

Low-Threshold AI Education as a Double Opening

An Educational-Theoretical Foundation and Its Implications for Teacher Education

Christian Filk¹ 

¹ Europa-Universität Flensburg

Abstract

This article develops an educational-theoretical foundation for low-threshold AI education. Beginning with a conceptual critique that identifies three incompatible meanings of «low-threshold» in the relevant reference documents, it unfolds the concept of the double opening: access opening (the dismantling of epistemic, techno-material, and socio-symbolic barriers) and subject-matter opening (the multi-perspectival engagement with AI as an epoch-typical key problem). The educational-theoretical grounding combines Klafki's theory of categorical Bildung with Freire's critical consciousness formation, and identifies the tension between these two positions as a productive engine of the concept. The combination of both dimensions – access and subject matter – is argued to be the necessary condition of low-threshold AI education in the emphatic sense: access opening without subject-matter opening produces inclusion in a narrowed canon; subject-matter opening without access opening produces multi-perspectivity as an elite project. For teacher education, three reform principles – de-disciplinisation, simultaneity, and empowerment – are argued for and defended against institutional objections. The article constitutes an educational-theoretical intervention in the AI literacy discourse, arguing that the Bildung-theoretical question – what should the subject matter be, and for whom, under what conditions? – cannot be adequately posed within a literacy framework alone.

Niederschwellige KI-Bildung als doppelte Öffnung. Bildungstheoretische Grundlegung und Konsequenzen für die Lehrkräftebildung

Zusammenfassung

Der Beitrag entwickelt eine bildungstheoretische Grundlegung niederschwelliger KI-Bildung. Ausgehend von einer Begriffskritik, die drei inkompatible Bedeutungen von Niederschwelligkeit in den einschlägigen Referenzdokumenten identifiziert, wird das Konzept der doppelten Öffnung entfaltet: Zugangsöffnung (Abbau epistemischer, technisch-mate-

rieller und soziosymbolischer Barrieren) und Gegenstandsöffnung (multiperspektivische Erschließung von KI als epochaltypischem Schlüsselproblem). Die bildungstheoretische Fundierung verbindet Klafkis kategoriale Bildungstheorie mit Freires kritischer Bewusstseinsbildung und weist die Spannung zwischen beiden Positionen als produktiven Motor des Konzepts aus. Die Verbindung beider Dimensionen – Zugang und Gegenstand – wird als notwendige Bedingung niederschwelliger KI-Bildung im emphatischen Sinne begründet: Zugangsöffnung ohne Gegenstandsöffnung erzeugt Inklusion in einen verengten Kanon; Gegenstandsöffnung ohne Zugangsöffnung erzeugt Multiperspektivität als Eliteprojekt. Für die Lehrkräftebildung werden drei Reformprinzipien – Entdisziplinierung, Simultaneität und Empowerment – begründet und gegen institutionelle Einwände verteidigt. Damit konstituiert der Beitrag eine bildungstheoretische Intervention in den AI-Literacy-Diskurs: Die Bildungs-Frage – Was soll der Gegenstand sein, für wen und unter welchen Bedingungen? – lässt sich innerhalb eines Literacy-Rahmens allein nicht angemessen stellen.

1. Introduction

Generative AI systems radically lower barriers to use. A single prompt suffices to produce texts, images, and code; intuitive interfaces make technologies accessible whose inner workings remain only partially transparent even to specialists. At the same time, educational policy and scholarship speak of dismantling the barriers to AI education. This paradox – falling barriers to use alongside persistently lamented barriers to education – points to an underspecified concept. What exactly does «low-threshold» mean in the context of AI education?

The relevant reference documents provide no unambiguous answer. The EU AI Act (Regulation (EU) 2024/1689; European Union 2024) mandates in Article 4 the promotion of AI literacy; the KMK Recommendations (2024) call for the systematic integration of AI into school-based educational processes; the AILit Framework (OECD/EC 2025) postulates comprehensive enablement of all learners. All of these employ «low-threshold» emphatically, but with insufficient theoretical specification. The AI literacy frameworks (Long and Magerko 2020; Ng et al. 2021; UNESCO 2024) operate with implicit low-threshold assumptions without making them explicit. The ICILS 2023 findings (Eickelmann et al. 2024) simultaneously document substantial competency differences correlated with social background – present-day AI education is anything but low-threshold.

This article addresses this problem from an educational-theoretical perspective. The guiding question is: How can low-threshold AI education be defined in a theoretically consistent manner such that it opens access to AI knowledge and broadens the subject matter of AI education – and what follows from this for teacher education? A conceptual critique lays bare the polysemy of the term (Section 2). Two educational-theoretical reference points provide the conceptual resources (Section 3). From these, the concept of the double opening is developed (Section 4) and consolidated into an

integrative definition (Section 5). Consequences for teacher education are then drawn (Section 6), before tensions and desiderata are identified (Section 7).

