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Fostering children's agency in their learning futures: Exploring the synergy of generative AI and sensory learning

by Natalia I. Kucirkova

Abstract

The discourse surrounding the potential educational transformation brought about by generative AI has largely neglected the sensory aspect of learning. In this position paper, I emphasize the significance of sensory studies and their theoretical foundations of embodiment and multimodality as catalysts for novel perspectives on the intersection of AI and the future of education. I delve into the question of whether generative AI serves as a precursor to a new literacy or merely arises as a consequence of ongoing theoretical advancements in contemporary literacy studies. I argue that the concept of agency, which includes both personal and social aspects, should be central to recognizing the importance of sensory learning as an emerging paradigm in reimagining learning futures.

Contents

Introduction

The advent of generative artificial intelligence (GAI), has been heralded as a ground-breaking approach poised to revolutionize the field of education. Given that GAI significantly impacts the ways information is shared and communicated, it raises the need to develop new literacies specific for GAI technologies (Bozkurt, *et al.*, 2023). In this conceptual paper I ask: which types of novel literacies should be cultivated to ensure the comprehensive development and prosperity of all children now and in the forthcoming AI era?

In contemplating learning futures and technological innovations, Facer (2011) reminded us that 'thinking

about the future is always a case of thinking about it from somewhere and from a particular set of concerns' [1]. My starting point is children's literacies, and my particular concern is the effects of generative AI on the literacy futures for K-12 education. Based on a comprehensive analysis of published research in the past 10 years, Van Mechelen and colleagues (2023) issued a call for a collaborative research agenda for K-12 literacies, driven by a shared scholarly commitment to children's agency. Others have emphasized the importance of placing children's agency as a key variable that manifests in novel ways with the emergence of new literacy types (*e.g.*, see also Lotherington and Jenson, 2011), including advancements in artificial intelligence (Adams, *et al.*, 2023; Kucirkova and Hiniker, 2023).

The groundwork development for new agency-centric literacy types needs to stand on some premisses. The epistemological premise that I follow is the socio-cultural learning tradition. According to this tradition, learning is a dynamic process that occurs within specific socio-cultural contexts, where individuals and educational tools interact and influence one another (Vygotsky, 1993, 1978). I understand learning as a social process that involves the construction of meaning and the generation of practical knowledge, underscoring the interactive nature of learning and emphasizing its collective and contextual dimensions (*e.g.*, Verenikina, 2010; Rojas-Drummond, *et al.*, 2023). With this understanding of the learning process, I delve specifically into the potential of generative AI to stimulate the emergence of new literacies, examining their characteristics and implications for the future of K-12 literacies, and by extension, K-12 learning.

Regarded as a ground-breaking advancement in the field of artificial intelligence, OpenAI introduced Chat GPT in November 2022, resulting in several debates and critiques regarding the role of generative AI in all aspects of life, including education (Sadasivan, *et al.*, 2023). As an educational researcher and professional, it becomes imperative for me to not only acknowledge, contemplate, and devise solutions for these impending realities but also to actively pursue the redesigning of detrimental future trajectories through ontological recalibration. It is the ontological recalibration that I call for in this paper as I contemplate educational futures from the vantage point of sensory learning and children's agency. The sensory nature of learning has been little discussed in the analyses of educational transformation by generative AI. I highlight sensory studies, and their theoretical antecedents of embodiment and multimodality, as a catalyst for new thinking about AI and future of education. I attempt to answer these questions:

> *RQ1*: Is generative AI the antecedent of a new literacy or simply a by-product of theoretical developments happening in contemporary literacy studies?
>
> *RQ2*: What does the current co-existence of generative AI and sensory learning paradigms imply for children's learning futures?

I structure my argument in three parts: first, I contextualise the focus on K-12 literacies in the current discussions of generative AI as a new area of transformative learning. I posit that instead of signalling the decline of learning opportunities, the advent of GAI signals the increased significance of senses in learning. I then go onto explaining what sensory learning is and the theoretical premises it is based on. I argue that the embodiment and multimodality theories foreground the connection between agency and learning, and their importance becomes visible in challenging the trajectory of educational inequalities. In Part II, I trace the shifts in understanding of literacies as multisensory and generative AI as learner-empowered paradigms. I specifically direct my attention to the ways in which the fields of sensory learning and generative AI define and empirically approach learners' agency. Finally, in part III, I propose that a viable alternative to learning futures is sensory, agentic, learning.

