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Evolving AI capabilities
and the school curriculum:
Emerging implications and a
case study on writing

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Abstract

This paper proposes a conceptual framework for examining how advances in artificial intelligence (AI) may reshape school curricula. It aims to clarify how curriculum developers and policymakers can think systematically about the relationship between AI capabilities and curricular aims, goals and assumptions. Drawing on curriculum theory and historical perspectives, the paper situates AI within broader debates about what knowledge is worth teaching and how technological change impacts those decisions. The framework is illustrated through a case study of writing, a domain where AI's capabilities are already highly visible and where potential curricular implications can already be observed. Hypothesising about future advances in AI, the paper extends the discussion beyond writing to examine scenarios in which AI masters wider sets of human capabilities, with possible consequences for curriculum development and for schooling more broadly.

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1 Introduction

Countries across the OECD and beyond have the responsibility to ensure that all individuals have access to high-quality, equitable education that prepares them for their present and future. Central to this goal is the question of what students should learn, a question that becomes more complex as technology continues to transform the ways in which we live and work. Today, advancements in artificial intelligence (AI) are laying the groundwork for extensive and rapid transformations in society (Lipsey, Carlaw and Bekar, 2005^[1]). As the capabilities of technology continue to grow and begin to reshape how humans carry out tasks across various context, including education, we are confronted with the question: *what forms of knowledge should our education systems promote for a world with AI?*

This paper originates from an ongoing effort by the OECD's Centre for Educational Research and Innovation to gather and consolidate information on AI capabilities with the goal of building comprehensive indicators of what AI can do across capability domains relevant to humans (see (OECD, 2025^[2]) for the beta indicators). With this effort, the project seeks to facilitate meaningful assessments of how *work* and *life* tasks might shift as humans increasingly use AI to carry them out (2023^[3]; 2021^[4]; OECD, 2025^[2]).

Such work also provides a foundation for considering AI's implications for education, particularly in terms of what humans may need to learn in the future. However, while analyses of AI capabilities can reveal which areas of human activity AI systems are *technically able* to replicate or transform, they cannot determine what should remain *valuable* for education to focus on. Decisions about which human capabilities schooling should promote — and which forms of knowledge underpinning them are worth teaching — are value-laden, shaped by social priorities and beliefs.

Building on this distinction, and moving beyond the identification of AI capabilities, the present paper draws on a non-systematic review of literature in curriculum theory, technology studies, and cognition and learning research to inform curriculum developers and educational authorities with respect to the following questions:

- How does AI challenge what human capabilities we value in education?
- What types of knowledge will remain – or become – important for humans to develop?
- How do we reorganise curricula in response to emerging AI capabilities and shifts in knowledge value?

These questions relate to key issues in curriculum development and how they intersect with technological change. The paper hence begins by exploring the literature about how curricular goals and related content are selected and the impact that technology has on this process. Against this backdrop, it compares the historical case of the integration of calculators in classrooms with the ongoing irruption of generative AI. The analysis focuses on the implications of generative AI for literacy development, arguing that the emergence of AI tools leads to profound questions about what constitutes “basic” knowledge of writing. Projecting the discussion into the future and beyond the case of writing, the paper considers how further advances in AI capabilities could generate increasingly profound curricular implications. It explores scenarios in which AI masters different sets of human capabilities and examines how these might challenge not only the organisation of curricular knowledge but the very purposes of schooling itself.

This paper uses the term ‘capabilities’ to refer to functional performance — that is, what AI or humans can do. This usage is useful for making comparisons without implying that AI knows or understands in the human sense. The term is used descriptively, in contrast with its normative use in the capability approach literature, where it refers to people’s potential or freedom to act and pursue valued goals (Robeyns and Byskov, 2025^[5]). While distinct, the two senses overlap in education, where fostering both performance and agency is often taken as a goal. ‘Knowledge’ is the term most used in the curriculum literature reviewed, and therefore the one maintained in the analysis that follows. Its use here is broad, overlapping with terms such as competencies, skills, and distinct narrower forms of knowledge, as commonly used in policy frameworks to refer to what humans must learn in order to sustain or expand capabilities.

The paper urges policymakers and educators to consider whether rapid AI developments call for rethinking current foundational assumptions about the school curriculum. While AI progress undoubtedly has major implications for the teaching profession and for how education is organised, this topic lies beyond the scope of the present paper and will be addressed in subsequent OECD analyses.

2 Knowledge and the school curriculum

The term “curriculum” is often confusing, as its use varies even in specialised literature. Luke, Woods, and Weir (2013^[6]) differentiate between a broad conception of 'curriculum' and its 'technical form'. The broad formulation includes all intellectual, human, and material resources: the societal aims for education and their translation into educational programmes and classroom practice (Deng and Luke, 2008^[7]). The technical form refers to the structured summary that education authorities issue through official documents like frameworks and standards to formally outline what should be taught and learnt in schools (OECD, 2020^[8]; 2013^[9]).

As Yates notes, the job of curriculum developers involves both “big picture thinking” and “attention to everyday pragmatics” (Yates, 2006, p. 3^[10]). The former concerns defining what constitutes subject matter considering societal expectations for education. This involves epistemological and normative questions such as what kinds of knowledge exist and why are they socially relevant. The latter concerns practical decisions about how to translate such knowledge into concrete curriculum products, considering the broader aims of schooling against the constraints of teaching time and what is known about how students learn. Here, key questions include how to arrange content into areas of study and how to articulate it over time to support learning (Deng, 2015^[11]; Ornstein and Hunkins, 2018^[12]).

The two elements take on new meaning in the context of evolving technology: Should we continue to teach things that AI can already do? And if so, why? Should we exclude content from the curriculum without considering its interconnectedness with other content? As technology advances, the relevance of these questions becomes clearer.

Types of knowledge and knowing

In the mid-19th century, Herbert Spencer framed the question ‘what knowledge is of most worth?’ as central to curriculum design. The question underscores a key challenge of curriculum development: choosing what to include or exclude from the vast archive of human knowledge in school programmes (Apple, 1990; in Luke et al. (2013^[6])). The selection of curricular content is never arbitrary. All curricula rest on some form of knowledge theory that guides decisions about which types of knowledge are to be included or excluded. Recognising that different types of knowledge and forms of knowing exist is hence a first step to understand the decisions curriculum developers make, as they prefigure decisions on what constitutes subject matter.

There is a vast scholarly literature studying what knowledge is and how to categorise it. Views range from historical accounts like those distinguishing theoretical, practical and productive knowledge (Aristotle) to modern distinctions between factual (know-that) and procedural (know-how) knowledge (Ryle) or explicit and tacit knowledge (Polanyi).

In a review of the literature, Deng and Luke (2008^[7]) propose three knowledge types to guide curriculum discussion, which, as they note, constitute analytically different although not practically separate modes of knowing:

- *Disciplinary knowledge*: This refers to formal knowledge developed within specialised communities adhering to rigorous methods of inquiry and validation, such as mathematics, history, and the sciences – i.e. the disciplines. Aimed at providing frameworks to understand and explain the world, this knowledge is systematically structured and different from knowing grounded in everyday experience.
- *Practical knowledge*: This relates to knowing how to act effectively in specific situations, often with an emphasis on achieving desired outcomes or solving concrete problems. This type of knowledge includes procedural skills, like programming or operating machinery, as well as context-sensitive judgement, such as decision-making in social or professional settings. Practical knowledge may require mastery of tools and techniques, as well as an understanding of when and how to adapt actions based on situational demands.
- *Experiential knowledge*: This arises from personal and social experiences, where understanding is shaped through direct interactions with the world and the people within it. Unlike disciplinary and practical knowledge, which can often be formalised and taught, experiential knowledge is inherently subjective and situated, grounded in the individual's own encounters and reflections. This type of knowledge develops continuously through lived experience, such as in learning the nuances of cultural practices and navigating social relationships.

School programmes often emphasise disciplinary, practical and experiential knowledge, though the balance among them varies with distinct philosophical and educational views.

Selecting and organising curricular content

The selection of knowledge for school curricula is not neutral, it reflects judgements about what is desirable for students to learn and be able to do to meet broader social, cultural and economic expectations. Ultimately, fitness-for-purpose serves as the central criterion for knowledge selection, where purpose is defined by the functions that different actors expect schools to fulfil and the ways in which they expect schools to fulfil them.

By the mid-20th century, Ralph Tyler had already emphasised the centrality of purpose in curriculum design. In the seminal *Basic Principles of Curriculum and Instruction* (1950^[13]), he proposed a systematic approach where broad educational aims shape specific learning goals, experiences and assessments. These aims, he argued, should emerge from a careful consideration of societal needs, learners' interests and disciplinary expertise. His work cemented the triad of knowledge, learners and society as key sources for defining educational objectives, which has influenced curriculum thinking to date (Ornstein and Hunkins, 2018^[12]; Thijs and van den Akker, 2009^[14]).

While Tyler draws attention to the sources that inform educational aims, subsequent theorists have expanded this view by asking what education is ultimately for. In this light, Biesta (Biesta, 2008^[15]) identifies three fundamental functions of education that help clarify its purposes and guide curriculum decisions:

- *Qualification*: involves equipping students with knowledge and skills to function in society, ranging from specific vocational competencies to broader capabilities for civic and social participation.
- *Socialisation*: refers to how education introduces students to norms, values and cultural traditions, fostering a sense of belonging within social and political communities.
- *Subjectification*: focuses on the development of autonomy, enabling students to critically reflect on their identities, beliefs and roles in society.