2. Conceptual Critique: «Low-Threshold» as an Under-Theorised Boundary Concept

2.1 Genealogy

The concept of «low-threshold» does not originate in educational science but in social pedagogy and addiction services. In drug counselling and homelessness support during the 1980s, «low-threshold» designated the deliberate removal of institutional access barriers – for instance, the abandonment of mandatory appointments or abstinence requirements as preconditions for receiving assistance. The concept was pragmatic and operational; it defined not what assistance should mean in terms of content, but rather the conditions under which it became reachable. From addiction services it migrated, via health science and social work, into educational policy.

In none of these fields was «low-threshold» explicated in educational-theoretical terms. The concept remained an operational-pragmatic boundary concept whose normative implications were carried along implicitly; its vagueness allowed contradictory measures to be gathered under a single label.

2.2 Three Implicit Meanings in the Reference Documents

An analysis of educational policy and academic reference texts reveals that the concept of low-threshold currently oscillates between three distinct, incompatible meanings.

(a) Low-threshold as techno-pragmatic access facilitation. This reading dominates in the EU AI Act and in Digital Promise (2024). Regulation 2024/1689 defines AI literacy (Art. 3(56)) as the «skills, knowledge and understanding» that allow an «informed deployment of AI systems», while Art. 4 obliges providers and deployers to ensure a sufficient level of it. The implicit premise is that there exists a defined body of knowledge that must be transmitted; the barrier lies in access to this knowledge and to the technical infrastructures. This reading operates within a deficit-and-access paradigm: something is lacking (knowledge, access), and policy provides it.

(b) Low-threshold as normative-political promise of inclusion. This reading dominates in the documents of the KMK (2024) and UNESCO (2024). The KMK insists that «the participation of all learners must be ensured» (KMK 2024, 10; my translation) and frames the matter as one of educational equity (*Chancengerechtigkeit*); UNESCO holds that access to and deployment of AI should be «equitable and inclusive», to be ensured for all students «regardless of their gender, ethnicity, abilities or socio-economic or

migration status» (UNESCO 2024, 17). The implicit premise is that the question of distribution, rather than the body of knowledge, takes centre stage. This reading adds a justice dimension to the access paradigm but leaves the subject matter untouched. Inclusion here means: everyone may participate – in a canon they do not help to determine.

(c) Low-threshold as didactic reduction principle. This reading is found in practice-oriented handbooks and implicitly in the AI literacy frameworks. Long and Magerko (2020) formulate «design considerations» explicitly targeting «non-technical learners» – visualisations, interactive demonstrations, playful approaches. The implicit logic holds that complex expert knowledge is translated into simplified versions for various target groups. This reading operates within a transposition paradigm: expert knowledge is didactically transposed, while the direction (from top to bottom) and the hierarchy (experts define the canon, laypersons receive it) remain unreflected.

A *terminological note* is warranted at this point. This article consistently employs «AI education» rather than «AI literacy» as its governing term. The choice is theoretically motivated. «Literacy» connotes a defined competency set to be acquired – a framing that, as the analysis of readings (a) through (c) shows, already presupposes a fixed subject matter and asks only about the conditions of its transmission. «AI education», by contrast, holds the *Bildung*-theoretical question constitutively open: what should the subject matter be, and for whom, under what conditions? The article thereby positions itself as an educational-theoretical intervention in the AI literacy discourse.

2.3 Finding: Polysemy and Shared Lacuna

The three meanings are not compatible: (a) addresses infrastructures, (b) participation rights, (c) didactic transposition. Educational policy documents can demand «low-threshold» approaches without committing to any one of these. Teachers receive contradictory signals: Create access to tools (a)? Support disadvantaged learners (b)? Simplify content (c)?

Beyond these differences, all three readings share a common underlying structure – and therein lies the decisive lacuna: all three take the subject matter of AI education as given and only ask about access to it. The *Bildung*-theoretical question of whether the subject matter to which access is to be opened has itself been adequately determined is posed in none of the three readings.

This lacuna is not trivial: curricula are oriented around implicit subject-matter definitions that have never been made explicit, and the question of whether AI education should be more than the transmission of techno-informatic knowledge is systematically suppressed. Resolution requires an educational-theoretical foundation that addresses both the access question and the subject-matter question.

3. Educational-Theoretical Reference Points: Klafki and Freire for the Algorithmic Age

The conceptual critique has identified a double lacuna: the access question is posed without reflection on power relations; the subject-matter question is not posed at all. Two reference points are chosen to address each lacuna precisely: Klafki's theory of categorical *Bildung*, because it poses the subject-matter question in educational-theoretical terms, and Freire's critical consciousness formation, because it radicalises the access question in terms of a theory of power.