The focal point of my thesis is literacy — understood as the process of deriving meaning from texts in reading and writing — due to the fundamental significance literacy carries for children's education. Literacy serves as a gateway to various other subject areas (Cazden, *et al.*, 1996) given that proficiency in reading is crucial for achieving academic success (Snow, 1983). Moreover, literacy, understood as reading

and writing, is not an innate skill; rather, it requires intentional instruction (Wolf, 2007). Therefore, exploring literacy within the context of automatically generated texts with AI provides a compelling example for discussing broader principles of agentic learning acts.

Part I: Generative AI as a force to transform education

In this section, I provide the necessary context for my argument by situating it within ongoing discourse surrounding generative AI as an emerging domain of transformative learning futures. I first offer an expanded definition of generative artificial intelligence to adequately reflect GAI as as a potential area of learning futures.

What is generative AI?

Generative artificial intelligence is a type of machine learning technology that can create novel data based on provided training data as well as acquire the ability to train itself to create new data. By analysing and studying training examples, the GAI model learns the underlying patterns and distribution of the provided training data in order to generate new artifacts (Baidoo-Anu and Owusu Ansah, 2023; Ray, 2023). Advancements in deep learning research have facilitated the creation of various artificial relics based predominantly on video, images/graphics, text and audio data (Grassini, 2023). Generative AI systems typically consist of a discriminator or transformer model that is trained on a corpus or dataset. These models possess the capability to map the input information into a latent high-dimensional space. Complementing this, a generator model is employed, which can generate novel content in each trial, even when provided with the same prompts as input (Gozalo-Brizuela and Garrido-Merchan, 2023). The learning process of these generative AI systems can be categorized as unsupervised, semi-supervised, or supervised, depending on the specific methodology employed (Gozalo-Brizuela and Garrido-Merchan, 2023). Although the development of generative AI models is advancing swiftly, the primary focus lies in enhancing the quality of generated outputs, particularly in terms of the visual modality and textual and image-based outputs (Solaiman, 2023).

Generative AI in education

Following its initial public release on 30 November 2022, ChatGPT swiftly amassed over one million subscribers within a mere week. A specific generative artificial intelligence tool, known as ChatGPT, captivated the imagination of many with its remarkable capability to execute complex educational tasks, including writing coherent essays or producing research papers (Conroy, 2023). Jennifer Carolan, co-founder of the venture capital firm Reach Capital, which has been successfully investing in education technology since 2008, offered a preview of what is yet to come, professing that "the proliferation of AI tutors will end busywork, reporting, hours of grading, and ultimately elevate the human social learning experience to something considered valuable, special and to be protected" (Carolan, 2023).

Scholarly considerations of the potential of generative AI for education have primarily been through a comparative lens of education driven by humans versus education driven by technologies (machines). For example, trade-offs and benefits of using generative AI for traditionally time-consuming written tasks, including problem-solving, coding, creative composing in music or narrative art, have been widely debated, reflecting the nascent nature of the technology and its wide availability through open access (Bozkurt, *et al.*, 2023). Specific criticism by leading educational scholars centre around the distinctive attributes that differentiate human tutors from AI counterparts. For example, Senechal, *et al.* (2023) reiterated the social and emotional aspects of learning that are lacking in AI but are present in empathetic teachers, crucial for early learning. Sharples (2023) highlighted the missing capacity of AI to reflect on its output and consolidate knowledge gained from each conversation. Given that generative AI neglects the affective and experiential dimensions inherent in the learner-teacher dynamic, it represents an inherently indifferent and

unconcerned learning partner, Sharples (2023) argued.

In this analysis, I extend prior deliberations on the distinction between generative AI and holistic learning by emphasizing the sensory processing capabilities of AI systems and humans. Generative AI does not appraise the world through sensory perception (Chat GPT cannot see or smell its surroundings) but the technology relies on data and content that are increasingly combining multimodalities in their outputs. The conceptual problem that I consider is that generative AI promotes education of "higher senses" of vision, hearing and touch at the expense of "lower senses" of olfaction, taste and proprioception, thus neglecting the learning principles of sensory learning.