Curriculum design inevitably reflects judgements about how these functions should be balanced. Curriculum developers may interpret and weight them differently and, in practice, schools may struggle to fulfil all three equally well (Egan, 1998^[16]). Nevertheless, debates over curriculum aims continue to shape how knowledge is selected and organised, with scholars offering different frameworks to classify the ideologies behind such choices (Coşkun Yaşar and Aslan, 2021^[17]). Deng and Luke (2008^[7]), for instance, distinguish the following competing views:

- *Academic rationalism*: Emphasises the transmission of disciplinary knowledge to develop students' intellectual capacities and to maintain cultural continuity. Academic fields serve as authoritative sources for curriculum content, focusing on canonical bodies of knowledge, techniques and ways of knowing that substantiate the qualification and socialisation functions while providing the necessary intellectual tools for individuals to act in the world.
- *Social efficiency*: Prioritises preparing students for social and economic productivity. The curriculum is strongly shaped by statements on human capital production, where subject matter is selected for its functional and utilitarian value. Knowledge is justified primarily by its relevance to vocational, professional and practical contexts. This orientation adapts as economies and societies shift, drawing on applied fields and taxonomies of skills that are deemed important to learn and transfer to areas such as citizenship, consumption and the workplace.
- *Learner-centeredness ideology*: Places individual learners at the centre of curriculum development, focusing on personal growth and self-actualisation. Curriculum content is selected to provide intrinsically rewarding experiences that foster personal development and freedom for learners to aspire to what they wish to become. This orientation embraces experiential knowledge, structured around developmentally appropriate activities that support self-realisation, drawing on a wide array of resources to nurture expression and autonomy.
- *Social reconstructionism*: Views education as a tool for social reform, prioritising sociocultural contexts over individual needs. The curriculum is designed to critically engage students with social issues and contexts, encouraging them to analyse and construct their own standpoints and actions. Education is structured around meaningful learning activities for students and their communities. It aims at fostering social agency, often incorporating diverse knowledge sources to cultivate critical awareness, civic responsibility and action skills.

These orientations place different emphases on the functions schools should serve and on the balance among knowledge, learners and society (Ellis, 2014^[18]). Both academic rationalism and social efficiency highlight the role of disciplinary knowledge — the former for its epistemic power¹ to help humans understand and explain the world, the latter for its instrumental value in supporting innovation and productivity (Muller, 2009^[19]). Within these orientations, some stress the transmission of the final products of disciplinary work – canonical facts, concepts and theories – while others emphasise engaging students with the ways of thinking and working that generate such knowledge (e.g. reasoning like a historian, mathematician or scientist). By contrast, learner-centred and social reconstructionist perspectives prioritise experiential knowledge, the first emphasising personal meaning and development, the second collective engagement with social challenges.

In sum, curriculum ideologies position themselves differently with respect to the epistemological and normative questions outlined earlier. They assume more or less continuous relations with the academic disciplines (Stengel, 1997^[20]), defining curriculum content variously as disciplinary knowledge, practical or instrumental knowledge and skills, learning experiences and socio-cultural action (Deng and Luke, 2008^[7]). These positions affect curriculum design not only in what is taught but also in how it is organised – whether through subjects mirroring academic and occupational divisions or more fluid projects rooted in personal or social relevance. They also shape how content is sequenced, depending on whether authority for ordering and pacing lies with experts or learners (Ellis, 2014^[18]).

Sequencing decisions may be shaped by different logics². When experts hold authority, sequencing is strongly influenced by the internal structure of knowledge, where concepts derive meaning from specialised relationships, and by research on learners' development and typical learning progressions in addition to other practical and political considerations (Ornstein and Hunkins, 2018^[12]). The links between topics stemming from these logics – whether grounded in disciplinary structures or in empirically observed progressions – merit careful attention. If such links are overlooked when removing or restructuring content in response to AI, there is a risk of creating unintended gaps in students' ability to connect ideas over time.

3 The impact of technology on how we know and what we need to know

In broad terms, technology can be defined as the process by which humans modify nature to meet their needs and wants. As this process unfolds, what is deemed important for humans to learn can shift drastically. This is evident if considering how many tasks were historically transformed by new inventions and related social practices. For instance, one can think of how tools like fences and harnesses in combination with herd management techniques made possible the practice and extension of ranching, changing the skills needed for survival from tracking and hunting to animal husbandry and agricultural management. Similarly, from an educational lens, one cannot understand the emergence of education, the school and mass schooling systems as we know them without considering the development of language, writing and the printing press (Enguita, 2023^[21]).

Technology extends what humans can accomplish

Even though we might often have specific artefacts in mind when thinking of technology (e.g. the pen, the phone, the light bulb), its critical social impact lies in how inventions change the ways in which humans perform tasks and the transformations these changes trigger in the wider cultural context (Lievrouw and Livingstone, 2002; in Selwyn (2011^[22])). Technology has a technical and a social component, the latter comprising how tool use reshapes what tasks we engage, how we engage them and, thus, what knowledge is most useful.

Discussing the impact of technology on human cognition, Salomon, Perkins and Globerson (1991^[23]) pointed out that there are tools that work for us and others we work with: some technologies carry out entire tasks alone (e.g. the engine), while others require our active participation (the car). This distinction highlights how much of what we can accomplish across life and work contexts depends on working in partnership with technology. Once appropriate tools become available and used, our abilities become shared with them through a new division of labour: the brain performs some functions while delegating others to external entities. This process, known as cognitive offloading, involves using tools to reduce the internal cognitive demands of a task, which enables humans to overcome capacity limitations and perform tasks more efficiently, or even tasks that would otherwise be unfeasible (Risko and Gilbert, 2016^[24]). In this way, technology extends the human mind, as cognition is no longer confined to the individual brain but relies on environmental supports (Clark and Chalmers, 1998^[25]). Performing long multiplications with pen and paper illustrates how external tools aid internal cognitive processes, where the brain handles conceptual operations while pen and paper are used to track intermediate steps.

The coupling of human and technology leads to changes in performance when carrying out tasks with tools. Tools enhance individual performance and, in so doing, bridge cognitive gaps between individuals with varying abilities or expertise. For example, consider the use of GPS navigation systems: individuals with varying spatial reasoning abilities and memory can all reach their destinations effectively by relying on the tool to handle route planning and real-time adjustments. This equalising effect demonstrates how

technology can expand access to outcomes that might otherwise depend heavily on innate ability and prior knowledge. A growing body of research highlights such equalising effects for current generative AI tools across a range of contexts (Brynjolfsson, Li and Raymond, 2023^[26]; Choi, Monahan and Schwarcz, 2023^[27]; Dell'Acqua et al., 2023^[28]; Noy and Zhang, 2023^[29]).

Additionally, Salomon and colleagues also noted that technology use can lead to cognitive changes that persist even after the tools are no longer in use. These effects represent the internalisation of new processes and ways of thinking learned through technology use, resulting in improved task performance once the tool is removed. For example, abacus users often internalise its structured steps – grouping numbers, carrying values, breaking calculations into parts – strengthening their ability to compute independently. At the same time, reliance on technology can also lead to deskilling, as reduced practice with underlying capabilities weakens independent performance. The widespread use of search engines illustrates this trade-off: while offloading memory demands enhances efficiency, it can diminish our ability to recall information without external support. In a widely-cited investigation, Sparrow et al. (2011^[30]) found that such reliance shifts cognitive effort from remembering content to remembering where information is stored.

Although the availability of technology is barely problematic given its increasing ubiquity, the importance of ensuring that individuals can rely on internal processes continues to be a common argument when new technology enters the curriculum debate. This is illustrated below with a discussion of the integration of calculators in mathematics instruction. Importantly, AI represents a significant leap in cognitive extension compared to earlier technologies because it performs functions analogous to human cognitive processes, surpassing human capabilities in many cases – see Box 3.1. For instance, AI can recognise patterns in vast datasets, detect visual or auditory inputs beyond human perception and process complex correlations to generate actionable insights. Moreover, it can leverage these abilities to compensate for human cognitive limitations, framing and providing context to user questions, bridging gaps in understanding and offering suggestions to optimise workflows.

The impact of AI on cognition may thus be far-ranging, and concerns about AI overreliance, where users defer excessively to AI systems that produce unreliable or biased outputs, are increasingly widespread. Additional issues include privacy concerns, intellectual property conflicts and potential skill attrition, where individuals cease to rely on their own judgement for decision-making due to uncritical use of AI tools (Zhai, Wibowo and Li, 2024^[31]; Gerlich, 2025^[32]; Vidal, Vincent-Lancrin and Yun, 2023^[33]). In addressing these concerns, ongoing research is crucial. Efforts are being made to mitigate algorithmic bias, enhance reliability and increase the transparency of AI tools (Bernardo, 2023^[34]). Such developments suggest that many of the challenges associated with AI are technical issues that can be overcome through dedicated research and development. Consequently, AI tools have the potential to not only grow more capable but also become safer and more reliable.

Yet, even if AI explainability and reliability improve alongside capability, concerns over skill attrition might remain. Salomon et al. noted that a distinction should be made between offloading tasks like basic arithmetic, such as square root calculation, and tasks like medical diagnosis, as the latter seemed too critical to delegate to "black box" systems. However, if we reach a point where even complex tasks can be safely delegated to AI, we should expect an expansion in the types of tasks considered appropriate for AI involvement. In other words, we will likely see the 'machines that work for us' category expand as AI's capabilities and reliability grow alongside social trust in their safety, with the effect of having to rethink how we approach content selection and organisation in the school curriculum.

Box 3.1. How may AI impact human capabilities?

- **Memory support:** AI can improve memory by creating personalised reminders, developing strategies to help retain information, and tagging experiences (e.g., linking people, events, or concepts) to make them easier to recall later.
- **Sensorimotor interaction:** AI can interpret patterns from new types of sensors (e.g., detecting environmental changes) and translate this information into formats we can easily understand, making interactions more intuitive and useful.
- **Visual processing:** Advanced AI tools can enhance images and videos or show us things we cannot normally see, such as hidden patterns, through tools like augmented reality.
- **Auditory processing:** AI can focus on important parts of a conversation, ensuring users don't miss critical details, and even prompt users when an interesting topic arises.
- **Attention and search:** AI can help users stay focused by prioritising important information and drawing attention to details they might have overlooked.
- **Planning, decision making and acting:** AI assistants can plan schedules, suggest the best times for different activities, and help manage tasks more efficiently, saving time and energy.
- **Comprehension and expression:** AI can rewrite or simplify complex information to make it easier to understand, whether it is text, video, music, or other forms of media.
- **Communication:** AI can draft emails, compose messages, and even deliver sensitive information (e.g., communicating tough decisions) in the best possible way.
- **Emotion and self-control:** AI systems can detect emotions – both ours and others' – and help manage emotional responses effectively in real time.
- **Navigation:** AI can go beyond GPS by linking places and routes with personal memories, people, or events, providing a richer sense of location and time.
- **Conceptualisation, learning and abstraction:** AI can uncover patterns and ideas humans might never notice, explaining these insights in ways that help us think and reason more effectively.
- **Quantitative and logical reasoning:** AI can assess probabilities, track data trends and quantify risks in real time (e.g., predicting accidents or counting people in a room). It can also structure complex problems, processing uncertainty and drawing logical inferences to support decision-making.
- **Mind modelling and social interaction:** AI can model social interactions by predicting others' beliefs, intentions, or preferences, enhancing our ability to navigate social situations.
- **Metacognition:** AI can identify its own and the user's strengths and limitations, helping people reflect on their actions and make better use of both human and AI capabilities.