The choice of Klafki and Freire as primary references implies a deliberate limitation that must be disclosed in relation to possible alternative frameworks. Within the German-language *Medienbildung* tradition, several positions would offer partially compatible frameworks, but each addresses only one side of the double lacuna. Structural media education (Jörissen and Marotzki 2009) would offer a compatible framework, but focuses on processes of transformation within medial articulations; it opens up AI as a space of articulation rather than as a key problem that must be engaged multi-perspectively and subjected to power-critical scrutiny. Action- and competency-oriented media education (Tulodziecki, Herzig, and Grafe 2021) and Baacke's (1997) media competency model provide practice-oriented differentiations, but operate within the deficit-and-access paradigm that the conceptual critique has already identified as insufficient. Biesta's (2014) theory of subjectification sharpens the educational-theoretical distinctiveness vis-à-vis competency models, but offers no key-problem systematics that opens the subject matter of AI multi-perspectively. The restriction to Klafki and Freire is not an oversight of these discourses but a strategic argumentative choice: the double question – what should the subject matter be, and who determines access? – requires one position that places the subject-matter question (Klafki) and one that places the power question (Freire) at the centre.

3.1 Klafki's Categorical Bildung and the Concept of Key Problems

Wolfgang Klafki's theory of categorical *Bildung* (Klafki 1985/2007) provides a framework that addresses the subject-matter question with precision. Categorical *Bildung* designates the dual process through which the subject opens up the world (the material dimension) and the world opens itself to the subject (the formal dimension). This foundational figure overcomes a dichotomy that latently structures the AI literacy discourse: the distinction between knowledge about AI and skills in working with AI. Categorical *Bildung* insists that both are only possible in their interconnection.

For the question of the subject matter of AI education, Klafki's concept of epoch-typical key problems is decisive. Key problems are societal challenges of epochal significance at which categorical insights can be gained. More precisely, a key problem in Klafki's sense is an epoch-typical structural problem of society-wide – frequently supra-national

or global – significance that nevertheless centrally concerns every individual, and that forms a problem-canon open to revision into the future (Klafki 1985/2007, 59–60; my translation). It is here that Klafki's distinctive contribution to the AI education debate becomes tangible: whereas the competency-oriented frameworks take the subject matter as given and ask only how it is to be transmitted, Klafki supplies a content-level, criterion-based justification of which societal challenges warrant categorical engagement at all – and AI is a paradigm case. Tellingly, Klafki's own catalogue already names, as its fourth key problem, «the dangers and the possibilities of the new technical control, information, and communication media» (Klafki 1985/2007, 59–60); AI is the contemporary radicalisation of precisely this problem. It meets the criterion on every count: it transforms work, communication, and knowledge production; it is omnipresent in learners' lifeworlds; and it makes fundamental questions about the relationship between human beings and technology amenable to exemplary treatment.

Equally decisive is a requirement on their treatment: key problems must be opened up from various perspectives – technical, ethical, political, aesthetic, and lifeworld-related. Klafki grounds this in educational theory: only multi-perspectival engagement enables categorical insights that extend beyond the individual case. An AI education that reduces its subject matter to the techno-functional dimension fails the educational claim. Opening the subject matter is an educational-theoretical necessity, not a pedagogical nicety.

3.2 Freire's Critical Consciousness Formation and the Concept of Empowerment

If Klafki answers the subject-matter question, Freire addresses the access question – more radically than the documents analysed above. In his *Pedagogy of the Oppressed* (Freire 1970/2018), he develops a fundamental critique of the «banking concept» of education: the idea that education consists in the depositing of knowledge into passive recipients. The asymmetry is constitutive: whoever determines what is learned has power; whoever receives it has none.

Freire's diagnosis applies to large parts of the AI literacy discourse. Much of the AIED research automates existing pedagogical assumptions rather than interrogating them (critically, Williamson et al. 2023; affirmatively, Holmes, Bialik, and Fadel 2019). The competency models define what learners should know and be able to do – know and understand, use and apply, evaluate and create, and ethical issues (Ng et al. 2021) – and address learners as deficient subjects. The question of whether learners should be involved in defining the subject of learning is not raised. In this sense, Rancière's (1991) concept of the «explicative order» – the assumption that knowledge must be transmitted from those who possess it to those who lack it – applies with particular force to AI education: the very frameworks that claim to democratise AI literacy frequently reproduce the hierarchy they ostensibly dismantle.