Sensory learning

Sensory learning, also known as multisensory learning, refers to an understanding of learning that centres the individual contribution, and joint interplay, of all key human senses (vision, hearing, touch, smell, gustation and proprioception). Sensory learning as a discipline was formed in parallel with the sensory turn in social sciences (see Howes, 2022), building upon the idea that our sensory system (known as the sensorium) is centrally implicated in how we perceive and understand the world in collaboration with others (Mills, *et al.*, 2017; Kucirkova, 2024).

This understanding has its antecedents in sensory perceptual learning applied to neurological and consumer research (*e.g.*, Spence, 2019) and socio-cultural and anthropological studies (see Howes, 2003). The studies offer a countermeasure to the conventional language- and vision-centric approaches to human meaning-making and challenge the homogenized concept of "the body" prevalent in contemporary scholarship. Together, sensory approaches propose a relational approach to disrupt the assumption of bodily unity, inherited from modernist ideas of subjectivity, and instead emphasize the diverse development of the senses across different contexts and time periods, thus highlighting the varied forms of human sensory experiences and physical capacities (Bull, *et al.*, 2006).

The literature disagrees on how many senses are central to the study of sensory learning. This is partly because of the overlap between sensory processing when more than two senses get activated (Follman, *et al.*, 2018), and partly because of disciplinary differences in defining a sense (see Calvert, *et al.*, 2004). While the neurobiological research proposes that humans possess a minimum of 10 senses (rather than the traditionally recognized five senses), emerging evidence suggests that there may be as many as 22 senses, and some radical estimates even propose a figure as high as 33 senses (Howes, 2022). In this article, I limit the focus to the widely agreed six senses of vision, hearing, touch, taste, smell and proprioception, positioning each sense as encompassing both the physical sensation and the symbolic meaning of "sense" (Howes, 2023, 2022).

The human sensory apparatus affords comprehension and interpretation of the world through visual, auditory, haptic, gustatory or olfactory stimuli, involving the complex interplay between sensory organ (eyes, ears, skin, nose, tongue and body) and the specific sensory system (*e.g.* visual, auditory system). Proprioception refers to the sensory perception of the body's position, movements and spatial orientation, and is different from the five senses in that it does not rely on one but several sensory organs (receptors in muscles, tendons and joints). Sensory processing varies across brain states (awake, asleep and bouts of oscillatory dynamics, see Olcese, *et al.*, 2018), but the process of organising information from the senses and prioritising this information for reaction is not confined to the brain. The finding that sensory systems and sensory cells get activated throughout the body and involve a bodily perception of sensation across individual sensory systems (visual, auditory, haptic, olfactory, gustatory and proprioceptive), comes from sensory integration studies and clinician observational data (*e.g.*, Myles, 2000; Ayres and Robbins, 2005). In addition, recent neuroscientific and biobehavioural studies suggest the existence of a "body-matrix" (Moseley, *et al.*, 2012), further highlighting the complex relationship between the brain and the body in processing sensory information.

Throughout various times and sociocultural contexts, the relative contribution of human senses has

consistently played a role in education, albeit in different forms. In introducing a special issue on sensory learning, Thyssen and Grosvenor (2019) return to Classen's assertion that the senses are brought into play in the learning process [2], which might seem obvious at first glance, but less so when inspecting the design of contemporary learning resources and environments. While it appears intuitive that learning engages all senses, and not just the visual sense, the learning sciences field is rich with examples of vision-centred practices in mainstream education. Conversely, the role of non-visual senses such as touch or proprioception dominates multisensory learning studies from special educational practice (*e.g.*, van Staden and Purcell, 2016; Campbell and Bergelson, 2022).

This division of higher versus lower senses and mainstream versus special education has been criticised for its scientific inadequacy and propagation of educational inequities, notably by scholars working in the new and critical pedagogy and critical literacy tradition (*e.g.*, Leu, *et al.*, 2004; Burnett, *et al.*, 2014; Kucirkova, 2024). These and other critical literacy scholars stress the relationship between learning and the mind-body connection and between meaning-making and multiple modes and modalities of engagement — conceptual presumptions rooted in the embodiment and multimodality theories, which I review next.

Sensory learning theories

The existing social sciences theoretical groundwork pertains to the multifaceted nature of engagement across different modes of communication (*e.g.*, Kenney, 2016), which can be traced to several theoretical frameworks including affective literacies, materiality, post-humanist and feminist approaches to literacy and others. The reason that I highlight the embodiment and multimodality theories is because of the two theories' preoccupation with multiplicity in social justice, or the importance of all senses in the learning for all children, thus providing the necessary directions for discussing GAI's role in equitable learning futures.