Source: Adapted from Hernández-Orallo and Volt (2019^[35]).

Knowledge, technology and the curriculum: The case of calculators in mathematics

The question of which tasks should be offloaded to technology and which must remain central to human mastery is not new. Throughout history, the integration of new tools into education has prompted debates over their impact on learning and skill development. This is particularly evident in the case of calculators, which became a subject of intense discussion during the last quarter of the 20th century. Education specialists are sometimes reluctant to compare the impact of AI to that of calculators, partly due to the very different nature of the two technologies, which – undoubtedly – provoke different considerations and implications. However, the debate over calculators and their role in mathematics education may offer valuable insights into how the effects of technology influence curriculum decisions such as what students should learn and why. A similarly reflective debate may now be necessary to consider how AI's growing capabilities challenge common assumptions in mathematics as well as in other curricular domains.

The 1970s, when hand calculators started to become widespread, were marked by significant debate over their use in classrooms. Evidence on the educational impact of calculators was only emerging, and both learning professionals and the public were divided on their integration in instruction (Banks, 2011^[36]). Critics expressed concerns about using a tool the effects of which had not been thoroughly researched. They feared that reliance on calculators could neglect skills deemed crucial for functional literacy, and argued that, without these foundational skills, individuals could become overly dependent on the device. By contrast, supporters viewed calculators as a key tool to enhancing the math curriculum. They advocated for complementing an instructional focus on basic arithmetic skills with the application of calculators to tackle complex, real-life problems, an approach that was seen to foster student motivation and deepen understanding through engagement with mathematical reasoning. Two related phenomena underpinned this view: the perception that what constituted basic mathematical competence needed to be revised to prepare students for the “knowledge economy”, and the growing realisation, grounded on emerging scientific research, that effective mathematics learning required new approaches to curricula and instruction.

The aims and goals of math education: A long-standing controversy

With a focus on the United States, the adequacy of the math curriculum has been a central theme in educational debates for over a century (Majewska, Rushton and Shaw, 2022^[37]; Klein, 2003^[38]; Furr, 1996^[39]). At the start of the 20th century, the discussion centred on how education could best serve the needs of a rapidly growing and increasingly diverse student population. The dominant progressive view argued for an instrumental approach that addressed students' practical needs. Along these lines, basic computation was prioritised to prepare learners for math-related tasks like bookkeeping, while topics like algebra, geometry and trigonometry were considered necessary only for those with academic aspirations. Progressivist views drew on contemporary research questioning transfer of mathematical ability, contrasting with earlier beliefs that advanced mathematics strengthened general intelligence.

The debate shifted by mid-century. World War II revealed deficiencies in recruits' computational and problem-solving skills, later amplified by Cold War competition with the Soviet Union. These anxieties fuelled the “new math” reforms of the 1950s and 1960s, which elevated disciplinary content through the involvement of subject specialists in curriculum design. Yet the movement was soon judged a failure, criticised as overly abstract and disconnected from students' basic skill needs. By the early 1970s, a widespread “back to basics” agenda reasserted rote mastery of computation, this time in line with mainstream behaviourist views.

At the same time, calls grew for deeper knowledge and problem-solving skills, and the meaning of “basic” math came under debate. The National Council of Supervisors of Mathematics (1977^[40]) argued that

fundamental skills should extend beyond computation, a view reinforced by the growing importance of numeracy for work and the arrival of calculators. Emerging research on expertise further challenged traditional assumptions, showing that competence involves not just factual and procedural knowledge but also knowing when and how to apply it. This work refuted the idea that hand-calculated arithmetic was a prerequisite for advanced concepts, instead emphasising authentic learning practices that engage reasoning with numbers, discussion and reflection. The National Council of Teachers of Mathematics (NCTM), an organisation representing school teachers across the States, was explicit in calling for a serious re-evaluation of dominant curriculum assumptions. NCTM emphasised that identifying basic skills is a dynamic process that needs constant updating, and argued for a change in instructional priorities at a time where “daily life will be more deeply permeated by multiple and diverse uses of mathematics than ever before” (NCTM, 1980, p. 6_[41]) (see Box 3.2).

Box 3.2. Redefining basic mathematic skills for the 1980s

Recommended changes in instructional priorities by NCTM, 1980

There should be increased emphasis on such activities as:

- locating and processing quantitative information
- collecting data
- organising and presenting data
- interpreting data
- drawing inferences and predicting from data
- estimating measures
- measuring using appropriate tools
- mentally estimating results of calculations
- calculating with numbers rounded to one or two digits
- using technological aids to calculate
- using ratio and proportion to deal with rate problems in general and with percent problems in particular
- using imagery, maps, sketches, and diagrams as aids to visualising and conceptualising a problem
- using concrete representations and puzzles that aid in improving the perception of spatial relationships.

There should be decreased emphasis on such activities as:

- isolated drill with numbers apart from problem contexts
- performing paper-and-pencil calculations with numbers of more than two digits
- mastering highly specialised vocabulary not useful later either in mathematics or in daily living
- converting measures given in one system to corresponding measures in another system
- working with tables whose usefulness as aids to calculation has been supplanted by calculators and other technological aids (e.g., numerical computations with logarithms and clogs).

Source: NCTM (1980_[41]), <https://www.nctm.org/>.

The impact of calculators on the mathematics curriculum

Overall, it took about two decades for the calculators to become a widely accepted educational tool. Even today, questions about when and how calculators should be best introduced remain contested. Yet the integration process was rather fast and successful. In 1986, only about one-fifth of middle school students and slightly more than a quarter of high school students reported having access to calculators in their mathematics classrooms. However, this situation rapidly evolved over the following years. By 1992, the availability of calculators had dramatically increased, with 81% of middle school and 92% of high school students reporting access to these devices in their math classes. Policies for calculator use in examinations also began to adapt. Only 33% of eighth graders were allowed to use calculators for their mathematics tests in 1990. Just six years later, that permission had more than doubled, with 70% of eighth graders being allowed to use calculators in tests. Daily use of calculators in class became the norm, with nearly 60% of eighth graders regularly using them by 1996 (Waits and Demana, 2000^[42]).

The perspective of time helps draw conclusions about the impact of calculators on curriculum development and design. Three interrelated aspects deserve attention: the offloading of tasks to the tool, the equalising effects over student performance, and the shift in curricular focus toward previously underemphasised areas. Long manual computation drills, which had dominated mathematics instruction, were de-emphasised in favour of open-ended tasks and problem-solving activities (OECD, 2024^[43]). By leveraging calculators, students could focus on developing the mathematical reasoning skills necessary for progression toward more advanced concepts (Van de Walle, 2007^[44]).

The use of calculators had an equalising effect. For students who struggled with arithmetics, the traditional emphasis on manual computation often created barriers to progression – either external, through formal teacher evaluations and related advancement decisions, or internal, manifesting as math-related anxiety. The ability to offload computing tasks contributed to bridging these gaps. By the turn of the century, results from the National Assessment of Educational Progress (NAEP) showed that appropriate calculator use did not undermine essential mathematical abilities. At grade 4 there was no significant relationship between teachers' reports of calculator use and student performance on an assessment designed to measure aspects such as problem solving and conceptual understanding, but at grade 8, students in classrooms with more frequent calculator use tended to score higher (NCES, 2001^[45]).

Calculators, first, and personal computers later provided educators with greater flexibility to imagine and organise the mathematics curriculum. Schmidt et al. (2022^[46]), who examined curricular changes across 19 countries and jurisdictions over several decades, note that the integration of these technologies might have influenced the focus and coverage of topics. While the foundational elements of formal mathematics education, such as arithmetic and algebra, appear to have remained largely consistent, the study indicates that the inclusion or exclusion of certain subjects, and the amount of instructional time devoted to them, may have shifted. For example, areas like probability and statistics, long advocated as essential (e.g. see Bureau of Education (1922^[47])) but traditionally underrepresented, have gained more prominence in recent decades. The shift away from time-intensive computation drills facilitated by technology arguably played a role in these changes, suggesting that it is now possible for teachers and students to devote more attention to advanced topics that align better with contemporary social and professional demands.

Retrospectively, the integration of calculators in schools is a story about societal concerns surrounding the effects of technology on education. Early debates reflected fears about diminishing focus on traditional topics and instructional methods that had shaped the education of older generations. Over time, however, the gradual acceptance of calculators underscores how tool use can enhance students' ability to perform tasks effectively, and the results this has on curriculum design through the incorporation of new topics, at least in formal curricula.

4 Emerging implications of AI: Large language models and the writing curriculum

The implications of generative AI applications for education have become increasingly common in research and media commentary, reproducing some of the fears calculators raised when first entered the educational debate. The conversation often focuses on AI's potential to undermine academic integrity and result in skill attrition by offering students an easy way to complete assignments without engaging with the underlying thought processes. Relatedly, there is also preoccupation with respect to AI's tendency to generate biased or unreliable output, which could lead students to rely on inaccurate or skewed information (Farrokhnia et al., 2023^[48]; Mollick, 2024^[49]). These concerns are significant and pressing, but they overlook where generative AI truly excels: language.

Recent advancements in AI, in particular large language models (LLMs) trained on vast datasets, have significantly closed the gap between human and machine performance in natural language tasks. LLMs have reached and even surpassed human performance in areas such as information retrieval, translation, speech recognition and certain question-answering tasks (Graham, 2023^[50]), and tools like ChatGPT have made these capabilities widely accessible at little to no cost, both through oral and in written interaction. LLMs have the ability to generate text of higher quality than average human writing (Herbold et al., 2023^[51]; Ariyaratne et al., 2023^[52]): even when they generate biased and nonsensical content, they do so with a remarkable command of language.

A compelling aspect of the calculator analogy is that generative AI's accuracy and versatility in writing resembles the computational precision of calculators. Many humans struggle to write like ChatGPT despite extensive training, just as many struggle to perform long computations mentally (Steele, 2023^[53]). Curriculum specialists must consider AI's potential to reshape how humans engage with texts, and the critical questions this raises: Is the current reading curriculum adequate when AI tools can summarise and explain complex texts to users? Can we continue to teach writing in the same way when AI can help us refine and translate our ideas into well-crafted texts?