Against the banking concept, Freire sets *conscientização* – a Portuguese term he reserves for the specific process of critical consciousness formation in which learners become subjects of their own education, resisting any translation that would domesticate its political force. Empowerment here does not mean equipping learners for AI use, but enabling them to shape their own relationship to AI in a self-determined manner – including well-founded refusal. Opening access is therefore not exhausted by the removal of barriers; it requires reflection on the power relations that generate barriers. This reading of empowerment finds a productive resonance in hooks's (1994) practice of teaching as the practice of freedom – a pedagogy that begins from the concrete experience and social position of learners rather than from a pre-given curriculum, and that treats the classroom as a site of mutual transformation rather than unidirectional transmission.

3.3 Productive Tension: The Combination as a Mediating Attempt

The combination of Klafki and Freire is suggestive – both pursue emancipatory educational goals, both criticise reductionist pedagogy – but it is not tension-free. The tension can be specified along three dimensions.

First, an institutional tension: Klafki operates within institutionalised education; Freire develops his pedagogy explicitly against it – the banking concept is for him the institutional normal form. Second, a tension concerning the theory of the subject: Klafki thinks from the educational subject matter, Freire from the oppressive relations experienced by learners – the life situation determines the point of departure. Third, a normative tension: Klafki aims at self-determination within a democratic-liberal order; Freire's concept of empowerment aims at the transformation of that order itself.

This article does not harmonise these tensions but takes them up as a productive engine. The subject-matter opening follows Klafkian logic – AI as a key problem requires multi-perspectival engagement. The access opening follows Freirean logic – barriers are expressions of power relations that must themselves become the object of reflection. Klafki reminds us that empowerment requires a subject matter; Freire reminds us that the determination of subject matter is a question of power. This approach corresponds to Critical AI Literacy (Veldhuis et al. 2025) and to Gapski (2021), who insists that competence-centred framings of AI fall short of a holistic, critical *Bildung*, but goes beyond both: Veldhuis et al. do not derive the subject matter from a key-problem systematics; and although Gapski foregrounds the power and information asymmetries of datafied environments, he does not develop the access question itself – who can take part in AI education, and on what terms – as a power-theoretical problem. The same holds for the interdisciplinary theses of Berges et al. (2025), the most proximate German-language position: they too call for a demystifying, critical-reflexive, and multi-perspectival KI-Bildung that rejects solutionism and foregrounds participation and co-design, and they

too reach conclusions close to those argued here. Yet their contribution offers a programmatic mapping of disciplinary questions rather than an educational-theoretical derivation of the subject matter from a key-problem systematics, and it leaves the access question theoretically open. Only the double opening systematically connects both.

4. The Concept of the Double Opening

4.1 Access Opening: Three Dimensions of Barrier Removal

The access opening can be differentiated into three analytically distinct, empirically interlocking dimensions. These three dimensions translate the access question into Freirean terms: if barriers are not neutral gaps but expressions of power relations (Freire 1970/2018), then opening access means addressing the distinct registers in which power operates as a threshold – the knowledge presupposed, the infrastructure required, and the cultural codes that decide who is addressed at all. They correspond, respectively, to the didactic, the techno-pragmatic, and the normative-political readings of «low-threshold» distinguished in Section 2.2.

Epistemic access opening asks: What prior knowledge is presupposed for AI education, and how can these presuppositions be systematically varied? It addresses the barriers of specialist language (informatics terminology as gatekeeper), mathematical-statistical prerequisites, and requirements for abstraction. The ICILS 2023 study (Eickelmann et al. 2024) documents that around 40 per cent of eighth-grade students possess only rudimentary digital competencies, with these competency differences strongly correlated with social background. Epistemic access opening does not mean abandoning rigour; it means systematically varying points of entry: lifeworld connections, phenomenological starting points, and the use of analogy.

Techno-material access opening asks: What infrastructures are required, and how can dependency on specific technologies be reduced? Regional heterogeneity in equipment creates unequal starting conditions. Techno-material access opening requires the diversification of tools: browser-based applications, open-source alternatives, offline-capable tools, and unplugged approaches that function entirely without digital technology.

Socio-symbolic access opening asks: Which cultural codes and gatekeeping mechanisms function as invisible thresholds? It addresses the coding of AI as masculine-technical expert knowledge, prestige hierarchies between STEM and the humanities, and mechanisms of self-exclusion («this isn't for me»). This dimension is the least well represented in the reference documents, although research evidence suggests it is particularly potent (Veldhuis et al. 2025; Bozkurt 2024). Crucially, Benjamin's (2019) analysis of the «New Jim Code» demonstrates that algorithmic systems do not merely reflect existing social hierarchies but actively encode and reproduce them – a finding that extends

directly to AI education, where socio-symbolic barriers are not incidental but structurally embedded in the design of tools and curricula. Socio-symbolic access opening therefore requires not only the deconstruction of expert discourses but the recognition that different forms of knowledge carry unequal institutional weight.