The embodiment theory

The embodiment and embodied cognition theories share the conceptual interest in the functioning of cognition that is influenced by the specific attributes of the physical body and its dynamic interactions with the surrounding environment. Embodied cognition refers to the theoretical perspective that cognition is shaped or influenced by the body itself or its interactions with the surrounding environment (Shapiro, 2019). This perspective challenges the notion that mental processes are solely computational in nature and rejects the idea that the brain serves as the exclusive locus of cognition (Foglia and Wilson, 2013). While not without its critics (see Wilson, 2002, for an overview of literature), embodied cognition has been increasingly applied in educational psychology research (Kirsch and Kunde, 2023) and technology-mediated education (*e.g.*, Hennig-Thurau, *et al.*, 2023).

The embodiment theory is a theoretical cousin with the multiple literacy theory in that it champions the connection between mind and body and an integrated view of perception and action in accessing textual literacy materials. As texts undergo a shift towards multimedia and scholars emphasize the significance of the body in comprehension, the theory of embodied cognition aligns conceptually with multimodality (McVee, *et al.*, 2017).

Multimodality

Over the course of the twentieth century, a paradigm shift that changed the emphasis from material textual properties to the texts' multimodal character is what is now commonly referred to as multimodality. Put simply, multimodality recognizes the diverse ways in which meaning is created and communicated through multiple modes of representation (Jewitt, *et al.*, 2016). Similarly to embodiment, multimodality emphasizes that meaning-making extends beyond language alone, incorporating various modes such as visual elements, nonverbal cues, gestures, sounds and spatial modes (ways of meaning-making) that interact and complement each other, contributing to the overall meaning (Westmoreland, 2022). As such, the embodiment theory resonates with sensory literacies due to its holistic focus, but it differs from it in that it pays attention to the merger of body and cognition rather than the dynamism of the interplay of senses in the merger. The multimodality theory, then, explains how the dynamic sensory interplay happens across

different modes.

Having identified embodiment and multimodality as the characteristics of, and variability within, the paradigmatic orientation of sensory learning, I now move to the primary variable within this paradigmatic orientation — learners' agency.

Learners' agency: What is it and why does it matter?

Embodiment and multimodality encompass interconnected theoretical concepts that present distinct lines of argumentation for the benefits of agency in sensory learning. Agency is a conglomeration of various attributes, including self-efficacy and control in psychology studies, and children's active participation in learning in social sciences (Brod, *et al.*, 2023). Agency studies are related to, but different from developmental studies of children's personhood, autonomy or identity, in that they do not focus on the conscious experience of perceiving one's self as an autonomous being but on children's ability to determine their own life, take control and volitionally make decisions (Brod, *et al.*, 2023). While agency is a fundamental human right, children across the world do not have equal opportunities in exercising their agency (Invernizzi and Williams, 2016). Therefore, understanding how children's choices are being shaped with diverse resources in varied learning environments, corresponds to pedagogical practices that highlight equality in the adult-child dialogue as the core of educational dignity (Vossoughi, *et al.*, 2021).

The embodiment and multimodality theories underscore the link between agency and learning and this link becomes evident when confronting and addressing educational inequalities.

Theorising agency in light of educational inequalities

The multidimensional aspects of sensory learning theories bring to light the current constraints of generative AI as a comprehensive model for learning. In the AI field, reliance is placed on a few selected modalities (mostly the visual and auditory modalities) to facilitate learning. In contrast, the sensory learning field incorporates multiple modalities to enhance the learning experience. This difference in the level of sensory engagement between human and artificial learning is not a rhetorical question but one that carries significant ethical implications, particularly in relation to inclusivity and equity of learning. Consider this: the educational landscape has long been dominated by the privilege of the sighted (Howes, 2022). Sensory learning was proposed to re-evaluate this focus, and considerable scholarly effort has been made to develop a sensory-oriented framework for comprehending the interplay between the body and the mind in children's literacy practices (Mills, 2016).

Furthermore, the emergence and rapid proliferation of AI prompted scholars' genuine concern for humanity by highlighting that the mere interaction with another human being necessitates the engagement of multiple senses in an intricate process of meaning-making (Leaton-Gray and Kucirkova, 2021). Collectively, sensory learning scholars have been advocating for moving away from ocular-centric interpretations of multimodality in textual practices, thus providing a more comprehensive understanding of the complete sensorium implicated in all children's learning. Yet, this sensory call is little heeded by current applications of generative AI in children's technologies.