While acknowledging that, within the literacy domain, AI applications include advanced functions for reading comprehension, this section focuses on writing. It explores whether school curricula should shift their focus from mechanical writing skills like handwriting and spelling toward higher-level composition processes, much like how calculators contributed to shift the focus of math instruction from manual computation to reasoning and problem solving. The section begins by examining the social role and core features of writing, then briefly reviews how it is taught and learned. This frames an analysis of the potential and limits of offloading aspects of writing to AI.

Writing: Importance, main components and instruction

Writing serves multiple important functions. By connecting people across time and space, it is a fundamental means of communication, learning and personal expression. It is also closely tied to identity: writing provides individuals with a way to articulate a voice of their own, to position themselves in relation to others and to construct aspects of who they are (Ivanič, 1998). Writing is a demanded skill in many jobs, where tasks such as drafting emails, writing reports and filling out forms are common (OECD, 2016^[54]). It is essential in education as well, where students are often assessed by the ideas they express in writing and by how well their writing expresses those ideas.

Writing transcends simple communication and transcription of speech. It aids thinking by facilitating the externalisation of thoughts through symbols. In written text, ideas become tangible artifacts that people can review, reflect upon and manipulate more easily. Writers write down their thoughts and new thinking emerges in the process because representing ideas on paper or screen allows a level of cognitive engagement that would be difficult to achieve mentally (Menary, 2007^[55]). This aspect of writing explains why writing is considered as a foundational skill in curricula, given its potential to unlock learning across all subjects.

Over the course of the 20th century, theories about writing evolved from focusing on communication and form to examining individual cognitive, motivational and psychological processes as well as broader social and cultural contexts (Behizadeh and Engelhard, 2011^[56]). Writing is now considered as a goal-directed activity influenced both by the characteristics of the communities in which it takes place and by the cognitive and motivational capacities of writers (Graham (2018^[57]), see Table 1).

From a social standpoint, writing is shaped by communities of writers, readers, collaborators and mentors who share certain assumptions and use writing to achieve their goals. From a cognitive and motivational perspective, writing happens in the individual minds of writers, who must have knowledge of the conventions of writing and the subject they want to write about and be able to self-regulate throughout the creative process of generating, organising and transcribing ideas into coherent texts.

Writing is thus a rewarding skill to develop, although one requiring extensive training to master. Effective writing instruction addresses both the social and cognitive aspects of writing in educating skilful writers (Graham et al., 2012^[58]; Bilton and Duff, 2021^[59]; Quigley and Coleman, 2020^[60]). Knowledge of writing builds on the development of strong oral communication skills and vocabulary in the early years, which lay the groundwork for effective written expression. As individuals begin to write, instruction in both transcription and composition skills becomes important.

Writing is difficult as it requires writers to juggle planning and organising ideas while simultaneously transcribing them into text, a task that places heavy demands on working memory, especially for younger writers. When skills such as handwriting and spelling are not yet developed to the point where they become automatic, they consume significant mental resources that could otherwise be dedicated to composing. In such cases, novice writers may forget their ideas in the process of writing them down or become frustrated by repeated transcription struggles, leading some to lose motivation and even avoid writing altogether (MacArthur and Graham, 2016^[61]). Explicit instruction targeting transcription skills have been found to improve writing fluency, length and quality (Santangelo and Graham, 2015^[62]; Graham and Santangelo, 2014^[63]), the latter referring to the coherence and quality of ideas in a text as well as the use of language (vocabulary and sentence structure).

Table 1. What does writing involve?

Main components of writing according to the writer(s)-within-community model

Component	Subcomponents	Description	Examples
Sociocultural	Purposes	Goals and assumptions of the community, which can evolve over time.	Improving writing skills, maintaining social connections, influencing others' opinion.
	Members	Writers, collaborators, readers and mentors with varying levels of participation and familiarity.	A language arts class, an online writing group.
	Tools	Instruments used for writing, including analogical and digital tools.	Paper and pencil, word processors, speech-to-text synthesisers, generative AI applications.
	Actions	Practices and activities to achieve writing purposes.	Gathering information, editing drafts, providing feedback, promoting collaboration.
	Written products	Texts and other outputs produced by the community.	Completed texts, drafts, plans, notes, pictures, videos, and images.
	Physical and social environments	Sites and relationships within the community, impacting motivation and the writing process.	Classrooms, offices, homes, digital platforms.
	Collective history	Shared experiences and practices that shape writing over time.	Shared writing tools, common writing approaches, evolving practices.
	Macro-level forces	Social, cultural, political, institutional and historical influences.	Cultural differences in writing, political mandates on writing instruction, historical events.
Cognitive and motivational	Long-term memory resources	Knowledge of oral language and reading, writing conventions and norms, content knowledge, different writing communities. Beliefs about value/utility of writing, attitudes/interest, one's own competence as writer, why one writes, why one is successful, writing identity, beliefs about writing communities	Knowledge of spelling, handwriting and sentence construction; knowledge of what one wants to write about or how to effectively retrieve useful information; knowledge of writing genres. Believing that writing is important for academic success; enjoying writing an essay; feeling confident on one's own ability; identifying as a poet; viewing a writing group as supportive or collaborative.
	Control mechanisms	Attention, working memory and executive control, enabling writers to direct and regulate their writing.	Focusing on brainstorming ideas for a paper while ignoring distractions. Holding and processing information while writing. Setting goals, planning the structure and revising and improving drafts for an essay.
	Production processes	Mental and physical operations including conceptualisation, ideation, translation, transcription and reconceptualisation.	Forming a mental representation of the writing task; brainstorming ideas for an essay; converting ideas into legible sentences and paragraphs; writing or typing for a school assignment; revising and rethinking a first draft for improvement.
	Modulators	Emotions, personality traits, and physiological states that moderate access to resources and processes.	Emotions such as joy, anxiety and pride; personality traits like openness and conscientiousness; physiological states like hunger, stress or fatigue.

Source: Graham (2018^[57]).

In parallel, instruction should support students' capacity to compose, an aspect that can start even before transcription skills have become fully automatised – for example, using drawings or invented spelling for children to construct their discourse. Explicitly teaching students how to plan (e.g. generate and structure ideas), draft (craft sentences), evaluate (self-monitor) and revise (peer review) their writing contributes to their writing prowess, especially when instructional activities involve student collaboration. Exposing learners to different text types and encouraging them to write for varying audiences and purposes (e.g. to narrate, inform or persuade) further enhances the quality of their writing (Graham et al., 2012^[68]; Slavin et al., 2019^[64]; Graham et al., 2012^[65]).

Developing a robust knowledge of writing early on can give students a powerful tool for thinking and learning across school subjects, particularly useful in upper grades when school education becomes more academic oriented. However, empirical research points to persistent gaps between effective and actual practices in writing instruction. In a meta-analysis of 28 surveys, observation, and mixed-methods studies, primarily from the United States, Graham (2019^[66]) makes the following observations with respect to the teaching of writing in schools:

- The time dedicated to writing instruction in schools is limited overall, with some regions reporting teaching writing as infrequently as once a week or less.
- Lower-order writing skills such as handwriting and spelling are overemphasised in earlier grades (K-3) in comparison to teaching for composition.
- While the emphasis on transcription and composing is more balanced in upper primary and middle school (grades 4-8), even less time is dedicated to writing and writing instruction compared to earlier grades.
- A significant portion of writing time in schools involves writing without composing, such as in writing short responses and note-taking, while neglecting more reflective and generative tasks like writing longer research reports and argumentative texts.
- Writing instruction frequently overlooks the importance of motivating students and fostering a positive attitude toward writing, and despite the prevalence of digital writing in modern life, digital tools are not adequately integrated into writing instruction in most classrooms.

Existing mismatches between recommended practices and actual instruction may explain why student writing performance is on average unsatisfactory according to existing evaluations. For instance, results from national assessments of writing in the United States have shown that only about a quarter of students can meet the communicative demands they are expected to need for success in academic and workplace settings (NCES, 2012^[67]). Beyond concrete assessment results, connecting Graham's account with the broader functions of writing discussed earlier, it seems that schools often focus on laying the building blocks for students to write, but give them limited opportunities to actually use writing as a tool for thinking, expression, and communication.

Changing writing instruction with AI: Opportunities and potential concerns

The evolution of writing assistance tools over the past few decades illustrates the growing potential for technology to support writing teaching and learning. Early digital tools like word processors provided basic functions such as spell-check and grammar correction, helping students refine their writing. Later, AI-powered programmes like Grammarly and DeepL offered more advanced functions, such as composition analysis, style suggestions and automatic translation (Godwin-Jones, 2022^[68]). These tools have demonstrated positive effects on writing performance, and they have been shown to improve student writing skills when integrated in instructional programmes (Tseng and Warschauer, 2023^[69]; Morphy and Graham, 2011^[70]; NCES, 2012^[67]).

However, generative AI tools represent a significant change. Compare current AI chatbots, such as ChatGPT, Claude, Mistral, Gemini, with spell checkers. While spell checkers can only help people who already spell well enough to produce a close approximation of a given word, generative AI directly provides words that are orthographically correct following user commands, accounting for context if provided and effectively inserting such words in intelligible sentences, paragraphs and larger text structures. With the release of ChatGPT and similar tools thereafter, the nature of what writing means has changed for their users. Early versions of generative AI applications helped users structure tasks and proofread drafts, while newer models emerging support more powerful ways to refine content, improve drafts and integrate complex information. This evolution allows writers to offload more of the mechanical aspects of writing to technology, enabling a stronger focus on idea generation and argument development and revising (Mollick, 2023^[71]; Noy and Zhang, 2023^[29]).

Opportunities

Research has shown that when students are freed from the burden of transcription, they can engage more fully with discourse building. Studies comparing dictation with handwriting have demonstrated that young students produce more text and higher-quality writing when they do not have to spend efforts ensuring they are spelling words or forming letters by hand correctly. Similarly, research using speech-to-text software shows that students, particularly those with learning disabilities that impair transcription skills, produce better quality writing when dictating their work (MacArthur and Graham, 2016^[61]). While these studies have supported the importance of automating transcription skills early on in schooling, they also support the idea that externalising these skills entirely could lead to higher-quality writing overall.

Externalising transcription tasks would allow learners to concentrate more on the content of their texts. If AI were to take over writing-related processes such as spelling, punctuation, capitalisation, handwriting/typing and even sentence construction, it could also break the cycle of frustration and poor self-image that often accompanies difficulties with these processes. The ability to produce clear, formally correct text with AI could lead to a positive shift in learners' self-perception, boosting their motivation and engagement with writing. This effect would likely be most pronounced for students with learning disabilities such as dyslexia and dysgraphia, although it would extend to all individuals whose writing is negatively impacted by difficulties with transcription – difficulties that might persist beyond early grades up to secondary education for some students (Graham et al., 2024^[72]).

