instrumental and technical aspects at the expense of critical engagement.

Our analysis contributes to understanding AI literacy as a multidimensional concept that requires balance across operational, cultural and critical dimensions. The 3D literacy model proved capable of capturing these imbalances analytically and can serve as a valuable tool for analysing and designing AI curricula, for example, to foster critical thinking and active citizenship. Such aims become important as introducing AI into curricula does not automatically align with a holistic perspective on AI literacy but requires consideration and care, particularly regarding the critical dimension, which is essential for democratic participation.

The absence of a critical AI literacy dimension where the individual is positioned as an active agent has significant implications for both teacher preparation and students' opportunities to develop AI literacy in schools. Teachers require support to develop competence across all literacy dimensions and steering documents are important in this context. In the Swedish case, guidance is limited for fostering critical engagement with AI systems. Teachers and teacher educators thus have to navigate a policy gap. On the one hand, curriculum aims are stressing societal perspectives on AI. On the other hand, there is the actual conceptualisation of AI literacy in the subject content and teacher guides. How they navigate this gap may ultimately have implications for young people's opportunities to develop skills and knowledge in AI school subjects.

To expand on the results of this paper, future research could explore how teachers interpret and enact steering documents in practice in AI subjects, in Sweden and other national contexts. This includes how teacher educators understand AI literacy, particularly those teaching subject certification courses for teachers. Comparative studies could contribute towards identifying broader patterns in the Nordics, Europe and beyond, also with regard to how speculative and transformative pedagogies could support critical approaches to AI education. The 3D literacy model, as adapted in this paper, could guide the analysis and design of AI education curricula, contributing towards balanced, multidimensional approaches to AI literacy.

Ultimately, fostering such holistic AI literacy requires moving beyond technical-instrumental skills and knowledge to include meaningful opportunities for students and teachers to critically engage with and shape the sociotechnical ecologies of today and tomorrow. With AI systems increasingly influencing democratic participation, economic opportunities and social relations, education must prepare students not merely as users of AI technologies but as informed citizens capable of shaping AI's role in society.

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