GAI was introduced as a tool aimed at optimizing human activities, particularly within the context of streamlining workforce operations and aligning with neoliberal economic models (Bourne, 2019). This technology was positioned as a means to enhance efficiency and cost savings in the healthcare sector and accelerated learning outcomes, and was criticised by experts for potentially undermining democratic

systems and further concentration of global wealth and power in the hands of a few (Anderson and Rainie, 2023). In contrast, sensory learning paradigm emerged with a focus on addressing the needs of marginalized and disadvantaged individuals (Kucirkova, 2024). By prioritizing equitable access and opportunities, technological applications of sensory learning relate to tools designed for children with different abilities, such as for example story maps for children with impaired vision (Cullen and Metatla, 2019) or communication applications for children with hearing problems (Seita, *et al.*, 2022).

These insights reveal that unlike SL, GAI started with a trajectory that perpetuates an unequal distribution of resources and opportunities, thereby exacerbating societal disparities. As Trucano (2023) noted, access to AI represents a third digital divide in education where 'the rich have access to both technology and people to help them use it, while the poor have access to technology only'. Put crudely, the possible future learning paradigm pushed by GAI perpetuates the socio-educational disparities from the past under the veil of technological innovation.

What if we were to critically question the existing trajectory of AI and adopt an alternative approach rooted in the equity principles of sensory learning? A consideration of this possibility requires a historical survey of the fundamental paradigm shifts within SL and GAI. This inquiry forms the focus of the subsequent section, in which I provide a concise exploration of the evolution of sensory learning and artificial intelligence, along with an examination of paradigmatic shifts that have transpired within both domains throughout their relatively brief histories.

Part II: The paradigmatic shifts in SL and GAI

As central sensory learning theories, the embodiment and multimodality theories represent a shift in perspective, moving beyond a sole focus on cognitive, grammatical or social aspects of literacy practices to encompass the material interactions with physical technologies that are influenced by the body in distinct ways. Mills (2016) introduced the focus on senses alongside the social, critical, multimodal, spatial and material frameworks for studying children's meaning-making. Focusing on the contribution of specific senses and mapping reading as an embodied phenomenon, Mangen and Velay (2010) emphasized the haptic sense. Gallagher, *et al.* (2018) foregrounded the role of sound and the auditory sense and Kucirkova and Tosun (2023) the olfactory sense in learning. These, and other scholars, highlight the key role of senses in social sciences, and connect to what David Howes (2022) proposed as a *revolution* in understanding the ways people across historic periods and cultures *sense* the world (emphasis by the author).

While communication and meaning-making have always been multimodal, the conceptual understanding of them being such, has evolved over time. Specifically in the area of K-12 literacies, the field can be considered to have undergone three significant paradigmatic shifts in the twentieth century. Whether one conceptualises the shifts in terms of the substrate, or reading medium (*e.g.* print books, digital books), or in terms of modes (*e.g.*, visual, audio), one can see that the literacy evolution has witnessed three pivotal shifts: the print turn, the digital turn, and presently, the multisensory turn. These transitions have been characterized by advancements in scholarly understanding of the value of multimodal and multimedia communication (Jewitt, 2008), but also by advancements in technological developments of reading materials, facilitating engagement with multiple senses.

By building upon one another, these conceptual transformations allow for a comprehensive understanding of the sensory focus in contemporary studies of K-12 literacies and their shifting multimodal forms and spatial representations, which are divergent, open and fluid (Pool, *et al.*, 2023). The move to 4D representations of reality, which selectively and strategically engage all senses, is what lies at the core of current prognoses for innovative pedagogies in forthcoming literacies (Kukulska-Hulme, *et al.*, 2023). Figure 1 presents a simplified representation of the conceptual paradigm shifts, illustrating that the present era is defined by an academic understanding of literacy as a multisensory endeavour.