In fact, if comparing calculators and generative AI in terms of their potential impact on curriculum, it should be noted that while calculators would take care of computing leaving broader aspects of problem solving for humans to address, generative AI can go further than performing transcription work on its own and provide substantial *assistance with composition*. As reflected in Table 2, ChatGPT and similar tools can help users generate ideas and structure, revise and modify texts by retrieving and summarising information, suggesting connections between relevant ideas, and offering conceptual clarifications. Additionally, AI tools can help students with goal setting, tracking their writing progress, and offering real-time feedback on their work, thus fostering the development of self-regulation skills.

Table 2. A sample list of ChatGPT functionalities relevant to writing

ChatGPT Functionalities	Examples
End-to-end writing	Producing complete texts (essays, stories, reports, dialogues, etc.) from prompts of varying detail
Content development	Suggestions for potential topics, outlines, or resources
	Collection and summarisation of related information
	Facilitation of brainstorming through conversation
Corpus search	Retrieval of example sentences using the given vocabulary or grammar structure from a specific disciplinary corpus
Text modification	Adjustment of difficulty level
	Adjustment of genre, tone, voice, or formality
Feedback and revision	Editing and proofreading with explanations
	Revision for specific aspects of writing (content, organisation, clarity, etc.) with explanations
	Analysis of learner errors and mistakes
Response to questions	Providing answers to specific questions (appropriateness, confusing synonyms, etc.)
Support for sentence generation	Translation or articulation of a given sentence
	Generation of templates or sentence starters
Vocabulary / Grammar support	Providing definitions or explanations for unknown vocabulary or grammar items
Paraphrasing / Summary	Paraphrasing and summarising to meet specific requirements (length, style, etc.)

Source: Adapted from Warschauer et al. (2023^[73]), <https://doi.org/10.1016/j.jslw.2023.101071>.

With AI handling transcription and substantive elements of composition, curricula could evolve to emphasise students' capacity to plan, structure and rethink content, with learning activities emphasising writing as a social process (see Box 4.1 for an illustration). This could involve a stronger focus on assessing the quality of students' ideas, exploring different types of text and their functions and more time spent thinking how to match one's text with the needs of the intended audience. Time used for individual practice of transcription could be reallocated to encourage dialogue and collaborative work as a means to sharpen student reasoning through information sharing, joint evaluation of ideas and greater perspective-taking (García-Carrión et al., 2020^[74]; Lodge et al., 2023^[75]), where AI tools could contribute to the process acting as both coaches and peers for students (Mollick and Mollick, 2023^[76]).

Box 4.1. Students learn about the writing process with AI: An illustration

Applying the writing process in an upper elementary classroom where students in grades 4 through 6 write about robots, with and without AI, as part of a class project.

Teaching and learning the process of writing without AI:

The class discussed robots and what robots could do if they had certain specialty parts, such as telescopes on their heads to see great distances. Prompts such as toy robots and pictures of robots were used to spark discussion (planning).

Students created robot diagrams with vivid pictures and written descriptions of their robots. Students then wrote stories about their robots, explaining how they became friends and what they do together (drafting). They used their diagrams to help them describe their robots in the stories.

Each student shared his or her story with another student (sharing), who provided positive and constructive feedback (evaluating). The students then revised their stories using the feedback, along with their own evaluation of their texts (revising).

Students read their stories aloud in class (sharing). The class commented on what they liked and asked questions about anything that was unclear (evaluating). Students again revised their stories and were invited to publish them in a class book about robots.

Teaching and learning the process of writing with AI:

The class discussed ideas about robots and their functions. Students used AI to offer feedback on their initial ideas, prompting new directions for their stories (planning).

Students instructed an AI tool to generate various diagrams and written descriptions of their robots. They used these to outline the main aspects of the stories they wanted to create, asked the AI for feedback to strengthen their ideas, and prompted it to generate a first draft of the story (drafting).

Students shared their stories with peers, who provided feedback on plot, characters and clarity (sharing). Teachers and AI assisted with understanding points to be rethought and possible actions to be taken subsequently (evaluating). Students then used the AI to revise their drafts, selecting which feedback to incorporate (revising).

Students instructed the AI to read their stories aloud (sharing), sometimes requesting supporting illustrations or videos, or adding a theatrical flair. The class assessed the updated drafts and provided final comments before the stories were shared on the school's website.

Source: Based on Graham et al. (2012^[58]) for the premise and first illustrative activity (task without AI). The AI-enhanced illustration was developed by the author.

The effect of such combined cognitive offloading and extension effects on the writing curriculum can be metaphorically captured with a reference to the etymological meaning of 'curriculum' as 'to run'. Learning to write is like running a hurdle race. Students are trying to reach the goal of thinking and expressing their ideas clearly, but along the way, they have to jump over obstacles created by transcription demands, such as spelling correctly and writing legibly, which take up a lot of mental effort. When AI takes over these tasks, the race becomes much smoother: without hurdles to slow them down, students can focus on organising their thoughts, building strong arguments and shaping their writing for different audiences. But AI doesn't just remove barriers; it also accelerates students' progress in these more sophisticated

aspects – it helps them “run faster”. By supporting higher-level composition processes, AI gives students a boost, helping them develop well-structured, compelling texts more efficiently. Instead of getting stuck on the mechanics of writing, they can put their energy into generating and refining ideas, deciding how they prefer these to be expressed and ensuring clear communication. All with AI’s support every step of the way.

Potential concerns

While the potential benefits of integrating AI into the writing curriculum are significant, they exist alongside deeper questions. As with any technological advancement, potential concerns must be carefully addressed. Three possible risks or counterarguments to the shift suggested above are identified and considered next:

- AI may introduce new learning goals, such as effective prompting, which could create new performance gaps and offset time saved by offloading transcription and counting on advanced assistance with composition.
- Relying on AI for writing could undermine students’ ability to engage deeply and critically with content, affecting knowledge retention and understanding.
- Shifting focus to AI-assisted writing might hinder the development of separate but closely related skills, such as reading.

Emergence of new curricular demands

Integrating AI tools into school writing and instruction, as discussed above, raises the question of whether new kinds of knowledge are needed beyond traditional curricular goals. It may be argued that for students to use AI effectively in writing, they must learn to interact meaningfully with the tools. Specifically, knowledge of prompting – providing clear and specific instructions to guide the AI in generating content – may become a critical skill. While AI capabilities are strong, achieving outputs that meet users’ goals, particularly for longer or more complex tasks, is not always straightforward. Users often face a trade-off between AI output fidelity and communication cost, requiring multiple exchanges to refine the output (Castro, Gao and Martin, 2023^[77]; Lingard, 2023^[78]). Without an understanding of how to interact with both the tool’s interface and the AI itself – an important component of AI literacy (see Box 4.2) – students may not achieve the expected improvements in writing quality (Warschauer et al., 2023^[73]).

The importance of prompting is reflected in the SPACE framework for writing with AI (Kleiman, 2022^[79]), where prompting replaces writers’ traditional drafting efforts in the writing process:

- *Set directions*: Define the goals, content, and audience for the AI.
- *Prompt*: Provide specific instructions to generate the required content.
- *Assess*: Evaluate the output for quality and accuracy.
- *Curate*: Select and organise the best content from AI-generated options.
- *Edit*: Revise the combined human and AI content into a final draft.

This framework suggests that, rather than simply freeing up time by externalising transcription and facilitating composition, AI use may shift instructional demands to prompting. This has two key implications. First, teaching students to prompt effectively could consume instructional time that might otherwise be used to strengthen other aspects of the writing process. In other words, any time saved by writing with AI could be offset by time spent on developing AI literacy. Second, just as students differ in their writing abilities, they may also vary in their prompting proficiency. This means that performance gaps linked to transcribing and composing without AI could be replaced by new gaps related to students’ ability to

communicate effectively with AI, potentially undermining AI's promise of reducing inequality in writing outcomes.

Box 4.2. What is AI literacy?

AI literacy is the combination of knowledge, skills, and attitudes learners need to understand, use, and shape AI responsibly in life, study, and work. It is organised around four domains of interaction with AI:

- **Engaging with AI:** Recognise when AI is in use; find and interpret AI outputs; judge accuracy, relevance, and bias.
- **Creating with AI:** Collaborate with AI to brainstorm, draft, transform, and refine content; **prompt**, iterate, and keep outputs appropriate and attributable.
- **Managing AI:** Decide *when and why* to use AI; delegate tasks, set constraints, monitor fidelity, and align use with goals and values.
- **Designing AI:** Build a basic grasp of how AI works; explore data, models, and evaluation; examine fairness, privacy, and societal impact through hands-on activities.

Source: (OECD, 2025^[80]) *Empowering learners for the age of AI: An AI literacy framework for primary and secondary education (Review draft)*, <https://ailiteracyframework.org/>.

However, there are important counterpoints to this concern. First, learning to prompt well integrates naturally with the broader writing process. Mollick (2024^[81]; 2023^[82]) identifies three effective prompting strategies that mirror key components of good writing: (1) providing context (such as audience or genre) parallels goal-setting in composition; (2) giving examples is akin to drawing on strong models in writing instruction; and (3) breaking tasks into steps supports planning and revision. In this sense, teaching prompting can reinforce students' metacognitive and self-regulatory development as writers, particularly when students are given time to practice, with initial teacher support gradually fading (Graham et al., 2012^[58]; Quigley and Coleman, 2020^[60]).

Second, the demand for precise prompting is likely to decline over time. As AI models continue to improve, they are becoming more responsive to varied and less precise inputs. Even minimal prompting can increasingly produce high-quality output (Mollick, 2024^[83]; Hari, 2025^[84]). Combined with the growing availability of guides, tutorials, and examples – many of them designed for education (e.g. (Mollick and Mollick, 2024^[85])) – this means that prompt effectiveness will depend less on expertise. In the long run, the ability to prompt may no longer be a key factor in writing performance, and concerns about new performance gaps may diminish.

Compromising key educational outcomes

As noted earlier, writing plays a key role in human cognition by extending thought processes and enabling the organisation, review and manipulation of ideas. A second potential concern in rethinking the writing curriculum with AI is thus whether such changes could weaken students' ability to think and learn. Specifically, questions might arise about the impact of reducing students' involvement in writing tasks over their opportunities to engage deeply with curricular content and retain knowledge over time. Beyond cognition, writing also supports the development of identity and voice (Ivanič, 1998^[86]), raising questions about whether generative AI might limit or reshape students' opportunities for authentic self-expression.