The three dimensions interact systematically: epistemic thresholds reinforce socio-symbolic exclusion, material thresholds intensify epistemic barriers, and socio-symbolic thresholds prevent available resources from being used. This interlocking explains why monodimensional interventions – infrastructure alone, professional development alone, diversity campaigns alone – regularly fall short of expectations. Eubanks's (2018) empirical documentation of how automated systems concentrate disadvantage among already-marginalised populations provides precisely the kind of concrete evidence that the tripartite model must be able to account for: the failure in each case is not technical but structural, arising from the interaction of all three barrier types simultaneously.

The tripartite structure of epistemic, techno-material, and socio-symbolic barriers does not claim to constitute an empirically saturated taxonomy, but rather a theoretically grounded heuristic: it follows from the intersection of the three low-threshold readings identified in the conceptual critique with the Freirean reading of barriers as expressions of power relations rather than neutral deficits (Freire 1970/2018), as introduced at the outset of this section. Its analytical value lies in the distinguishability of levels of intervention – levels that monodimensional approaches fail precisely because they do not separate them. Whether the tripartition exhausts the field of barriers, or whether additional dimensions – such as affective barriers like technology-related anxiety – should be added independently, is an empirical question that can be generated from within the heuristic itself; therein lies its analytical capacity.

4.2 Subject-Matter Opening: Derivation from the Key Problem Concept

If AI is an epoch-typical key problem in Klafki's sense, then it must be opened up from those perspectives that a categorical engagement requires. Klafki's revised perspective-scheme for instructional planning distinguishes seven questions (Klafki 1985/2007, 270–271); of these, five bear directly on the constitution of subject matter – present, future, and exemplary significance, thematic structure, and accessibility – whereas the remaining two (verifiability and the teaching–learning process structure) concern method rather than content. These five serve here as a framework for derivation – it being understood that the mapping to substantive perspectives represents a reasoned concretisation that follows from the material structure of AI as subject matter, not from Klafkian systematics alone.

From contemporary significance follows a lifeworld-phenomenological perspective: learners encounter AI daily in recommendation systems, voice assistants, and image generators; these experiences are the didactic point of departure for categorical learning.

From future significance follows a political-economic perspective: labour market effects, the concentration of power, and questions of digital sovereignty directly affect learners' futures – a dimension that Couldry and Mejias (2019) illuminate through their concept of data colonialism, which frames the systematic extraction of social life through data as a structural analogue to historical processes of dispossession. Exemplary significance grounds a techno-functional perspective: AI is exemplary for the logic of data-driven systems and the difference between computation and understanding – comprehension of its modes of operation is a prerequisite for well-founded judgement formation. The thematic structuring grounds an ethical-normative perspective – and this follows from the material structure of the subject matter, not solely from Klafki's systematics: what distinguishes AI as a key problem from other technologies is the fact that normative decisions are already inscribed in its technical construction. Training data encode societal distribution patterns, optimisation functions operationalise value decisions (what is classified as «good»), and deployment contexts generate attributions of responsibility that are neither purely technical nor purely political (Crawford 2021). This structural property – the inseparability of technical construction and normative positing – makes an ethical-normative perspective necessary for the thematic structuring of the subject matter, because without it the material structure itself would be incompletely grasped. An epistemological perspective – centred on the opacity of machine inference and the warrant of its outputs – would be a fruitful complement; it is not made the structuring axis of the thematic core, however, because what constitutes AI as a key problem at this level is the inscription of normative decisions into technical construction, not epistemic opacity alone – though, as the opacity-generativity structure below shows, the two are linked. Accessibility and representability, finally, provide the formal slot for an aesthetic-cultural perspective; its substantive warrant, however – as with the ethical-normative perspective – follows from the material structure rather than from Klafki's systematics alone: AI is itself generative, producing images, text, and sound that imitate human creative practice, and thereby transforms cultural production and the concepts of authorship and originality. It is this generativity – taken up in the opacity-generativity structure below – and not didactic representability as such, that makes the aesthetic-cultural perspective constitutive rather than optional.

What distinguishes the subject-matter opening for AI from other key problems is the interlocking of opacity and generativity: AI systems produce outputs whose genesis remains only partially transparent even to experts, while imitating human cultural practices – writing, image production, argumentation. This dual structure makes multiperspectival engagement unavoidable: those who understand only the function miss the cultural transformation; those who discuss only the cultural effect miss the technical logic. That the majority of existing AI literacy learning experiences enact precisely this narrowing to techno-conceptual competencies is confirmed by the systematic review of Casal-Otero et al. (2023).