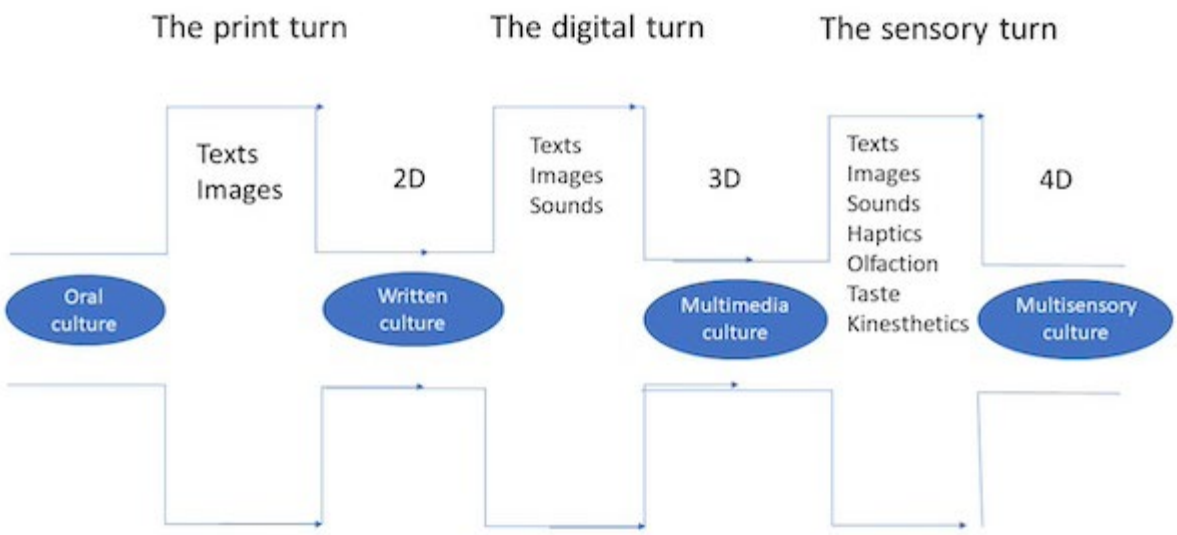

Figure 1: Conceptual paradigm shifts in academic understanding of literacy as a multisensory endeavour.

In contrast, the evolution of thought in the field of AI has progressed along very different conceptual lines, as explained next.

The paradigmatic shifts in the field of generative AI

According to Ouyang, *et al.* (2022), the field of AI has undergone three significant field shifts in its relatively brief history. The initial generation of AI in education adhered to a directive model, whereby the learner was perceived as a passive recipient, aligning with behaviourist theories of learning influenced by Skinner (1953, cited in Ouyang, *et al.*, 2022). The subsequent shift embraced AI as a support system, placing the learner at the centre and drawing inspiration from social constructivist perspectives, encouraging active collaboration among students. The third and current shift revolves around AI-empowered learning, where learners are positioned as leaders, with AI serving as an agent to enhance their dynamic learning experiences. This transition aligns with adaptive learning theories and with the contemporary human-centred AI field and the models of human-AI collaboration observed in generative AI technologies.

Figure 2 represents the conceptual shifts and maps them on the key modalities targeted by AI technologies.