Extensive research in cognitive and educational psychology highlights that the most effective study strategies involve learners actively making sense of information rather than passively reviewing it. Beyond ensuring that students revisit material multiple times over spaced intervals, high-impact study techniques

promote elaboration, encouraging learners to connect new ideas to existing knowledge and integrate them into meaningful structures. Strategies such as summarisation and self-explanation, for example, help students organise and restructure information, strengthening recall and comprehension (National Academies of Sciences, Engineering and Medicine, 2018^[87]; Dunlosky et al., 2013^[88]).

Considering this research in relation to writing tasks, the following general points can be made:

- *Writing can support learning strategies with proven efficacy:* Writing can play a positive role in several high-impact study techniques. Summarising the content of a reading or lesson talk in one's own words, for instance, might be done in writing, where students can externalise and organise their thoughts more easily with positive effects on comprehension (Graham and Hebert, 2011^[89]). Writing can support other learning strategies in similar ways, e.g. self-explanation.
- *But effective study strategies do not involve writing necessarily:* While writing can be beneficial, many effective learning strategies do not require written output (Fiorella and Mayer, 2015^[90]). Examples include students attempting to recall information from memory rather than rereading/writing, self-explaining ideas or teaching them to others and generating drawings and mind-maps to represent how a set of ideas relate.
- *In fact, some writing-related study strategies commonly engaged by students are ineffective:* Many students rely on study techniques that involve little to no elaboration, creating a sense of familiarity with the material but offering little benefit for comprehension and retention (Ruiz-Martín, Blanco and Ferrero, 2024^[91]; Graham, 2019^[66]). These ineffective strategies include activities such as rereading and highlighting text, as well as writing-related practices like verbatim notetaking (Mueller and Oppenheimer, 2014^[92]).

While writing can facilitate meaningful learning if used intentionally, it is not a prerequisite for deep engagement with content. In fact, generative AI offers new opportunities for students to interact with ideas. AI tools can generate quizzes for retrieval practice, serve as interactive dialogue partners for explanation, or scaffold complex tasks – supporting learning processes that once depended more heavily on writing and other people. Table 3 further illustrates how AI can promote deep learning without requiring writing.

These insights suggest that writing is one of several tools that can support effective learning, not an indispensable element of thinking or knowledge construction. Writing activities may aid comprehension in specific contexts, but they are not inherently tied to deep learning. AI can supplement or even replace certain traditional tasks by offering interactive and adaptive ways to engage with information. Similarly, fears that AI inevitably flattens students' identity or erodes their voice may be overstated. Used deliberately, AI can also scaffold experimentation with style and register, helping learners articulate perspectives they may struggle to express unaided. Concerns about the reduction of writing-related tasks in education, therefore, should be reframed: not as a loss of essential cognitive processes, but as a reorientation in how students approach thinking tasks and build knowledge.

Still, a broader concern remains: the potential for AI to externalise not just writing but thinking itself. As AI becomes more sophisticated, students may rely on it not only for mechanical tasks but also for outsourcing reflection and understanding altogether. In this scenario, AI's role shifts from being a tool that supports cognition to one that substitutes for it, raising questions about the long-term impact of AI-assisted learning on students' intellectual development and autonomy.

This challenge, however, is not without precedent. Past technological advancements, such as search engines and digital encyclopaedias, once raised similar concerns about students no longer needing to memorise or deeply engage with information, as facts became instantly retrievable online (Steele, 2023^[53]). Education responded by increasingly shifting its focus towards evaluating, synthesising and engaging deeply with knowledge rather than simply recalling it. There is little reason to believe AI should be any

different, so long as educators keep focusing learners' attention on talking and thinking for critical appraisal of ideas and understanding (Wegerif, 2019^[93]; 2013^[94]; Scardamalia and Bereiter, 2006^[95]).

Table 3. Generative learning strategies, writing and generative AI

Learning strategy	Description	Examples involving writing	AI-powered alternatives
Summarising	Stating key ideas into one's own words to enhance understanding and recall.	Writing summaries to synthesise and structure key ideas.	AI provides models of effective summaries, guides students to refine their own versions orally, and asks questions about key ideas (e.g. of a given text).
Mapping	Creating visual representations (e.g. concept maps, diagrams) to show relationships between ideas.	Writing helps label concepts and describing connections.	AI directly generates concept maps from multimodal input, or generates maps progressively, as talks to students.
Drawing	Creating illustrations to represent concepts and their interrelationships.	Writing is minimal but may include explanatory labels.	AI generates sketches based on learners' input, reducing cognitive load linked to the application of drawing mechanics.
Imagining	Mentally simulating concepts, processes, or scenarios to deepen comprehension.	Writing may be used to describe imagined scenarios or reflections.	AI transcribes text or generates equivalent visualisations, asks probing questions, provides analogies to enrich simulations.
Self-testing	Retrieving knowledge through quizzes or recall exercises.	Writing answers to practice questions.	AI can generate personalised quizzes, record and summarise responses and offer feedback to reinforce key concepts.
Self-explaining	Articulating understanding of a concept to oneself, either in writing or speech.	Writing explanations can solidify understanding but may be time-consuming.	AI can serve as a responsive interlocutor, asking follow-up questions to refine explanations and challenge misconceptions.
Teaching others	Explaining a concept to another person to reinforce knowledge.	Writing structured lessons or responses can help solidify knowledge.	AI can act as a "peer," allowing learners to explain concepts interactively while providing constructive feedback.
Enacting	Physically or verbally acting out concepts to improve retention.	Writing scripts or reflections can support deeper engagement.	AI can simulate real-world scenarios for students to role-play, offering feedback and adjustments based on their responses.

Source: Author, based on Fiorella and Mayer (2015^[90]) and Mollick and Mollick (2023^[76]).

Even in apparently mechanical acts such as sentence construction, learners often clarify and refine their ideas as they translate them into text. Eliminating such opportunities wholesale would risk losing valuable moments of reflection and meaning making. A guiding principle, therefore, is that AI should not diminish the thinking and learning that writing can foster, but rather be used to enhance them. Classroom dialogue and other interactive practices may provide complementary or alternative pathways. School tasks can be designed to continue supporting student thinking, argumentation and explanation, irrespective of AI availability and use. The question facing education is not whether we are willing to, or risk, outsourcing thinking to AI but if writing is necessarily the most effective vehicle for fostering deep engagement with knowledge, particularly the types of writing that students most commonly practice in schools at present (Anson and Straume, 2022^[96]).

Negative impact on different but related skills (reading)

A third concern about outsourcing writing tasks to AI relates specifically to potential impacts on reading development. Literacy research has long hypothesised significant relations between reading and writing

skills: they draw on the same or similar knowledge and cognitive systems, serve related communicative purposes, and inform each other through awareness of textual structures (Shanahan, 2016^[97]; Fitzgerald and Shanahan, 2000^[98]).

A comprehensive framework articulating these relationships is the Interactive Dynamic Literacy Model (IDLM) proposed by Kim (2020^[99]) which portrays reading and writing as distinct yet interrelated processes that rely on overlapping component skills. IDLM is structured around three core hypotheses: hierarchical, interactive and dynamic relations. Briefly, the hierarchical hypothesis suggests that higher-level literacy outcomes such as comprehension and written composition are supported by more foundational skills – including lexical-level literacy skills, such as word reading and spelling, and handwriting/typing – which in turn build upon emergent literacy and oral language skills. The interactive hypothesis posits that reading and writing skills influence one another bidirectionally but not necessarily symmetrically: improvements in one can support gains in the other, though the relative strength of influence may vary. Finally, the dynamic hypothesis emphasises that the nature and strength of these relationships change over time, with reading–writing links being strongest at the lexical level and especially critical during early development.

It is understandable why the idea of outsourcing writing might raise concerns. Transcription skills such as handwriting/typing and spelling have been shown to contribute meaningfully to early reading development. Spelling reinforces reading by strengthening students' knowledge of phoneme–grapheme correspondences and orthographic patterns. It supports the development of word recognition and helps students internalise the structure of written language (Graham and Santangelo, 2014^[63]; Bilton and Duff, 2021^[59]). Similarly, research indicates that explicit handwriting instruction enhances students' reading abilities by supporting the internalisation of letter shapes, thereby promoting accurate and efficient word recognition (Araújo, Domingues and Fernandes, 2022^[100]).

Given well-documented connections, it seems plausible that removing or reducing transcription practice too early via reliance on AI could deprive students of useful developmental opportunities. This is particularly relevant in the early stages of literacy, when transcription skills are closely intertwined with the development of core reading abilities. By analogy with calculators in mathematics, just as students are usually expected to master basic arithmetic before using calculators, there may be value in ensuring they first develop foundational transcription skills before outsourcing them to AI entirely.

However, the evidence is not as clearcut. First, the precise mechanisms explaining the benefits of handwriting for reading remain debated. Some studies support the sensorimotor hypothesis, which attributes the benefit to the physical act of letter formation. Others favour the amodal representation hypothesis, which suggests that the main benefit arises from exposure to varied visual forms of letters, something that could be replicated through non-handwriting activities (e.g., visually rich digital instruction) (Araújo, Domingues and Fernandes, 2022^[100]).

Second, while spelling clearly supports reading development, its relative importance may vary depending on a language's orthographic depth – that is, the consistency of its spelling–sound correspondences. In languages with shallow orthographies, where these correspondences are highly regular (e.g. Spanish or Finnish), spelling tends to reinforce reading more straightforwardly. In contrast, in languages with deep orthographies (e.g. English), where grapheme–phoneme relationships are less predictable, strategic spelling instruction may play a more critical role in supporting early reading development (Bilton and Duff, 2021^[59]).

Third, and perhaps most importantly, reading and writing have historically been taught as separate domains, demonstrating that it is possible to develop reading without direct reliance on writing instruction (Fitzgerald and Shanahan, 2000^[98]). All points taken together, even if writing is reduced or outsourced, strong reading development may still be supported through alternative instructional approaches.

All the same, the developmental view is not the only lens through which the future of literacy should be considered. There may also be broader changes taking place. These concern not just how we teach reading and writing, but whether and why people will continue to engage with these practices at all. These questions, though speculative, are becoming increasingly difficult to ignore.

Towards a post-literate society?