The derivation should not be understood as a closed taxonomy; further perspectives may be added – for example, an ecological perspective on the resource consumption of algorithmic systems (Selwyn 2025). The five identified are, however, at minimum necessary: whoever systematically excludes one of them fails the educational claim.

4.3 The Double Opening as a Unity

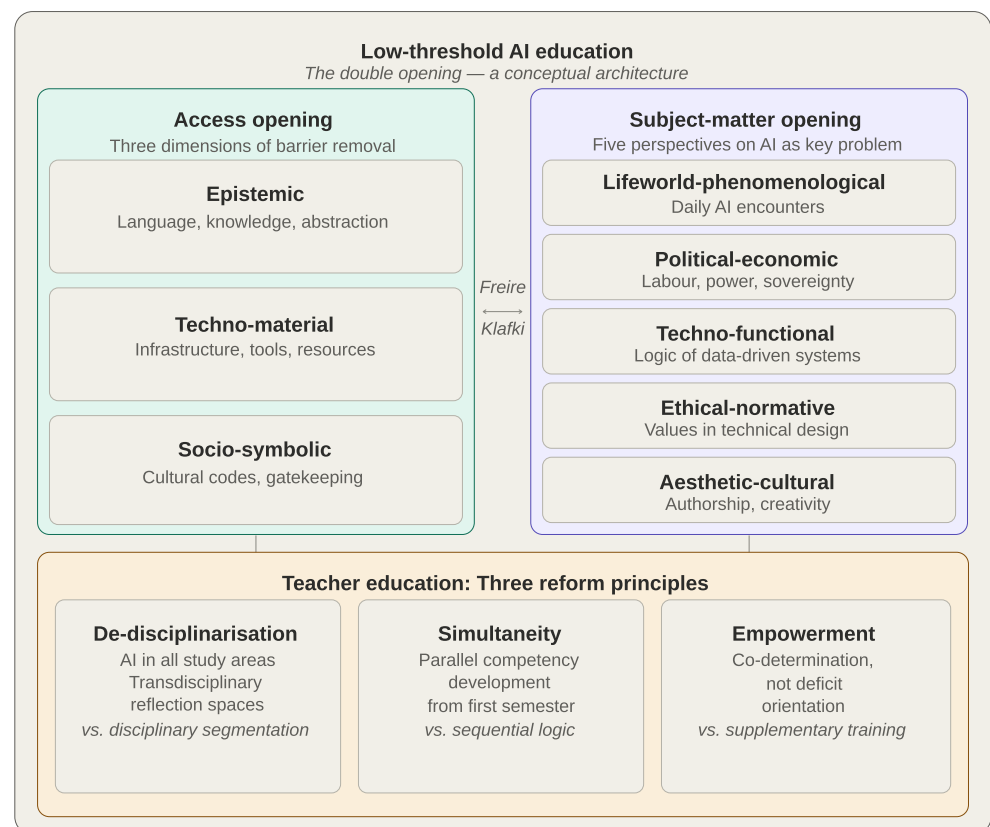


Fig. 1: The double opening – conceptual architecture of low-threshold AI education; the three reform principles for teacher education (lower section) are developed in Section 6.2. Author's own figure.

Access opening and subject-matter opening are each individually necessary, but only jointly sufficient. Fig. 1 provides an overview of the full conceptual architecture: the three dimensions of the access opening (left) and the five perspectives of the subject-matter opening (right), with Klafki's and Freire's positions marking the productive tension between them, and the three reform principles for teacher education shown below. Access opening without subject-matter opening produces inclusion in a narrowed

canon: everyone may participate – but only in techno-informatic knowledge. This is integration without *Bildung*. Subject-matter opening without access opening produces multi-perspectivity as an elite project: AI is engaged from five perspectives, but only by those who already have access. This is *Bildung* without justice.

Only the combination – the double opening – realises low-threshold AI education in the emphatic sense: access is opened to a subject matter that is itself opened. And the subject matter is opened for subjects who participate in the process of opening. In this interlocking, the Klafki-Freire tension operates as a productive engine. A concrete example: the techno-functional perspective of the subject-matter opening requires learners to understand how machine learning works – Klafki would insist that this engagement with subject matter belongs to educational content. Freire would ask whether this selection is not itself a power-laden positing that privileges technical expert knowledge and devalues experiential knowledge from the lifeworld. The concept of the double opening does not resolve this tension but makes it a task of didactic design: techno-functional knowledge is not eliminated, but its selection becomes reflexive, context-dependent, and subject to justification.