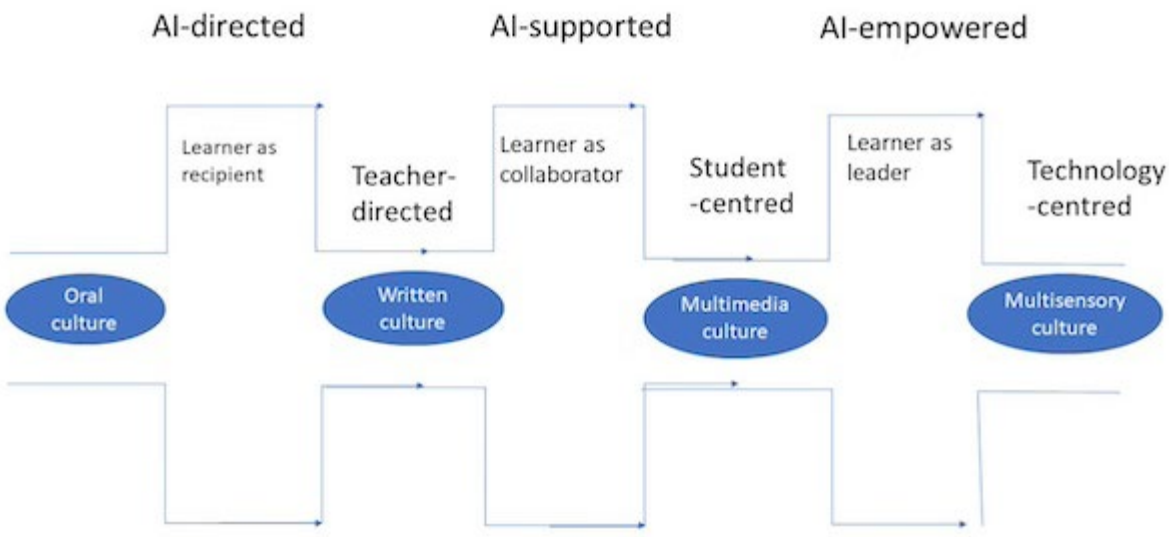

Figure 2: Conceptual paradigm shifts in academic understanding of AI as a leaner-empowering endeavour.

What can we learn from the conceptual shifts in the study and comprehension of literacies and AI? By studying the three paradigmatic shifts in both fields, it becomes evident that in the most recent area of inquiry, there exists a convergence between AI-empowered models and multi-sensory learning models. The two figures illustrate that the current era is conceptually defined by the sensory turn that propagates a multisensory culture characterised by an AI-empowered, technologically-centred 4D representation of reality. It is tempting to deduce that we are on the cusp of an emerging synergistic relationship as AI becomes increasingly multi-sensory and sensory learning becomes more empowered by AI. However, this assumption would primarily pertain to the technological aspects and the exploration of AI's capabilities, rather than the essential conceptual shifts required for contemplating new learning paradigms.

I posit that the extrapolation of potential future implications requires an outlook on education and learning around equipping individuals and collectives to effectively navigate the complexities of modern global society. Undoubtedly, no individual possesses a definitive foresight. However, one can employ a structured framework to compare the educational domains of generative AI and sensory literacies, thereby elucidating prospective trajectories for learning futures. The emerging new approach in sensory and AI fields signifies a paradigm shift, which can be potentially accelerated by technological innovations. For this to happen, the GAI field needs to place emphasis on the in-depth understanding of learner agency within the theoretical paradigms of new literacies. In the last section, I elaborate the argument that GAI's models need to be expanded through a more nuanced understanding of learners' agency if they are to align with the benefits derived from agency in sensory learning studies.

Part III: Learner agency

Given the shift towards AI-empowered applications, it comes as no surprise that Ouyang, *et al.* (2022)

anticipate changes in students' agency, and develop models to support learners to assume active collaboration with AI systems to strive towards learning objectives (see also Kim, *et al.*, 2022). However, unlike SL, the current GAI learning models position agency as an inherent attribute possessed by every learner, and define the role of both human and artificial tutors as to solely "empower" learner agency. Yet, agency is not equally available to all learners and optimal learning resides in calibrating agency (*i.e.*, reducing agency in some and increasing in other areas). It is precisely this nuanced understanding of agency that emerged from sensory learning studies.

Neurological research suggests that learning platforms that capitalise on multi-sensory input *and* children's self-produced actions facilitate learning because they allow the visual and motor systems to interact and form important links for learning (James and Bose, 2011). In the empirical studies, it was not children's watching or passively perceiving multisensory actions (*e.g.*, watching a teacher read to them) but children's direct and active participation that increased their memory for the letters and learning them (*e.g.*, the child tracing the letter shapes with their finger in the sand). Children's direct and active participation is necessary for cognitive processes involved in GAI, such as information processing, knowledge acquisition and problem-solving (Rupp and Mislevy, 2007; Minn, 2022), but also in non-cognitive aspects of learning, such as physical manipulation of objects and technologies (Plowman and Stephen, 2003; Wohlwend, 2013). Sensory studies, especially those conducted within the multimodal paradigm, underscore the importance of material objects, including scientific apparatus, tools, instruments and samples, in exerting and validating learner agency, as well as in exploring its limits (Esratd and Gillen, 2019).

The sensory learning model of agency is a dynamic model that corresponds to the multiplicity of engagement facilitated with multimedia and to the constraints of information processing, in proportion with the complexity of the task at hand. The dynamic agency model originated from experimental studies that showed that excessive agency opportunities can lead to environments that overwhelm the learner, rendering sensory learning counterproductive, as the cognitive load of children becomes overburdened (see Paas and Sweller, 2012, for an overview). Consequently, rather than facilitating increased learning outcomes, the excessive cognitive load may result in diminished learning efficacy (Zierul, *et al.*, 2019). Based on an interdisciplinary review, Brod, *et al.* (2023) therefore proposed a model where learner agency is optimised according to the child's dispositions, the context of learning and content of the activity, thus responding to the dynamic and multidimensional nature of learning.