“Writing, in the sense of placing letters and other marks one after another, appears to have little or no future. Information is now more effectively transmitted by codes other than those of written signs. [...] It really looks as though written codes will be set aside, like Egyptian hieroglyphs or Indian knots. Only historians and other specialists will be obliged to learn reading and writing in the future.”

— Vilém Flusser, *Does Writing Have a Future?* (1987)

Reading and writing have long been a gateway to participation in society. People read and write to follow the news, complete official paperwork, navigate public spaces, understand and execute job instructions, and engage with school tasks. In this way, literacy functions as a kind of operating system for modern life – a universal interface for accessing, exchanging, constructing and storing knowledge. But that interface may be breaking down.

A recent Financial Times article asked, provocatively, “Are we becoming a post-literate society?” (O’Connor, 2024^[101]). The question feels less speculative when viewed alongside shifts in how information is now consumed, produced and communicated. If reading and writing were once the default modes of literacy, it is no longer clear they remain at the centre of everyday communication, particularly for younger generations.

Signs of cultural disengagement from traditional reading are already visible, particularly among adolescents. Data from the OECD’s PISA 2018 assessment paints a telling picture: nearly half (49%) of all 15-year-olds across OECD countries agreed or strongly agreed with the statements “I read only if I have to” and “I read only to get information that I need”. In turn, 29% went as far as to say that “for me, reading is a waste of time” (OECD, 2021^[102]). These findings might be signs of a steady erosion in the cultural and motivational hold of reading, which adolescents report becoming more negative across PISA cycles.

Understandably seen as problematic, this shift may also be a rational response to how written communication itself has evolved. In digital environments, circumstances like information abundance and consequent time scarcity saturate our attention and favour shorter, faster, more expressive forms of communication. Such a change in communication incentives has already led to changes in how traditional text has been increasingly replaced or compressed by hybrid forms of expression. For instance, writing online is shaped by the norms of speed, immediacy and emotional resonance. It mimics the rhythms of speech and fills in the missing cues of face-to-face interaction through new symbols, like emojis and typographic play (Androutsopoulos, 2011^[103]).

At the same time, non-textual formats increasingly shape how young people communicate and consume information. For instance, over 50% of adolescents in the United States reported to visit or use YouTube “almost constantly” or “several times a day” in 2023 (Anderson, Faveiro and Gottfried, 2023^[104]). Audiobooks have also gained ground, particularly among younger adults: while 23% of adults in the United States reported listening to an audiobook in 2021, that figure rose to 30% among those aged 18–29, compared to just 12% among those aged 65 and older (Faveiro and Perrin, 2022^[105]). Meanwhile, voice notes, though still less common than other forms of messaging, are emerging as part of everyday communication, especially among young people. In the United Kingdom, one in eight 18–24-year-olds send voice notes daily, and nearly half say they enjoy receiving them (Smith, 2022^[106]).

What we might be witnessing is not a collapse of meaning-making, but a return to orality: to listening, speaking and watching as dominant modes of communication. This shift may seem like a step

back: reading is often seen as deeper and more precise, while speech is fleeting and harder to control. Written text can be revisited and parsed carefully; oral language tends to disappear as it is spoken. But this distinction is less clear than it may seem.

Research shows that reading and listening draw on similar cognitive and linguistic processes, and that comprehension is comparable when listeners can control the pace by pausing, rewinding or replaying content (Clinton-Lisell, 2021^[107]; Wolf et al., 2019^[108]). Oral formats also offer strengths of their own: tone, rhythm, and emphasis carry emotional and contextual cues that text alone cannot fully reproduce, or at least not as efficiently. Technology increasingly supports these modes. Voice interfaces, transcripts and playback tools make it easier to interact with spoken content on one's own terms. Practices like speed-watching (i.e. the act of watching online videos at faster playback speeds than normal) reflect how oral content is being actively shaped to fit the pace and pressures of contemporary life. And as technology keeps evolving, even post-verbal forms of communication based on visual, gestural, spatial, and interactive modalities could emerge driven by augmented and virtual reality as well as AI (Riparbelli, 2024^[109]; Perlin, 2016^[110]).

The idea of a post-literate society is easy to dismiss, but perhaps it is already emerging, quietly, in the ways people read less, write differently and still manage to navigate life, learn and connect. If these shifts continue, reading and writing may no longer serve as the universal gateways to knowledge and participation they once were. Their cultural centrality would be redefined and, if that is the case, the time, effort and resources devoted to ensuring every learner masters them may no longer be as self-evidently necessary.

All in all, it may be that we are only able or willing to make minor adjustments to how we read and write in our daily lives with AI. Consequently, the curricular changes required might also be minimal. However, we could be approaching a scenario where fully offloading writing tasks becomes increasingly practical, especially as such technologies become more widespread and socially accepted. We might even be witnessing a turning point where traditional literacy practices are being surpassed, paving the way for entirely new modes of communication. Only time will tell – the question is whether it will tell us sooner than we can imagine at present.

5

AI's implications for the school curriculum: Concluding remarks

Asked about ongoing technological developments in a recent TV interview, Bill Gates noted we are entering an era of profound transformation: a shift from a world of intelligence scarcity to one of intelligence abundance. When something scarce becomes abundant, its economic value tends to fall – and as machine capabilities increasingly overlap with those of humans, fundamental questions arise about the knowledge education programmes should promote in people (Korinek, 2024^[111]).

This paper has argued that this transformation is already underway. Generative-AI systems have started reshaping curricular tasks that have long been central to schooling, notably so in language. Large language models today are no longer mere supportive tools, but sophisticated co-authors, fundamentally altering the cognitive processes traditionally expected from students.

In recent history, we have seen technological developments like calculators, personal computers and internet search engines shift school curricula progressively “upward”, from mechanical tasks to more complex forms of reasoning and knowledge building – from memorising algorithms to analytic thinking, and from encoding facts about the physical and social world by rote to their critical appraisal. Yet, as AI continues to evolve rapidly in fields viewed as distinctly human, such as by developing reasoning-like capabilities, the metaphor of the curriculum as a “ladder” becomes less useful. Previously, each new technological advance prompted the curriculum to move higher, toward more abstract, sophisticated and uniquely human forms of knowing. Now, however, it seems that as we climb the ladder upward AI is waiting for us in the next rung.

AI challenges us to ask explicitly: Which capabilities remain uniquely human and what types of knowledge retain enduring value for humans as a result? Answering these questions is difficult because traditional curricular structures, their knowledge hierarchies and logical sequences, presume stable definitions of what knowledge is valuable. Yet, if AI rapidly masters tasks previously considered uniquely human, these structures become problematic. Instead, it may require rethinking how AI reshapes the sources of curriculum aims and recalibrates the very functions of schooling.

Evolving AI capabilities and the outlook for education

At present, curricular frameworks across the world commonly underscore similar goals for schooling, including preparing young people for citizenship and supporting their autonomy and well-being. More instrumentally, most jurisdictions emphasise developing human capital to meet a variety of social and economic needs (OECD, 2020^[8]). With this orientation, education systems are structured to develop a range of human capabilities deemed essential for both personal and societal progress. Broadly conceived, these include:

- *Basic capabilities*: like reading, writing and basic quantitative and scientific reasoning, are usually developed in formal education, often across the full population and in the younger grades.

- *Professional capabilities*: include advanced reasoning in subjects like medicine, computer science or plumbing. They are also usually developed initially in formal education (either academic or vocational). However, they are typically developed only by subgroups in the population and usually by older students in later secondary or tertiary education.

In addition to:

- *Common capabilities*: include understanding and using speech, reasoning about everyday situations, interpreting sensory information, moving one's body and manipulating objects, and interacting socially. These capabilities are usually acquired developmentally and learnt without much formal instruction. However, they may be later refined with specialised professional training.

As AI begins to perform increasingly well in tasks involving many of these capabilities – including complex tasks involving reasoning when humans carry them out – the justification for maintaining traditional curricular priorities comes into question. The evolution of AI will likely require reassessing which capabilities deserve emphasis, depending on where technology advances most effectively. Three broad scenarios can be envisaged, each with distinct implications for schooling (Elliott, 2023^[112]):

- **Scenario 1. AI progresses more quickly on common capabilities**: In this scenario there may be relatively more need for the basic and professional capabilities developed in formal education. Curricular content may remain largely unchanged, with a focus on enabling more people to attain higher levels of basic and professional capabilities – essentially an upskilling challenge.
- **Scenario 2. AI progresses more quickly on basic capabilities than on professional ones, or vice versa**: In this scenario, the mix between these two types of capabilities in formal education may need to change. If AI increases the need for basic capabilities, the challenge mirrors the first but with less emphasis on professional capabilities. If professional capabilities become more critical, questions arise about how essential “basic” capabilities are to developing professional ones successfully.
- **Scenario 3. AI progresses more quickly on both basic and professional capabilities**: In this third scenario, the duration and approach of formal education may need to be substantially changed. If AI progresses on common capabilities as well, many people could be displaced from work. The third scenario is the most disruptive, calling into question the very purpose of schooling. While the first two involve mostly technical challenges – such as curriculum redesign and improving teaching – the third raises deeper political and philosophical questions about what society expects from schools in such a transformed context.

The discussion in the previous section already pointed to potential shifts in what we count as “basic”: it has been argued that writing, long assumed to be a foundational skill, could begin to be offloaded to AI without necessarily undermining students’ intellectual development and autonomy. Beyond writing, further disruption in other domains appears plausible (OECD, 2023^[113]; 2025^[114]).

Speculating on this possibility, similar dynamics may soon apply to professional capabilities as AI tools improve and diffuse across the economy. For instance, recent evidence shows that AI systems have begun to rival physicians in diagnostic accuracy when working with the same patient data (McDuff et al., 2025^[115]). This development speaks directly to Salomon and colleagues’ earlier caution about delegating complex judgements such as medical diagnosis to “black box” systems, signalling capability overlaps even in fields we might not have expected.

Taken together, these examples foreshadow the third scenario above: if AI advances to the point of mastering both basic and professional capabilities, the very structure of schooling – its core purposes and approach (i.e. institutionalising, front-loading learning) – may need to change. If, in addition, AI masters common capabilities and challenges current social structures linked to employment, then the disruption deepens further.