This identifies a reflexive loop that concerns the present article itself: the subject-matter opening is unfolded here as a five-fold perspectivation whose selection performs precisely the technocratic positing that Freire's banking-concept critique addresses. This tension cannot be resolved by mere self-relativisation, but it can be productively redirected methodologically: the five perspectives are proposed as a theoretically grounded minimal framework that derives its legitimacy from the disclosure of its own logic of derivation and remains constitutively open to revision. Taking Freire seriously does not mean abstaining from any determination of subject matter; it means marking every such determination as provisional and supplying the conditions of its revision. In didactic practice, the five perspectives serve as an opening structure that learners can supplement, weight, and contest – subject-matter opening in the act of practice. One objection must be met directly: does a low-threshold concept not contradict itself when it is derived from so demanding an apparatus of critical theory? The contradiction is only apparent – the threshold lowered is the learner's threshold of access, whereas the theoretical demand falls on the educator's design rationale; low-threshold, as the following synthesis specifies, names a structure of enablement, not a level of intellectual difficulty.

5. Synthesis: Low-Threshold AI Education as an Integrative Concept

5.1 *Conceptual Determination*

The foregoing argument yields the following definition: *Low-threshold AI education* is the systematic combination of access opening (the dismantling of epistemic, technological, and socio-symbolic barriers) and subject-matter opening (the multi-perspectival engagement with AI as an epoch-typical key problem), with the aim of enabling all learners and teachers to shape their relationship to algorithmic systems in a self-determined and well-founded manner.

The four guiding concepts – low-threshold, AI education, teacher education, and empowerment – are not additively assembled in this definition but relationally integrated: Low-threshold is the structure of enablement (not a level of difficulty). AI education is the subject matter constituted by the double opening (not a fixed body of knowledge). Teacher education is the institutional site of professional enablement (not a process of supplementary qualification). Empowerment is the normative horizon (not a stage in competency acquisition).

5.2 *Demarcations*

The definition gains precision through three demarcations that address prevalent narrowings.

First: low-threshold AI education is not the same as simplified AI education. Didactic reduction is one possible element of epistemic access opening, but not its synonym. Low-threshold approaches can equally be achieved through shifts in perspective, life-world connections, aesthetic modes of access, or the transformation of institutional structures – without reducing the subject matter. The equation of low-threshold with simplification reproduces precisely the transposition paradigm identified as deficient in the conceptual critique.

Second: low-threshold AI education is not AI education for beginners. Low-threshold is a pervasive design principle, not a property of introductory stages. Advanced AI education also has threshold problems: the transition from technical understanding to ethical judgement is one for which institutions often make no provision; the bridge between informatics expertise and lifeworld relevance is absent from many curricula.

Third: low-threshold AI education is not informatics-poor AI education. The technofunctional perspective is one of the five perspectives of the subject-matter opening, not its opposite. Those who only discuss AI ethically, without understanding how machine learning works, are no more engaged in low-threshold AI education than those who exclusively explain algorithms.

5.3 Relational Positioning: Accessibility, Inclusion, and the Double Opening

Beyond internal demarcations, the concept requires positioning in relation to adjacent discourses. Accessibility, as demanded by the UN Convention on the Rights of Persons with Disabilities and the Universal Design principle, operates primarily as a techno-normative standard and addresses physical-sensory access barriers – a dimension that is subsumed within techno-material access opening. Inclusion, as a guiding educational policy category, asks who may participate in educational processes, but takes the subject matter as given. Both concepts thus reproduce the lacuna identified in the conceptual critique (Section 2.3): they address access, not subject matter. The double opening integrates the concerns of both – barrier removal and universal participation – but transcends them because it carries the subject-matter question as an independent quality criterion.

6. Programme: Consequences for Teacher Education

6.1 Three Structural Mechanisms as Institutional Thresholds

The concept of the double opening reveals that current teacher education generates high thresholds through three mechanisms. First, disciplinary segmentation: AI is institutionally assigned to informatics and, at most, to media didactics; teachers outside informatics-related fields do not feel responsible – a finding that transfers to the AI context the blind spots in school media education diagnosed by Schiefner-Rohs (2017) – a direct contradiction of the principle of subject-matter opening. Second, sequential logic: teacher education follows an implicit progression – first subject knowledge, then subject didactics, then practice; AI education is inserted as a late addendum and remains an alien element. The TPACK debate (Mishra and Koehler 2006) has shown that technological knowledge must be integrated from the very beginning. Third, deficit-oriented address: teachers are spoken to as subjects who lack the requisite competencies and need supplementary qualification. Even contributions that ultimately stress teacher agency, such as Seufert, Guggemos, and Sailer 2021, set out from this diagnosis of deficit – and rather than generating empowerment, such address tends to produce insecurity.

6.2 Three Reform Principles

Against each of these mechanisms, a reform principle can be developed in which the Klafki-Freire tension operates as a design principle.