Collectively, sensory learning studies suggest a more nuanced understanding of agency than that which is apparent in GAI literature. More specifically, and in addition to underscoring the dynamic nature of agency, sensory learning studies explicate that agency is not a singular concept but comprises both individual and collective sides. Kucirkova (2021) defined the individual side of agency as "self-determination" and the collective side as "social belonging", arguing that both sides can be practised and developed through educational activities: the individual side of agency is fostered through learning resources and environments that are responsive and adaptable to the multifaceted nature of learning, while the collective side of agency connects to the focus on our collective humanity and the responsibility that we bear for our shared planetary existence (Kucirkova, 2024, 2021).

The promotion of the collective aspect of learners' agency becomes evident in sensory projects widely employed in biodiversity and sustainability initiatives. For example, "SENSE", Sensory Explorations of Nature in School Environments, which is a Learning through Landscapes partnership run by a consortium of British universities or the research-based sensory learning project with educational implementation strategies "Sensory Orchestration" (https://www.sensestogether.com/) at Australian Catholic University, Australia and "Senses-based Learning" (https://sensesbasedlearning.org/) at the University of Maastricht in the Netherlands. The inclusive approach in the three example projects recognizes the importance of providing equal educational opportunities to all children, positioning children as active citizens (thus nurturing the individual side of agency), as well as the importance of caring for the environment and others (thus nurturing the social side of agency, see Mills and Unsworth, 2017; Taylor and Leung, 2020). Extending this logic, I propose that the notion of agency, encompassing both individual and social dimensions, needs to be at the core of the epistemic authority attributed to sensory learning as an emerging

paradigm in educational futures.

A new research paradigm: Sensory agentic literacies with AI

In-between denial and enthusiastic adoption of GAI for K-12 literacies is space for reflective undertaking that allows us to contemplate what GAI might represent for learning futures. Although current applications of AI are disembodied, it is likely that they become more multi-sensorial in the future, adding more extensions of senses via diverse media and new modalities. AI is already deployed on audio, visual and motion data (Bisig and Wegner, 2022), and used to create new fragrance and odour formulas (Marr, 2021). Recently, there has been a notable surge in fascination surrounding artworks and installations that prominently emphasize the sensory experiences of the human body (Spence, 2022). Combined with the trends around AR, VR and immersive technologies approximating metaverse (a shared virtual space where people can interact with one another in a fully embodied manner), it is plausible to anticipate the emergence of large language models trained on multisensory data.

Without a doubt, the adoption of more modalities by GAI will increase children's capability of mediated sensory experiences, but multisensory GAI will also raise concerns around its influence on children's agency. The key risk is that GAI engenders a future characterized by profound inequality wherein favourable learning outcomes are exclusive to a privileged minority, while sustainable futures remain unattainable for all. The goal of a new learning paradigm must be to confront this risk but also to generate new understandings.

As educationalists strive to attain a comprehensive treatise of the forthcoming predicaments, they need to be mindful of both the ramifications of technological advancements for individual agency as well as for our collective agency in enacting transformation on a global scale. The ultimate test for an optimal individual-collective agency is its power in addressing a wide range of issues such as climate change, population expansion, escalating poverty, persistent colonialism and educational inequities. I propose that a new learning paradigm that emphasizes the dynamic interplay between agency and sensory experiences, may open new dimensions within GAI, offering insights into the sensory choices children make as they navigate their shared reality in interactions with both human and generative AI entities.

To conclude, I contend that to advance the ambitious agenda of revolutionizing education with AI requires a deep understanding of agency along sensorial lines. In a divided world that is threatened with socio-economic inequalities and biodiversity loss, there is a need for a learning futures vision that allows educators to rethink and meaningfully reorganise the ways in which we support an optimal balance between children's individual and collective sides of agency. I submit that a new model of K-12 literacies, one that fuses sensory learning, generative AI and agency, could evolve as an effective new learning paradigm. FM

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Notes

1. Facer, 2011, p. 8.

2. Classen, 1999, p. 274.

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