Even if this third and most disruptive scenario remains distant, considering it is still helpful because it highlights the full scale of transformation potentially at stake. By imagining a future in which AI masters basic, professional and even common capabilities, we are forced to set aside many of the assumptions that currently underpin education — that certain forms of knowledge remain scarce, that humans retain comparative advantage in some domains, or that preparation for employment is a stable anchor for schooling. By stripping these assumptions away, the scenario clarifies how different curricular ideologies might frame education's role if traditional anchors of value were removed. It also offers a point for *backcasting*: by asking what would make schooling meaningful under such conditions, we can work backward to identify which assumptions and priorities may need to shift first (see Box 5.1).

Considering the third scenario from the perspective of academic rationalism, there may always be good reasons to engage with disciplinary knowledge. In line with Young's notion of *powerful knowledge*, this will continue to offer the most reliable means to understand and explain how the world works. Even though AI may surpass humans in applying such knowledge, its study may still be vital for understanding reality through multiple lenses and for contributing to both aesthetic and intellectual fulfilment. Disciplinary knowledge allows people to understand how the natural and social worlds work — including how AI works — and provides society with a shared knowledge base to sustain cohesion and public communication (Hirsch, 2020^[116]). Yet this view also raises questions: How much disciplinary knowledge is necessary, or sufficient, for humans to develop? Is it enough to cultivate habits of engagement with knowledge, such as reading celebrated studies, or should everyone reach a certain threshold of disciplinary understanding? Should that threshold be the same for all? And what are the consequences for those who do not meet it in a world where everyday tasks are supported by high-performing AI systems?

By contrast, in a context of significant AI advancements, learner-centred and social reconstructionist views could drive the curriculum focus away from standardised, hierarchical sequences of increasingly abstract or specialised knowledge. For learner-centred advocates, this might mean emphasising learners' intrinsic motivation, promoting contexts to see students' self-expression flourish and foster the development of social and emotional skills and awe (OECD, 2023^[117]). For social reconstructionism, the curriculum might centre on identity, critical consciousness and social responsibility. As Biesta (2022^[118]) notes, challenges related to social, economic and environmental sustainability are likely to remain constant, even in a future of technology-induced material abundance and expanded leisure (Frase, 2016^[119]). Therefore, the deployment of highly capable AI systems may offer an opportunity to invert the existing emphasis on the *qualification* and *socialisation* functions of education, paying greater attention to existential questions about how we live with ourselves, others and the planet. Schools would still prepare people for work, though not necessarily employment, redefining educational returns in terms of collective rather than purely individual value.

Ultimately, social efficiency views would be most directly challenged, since their current strength derives precisely from preparing individuals for economically valuable tasks and labour-market relevance. If employment itself shrinks significantly, this utilitarian curriculum model would need to be fundamentally reconsidered. The very meaning of 'efficiency' in such models might shift – gravitating toward the values upheld by the other three ideologies –, schooling careers could be shortened or the very need for public schooling more openly questioned.

Box 5.1. Backcasting the science curriculum in an AI future

Highlights from an OECD-NASEM workshop (September 2024)

As part of the *OECD AI and the Future of Skills* project, a pilot workshop was organised in September 2024 with the US National Academies of Sciences, Engineering and Medicine (NASEM). Science education scholars were invited to reflect on how the school science curriculum might need to adapt in a future shaped by advanced AI systems. The exercise assumed a context close to Scenario 3 outlined above: people's interactions with STEM knowledge and applications increasingly mediated by AI alongside substantial changes in STEM labour markets, with many tasks shifting from humans to AI.

In this scenario, participants stressed that the purpose of science education could not be confined to preparing a pipeline of future scientists. Instead, its central role would be to educate citizens able to understand, interpret and critically engage with scientific knowledge in everyday and civic life. Curricular priorities that emerged from the discussion included:

- **Epistemic insight:** helping students understand the nature of scientific knowledge — how it is generated, validated and bounded — and distinguish questions that can be answered scientifically from those that are ethical, religious or value-based.
- **Engagement with broad scientific phenomena:** enabling learners to connect with major paradigms and systems of thought, such as evolution or climate change, that provide foundational frameworks for interpreting the natural and social world.
- **Inquiry as meaning-making:** creating opportunities for students to ask questions such as “how does this work?” and “how do you know?”, fostering curiosity about both immediate and more distant issues.

The discussion underscored the importance of flexibility: while participants noted that schools retain responsibility for introducing all students to socially relevant issues, major scientific paradigms and aspects of the human and natural world that are not immediately familiar, they also stressed that not all learners need to engage with the same scientific content in the same way or to the same depth. Instead, emphasis was placed on cross-cutting concepts and systems as shared foundations for understanding and continued learning, while allowing space for curiosity, motivation and diverse pathways of engagement.

This pilot illustrates how backcasting – starting from a disruptive AI scenario and reasoning backward to identify curricular needs – can help surface hidden assumptions and generate alternative priorities. While this exercise focused on science education in the United States, participants suggested that the approach could extend to other domains and contexts.

Source: (OECD, 2025^[14]), <https://doi.org/10.1787/ca56c7d6-en>.

Looking forward

This paper sought to provide a conceptual framework for examining the curricular implications of highly capable AI, using generative AI's impact on writing to illustrate emerging disruptions. Its objective is not to recommend hasty curricular reforms after each new technological breakthrough, but rather to initiate sustained, critical dialogue about curricular priorities, aims and assumptions.

If the printing press re-organised learning around texts and the calculator around models, a world of widespread AI may ultimately re-organise schooling around something less tangible but more enduring: the

human capacity to interpret, to judge and to choose aims worth pursuing together in the company of machines. Whether that future arrives quickly or slowly, hopefully some of the ideas in this paper can help educators begin to systematically explore how the rapid advancement of AI could reshape their different fields of study. The central argument is not that schools should immediately overhaul their curricula in response to every AI development, but that these developments merit serious consideration because the stakes are simply too high.

Ongoing AI progress raises pressing questions about curriculum priorities and assumptions, and curriculum developers should track information on AI capabilities as attentively as they track student test scores. They should be attentive to changes in the needs of society and learners, and open to the possibility that, as technology develops further, some cherished basics might migrate from “essential for all” to “optional for some”. Rethinking the curriculum in response to AI means questioning deeply held assumptions about what education should accomplish and what kind of society it should help create. And, as AI progresses, even the most dominant, seemingly stable justifications for selecting and organising curriculum knowledge at present could quickly become unstable.

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Annex A. Principles of curricular sequencing

Table A A.1. Principles of sequencing curricular content

Type	Subtype	Definition	Example
World-related sequencing i.e. content structure reflects empirical relationships among events, people, and things.	<i>Space</i>	Ordering based on physical arrangement or position of phenomena (e.g. closest-to-farthest, bottom-to-top, east-to-west).	Teach the parts of a plant from the root, to the stem, to the leaves and flower.
	<i>Time</i>	Sequencing by chronological order from the earliest to the most recent events.	Teach the major ideas of Marx before teaching about the Russian revolution.
	<i>Physical attributes</i>	Ordering based on observable physical characteristics like size and shape.	Teach the hardness scale for minerals from softest to hardest.
Concept-related sequencing i.e. organises knowledge based on how concepts relate logically and structurally to one another.	<i>Class relations</i>	Teaching general classes before specific instances or members of that class or vice versa.	Teach about mammals before teaching about specific animals in that group.
	<i>Propositional relations</i>	Sequences based on relationships between propositions, such as entailment, reduction, contradiction, theory-application, premise-conclusion, theory-evidence, rule-example.	Teach the volume of a gas at several temperatures and pressures before teaching Boyle's Law (evidence-conclusion).
	<i>Sophistication</i>	Ordering by the complexity or abstraction of concepts.	Teach the real numbers before teaching about imaginary numbers.
	<i>Logical prerequisite</i>	A concept must be understood first in order to understand the subsequent concept.	Teach what "velocity" means before teaching that "acceleration" is the change in velocity.
Inquiry-related sequencing i.e. sequence derived from the nature of the processes of generating, discovering or verifying knowledge in a given area of thought.	<i>Logic of inquiry</i>	Sequencing based on the logical methods or norms of adequate inquiry.	Discover ways to light a bulb with a battery, then generalize a rule (induction).
	<i>Empirics of inquiry</i>	Sequencing derived from how successful inquiries are actually carried out or understood empirically.	Teach what other researchers have discovered about reinforcement schedules before teaching pupils to frame hypotheses about optimal reinforcement schedules.
Learning-related sequencing i.e. content sequences draw primarily on knowledge about how people learn, emphasising the alignment of content with psychological research.	<i>Empirical prerequisite</i>	One skill must be learned before another can be successfully learned, based on empirical evidence.	Teach discrimination between initial consonants before teaching word attack skills.
	<i>Familiarity</i>	Starting with content that is most familiar to learners based on their past experiences.	Teach the various occupations in the local community before teaching about careers in other communities and in other nations.
	<i>Difficulty</i>	Sequencing from easier to more difficult content.	Teach the spelling of short words before longer words.
	<i>Interest</i>	Beginning with content that is likely to evoke learners' interest.	Teach pupils how to pick a lock before teaching them how a lock works.
	<i>Development</i>	Sequencing according to the developmental stages of learners, their level of maturation.	Teach pupils to base their concept of morality on authority, then on democratically accepted law, and finally on individual principles of conscience.
	<i>Internalisation</i>	Ordering content to promote increasing internalisation of attitudes or values.	Teach pupils to recognise certain behaviours in others, then in themselves.
Utilisation-related sequencing i.e. content is structured based on how knowledge or skills will be used in personal, social or professional contexts	<i>Procedure</i>	Sequencing based on the steps of a process or procedure.	Teach the effects of air and water pollution (establish a phenomenon as a "problem"), then teach the causes (analyse the problem), and then teach how to eliminate or correct the factors that cause pollution (suggest solutions).
	<i>Anticipated frequency of utilisation</i>	Content is taught based on how frequently the knowledge will be used in the future.	Teach the use of chi-square and correlation coefficients before factor analysis.

Source: Posner and Strike (1976^[120]).

Notes

¹ Michael Young (2013_[122]) describes disciplinary knowledge as "powerful" due to its epistemological robustness. This knowledge is developed through structured, academic inquiry, undergoes rigorous testing, and remains open to scrutiny and revision. Unlike everyday knowledge, it provides frameworks that enable learners to generalise across contexts, think critically and address complex societal issues. It includes knowledge from science and mathematics as well as ethics, social sciences and the humanities.

² Posner and Strike (1976_[120]) provide a comprehensive list of principles for sequencing subject matter (see Annex A), which teachers and other curriculum developers use in combination at different levels of granularity, from whole-programme design to specific units and lessons.