The principle of de-disciplinarisation is directed against disciplinary segmentation and follows directly from Klafki's insight that key problems require multi-perspectival engagement: AI becomes the object of all study areas – not only informatics, but also educational science, subject didactics, and studies of school practice. This does not require

turning every subject into computer science, but rather the subject-specific engagement with the AI dimension – for instance: how does generative AI change the practice of writing in German as a school subject? An obvious objection: de-disciplinarianisation conflicts with the disciplinary logic of university chair structures. The answer: de-disciplinarianisation does not mean the dissolution of subject boundaries, but the establishment of transdisciplinary spaces of reflection alongside disciplinary core areas. The analogy with Education for Sustainable Development (ESD) is instructive: after two decades of institutional anchoring, ESD still permeates subject cultures unevenly. ESD shows that transdisciplinary spaces of reflection are institutionally realisable, but without structural support through examination regulations they degenerate into optional supplements. De-disciplinarianisation in AI education will therefore move beyond a programmatic demand only if it is curricularly anchored – a task that the present foundational article can identify but not fulfil.

The principle of simultaneity is directed against sequential logic. Subject knowledge, subject-didactic knowledge, and reflective competency are developed in parallel rather than in sequential stages – a structure that corresponds to Klafki's categorical *Bildung*: engagement with subject matter and competency development are mutually constitutive. Student teachers encounter AI from the very beginning of their studies – as object, as tool, and as occasion for reflection. Simultaneity does not mean the abolition of modular structures, but the creation of bridging formats – for instance, integrated project seminars in which student teachers use AI tools, reflect on them subject-didactically, and situate them in terms of educational theory.

The principle of empowerment over deficit orientation is directed against deficit-oriented address. Teachers are addressed as reflective professionals who already possess lifeworld AI experiences and can make these the point of departure for professional development. Empowerment here means not the liberal enablement for competent AI use, but the Freirean enablement for co-determination of the subject matter itself – including the possibility of contesting curricular givens. At the same time, it requires structures: formats that take practice as their starting point, time resources for reflection, and collegial learning communities. How teacher training oriented toward digital self-determination can be institutionally structured – from the individual teacher's reflective practice through institutional support to school culture, integrating media ethics and AI into everyday school practice – is developed in Filk (2025).

The three principles operate in concert: an integrative seminar in which student teachers from various disciplines jointly develop and reflexively evaluate an AI-supported teaching scenario realises de-disciplinarianisation, simultaneity, and empowerment simultaneously. In in-service and continuing professional development, the format of a collegial case workshop could realise the three principles: teachers from different subjects bring concrete classroom situations involving AI, analyse them together from technical, ethical, and subject-didactic perspectives, and develop in parallel both

alternative courses of action and instruments for reflection. The structural difference from conventional professional development: not a one-way lecture about AI tools, but multi-perspectival engagement with lifeworld AI experiences.

7. Tensions, Limits, and Research Desiderata

The concept of the double opening does not resolve all problems of low-threshold AI education; it does, however, make some of them more precisely describable. Three fields of tension deserve attention. The tension between opening and prescriptiveness: the double opening requires curricular latitude that educational policy standardisation constrains; the planned PISA 2029 Media & AI Literacy Assessment will exert pressure towards uniformity. The tension between conceptual ambition and institutional inertia: whether and how the reform principles can be implemented within existing structures is an empirical question requiring research. The tension between universality and context-sensitivity: concrete threshold structures vary by school type, region, and social milieu – context-sensitive concretisations are indispensable.

From these fields of tension, four research desiderata follow. First, the concept requires empirical validation: are the three dimensions of access opening complete? Do they interact as theoretically postulated? In particular, the unity claimed here between the two openings is argued conceptually rather than demonstrated empirically: whether subject-matter opening that runs ahead of access opening fosters emancipation or instead produces cognitive overload is an empirical question that the framework must leave open rather than redescribe as a mere problem of implementation. Second, curricular concretisation must be accomplished: what does low-threshold AI education look like concretely in different subject cultures – including vocational education and non-Western contexts, whose comparative analysis could render visible the cultural situatedness of the categories proposed here? Third, impact research remains to be undertaken: does the double opening lead to different educational outcomes than conventional AI literacy curricula? Fourth, systematic barrier research would be illuminating – research that empirically specifies the threshold types for concrete target groups; the OECD-EC AILit Framework (OECD/EC 2025) offers starting points for internationally comparative approaches.

The present article is intended as a foundation, not as a conclusion. The concept of the double opening provides an educational-theoretically grounded definition of low-threshold AI education that resolves the polysemy of current usage and poses the previously suppressed subject-matter question. Whether this foundation holds will be demonstrated by a specific test: whether the double opening – as distinct from existing AI literacy frameworks – generates research questions that those frameworks cannot pose, curricular designs that they cannot produce, and institutional reforms that they cannot motivate. That test remains open. It is the next task.

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