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Mindsets, Cultures, and Technologies: Supporting End-User Development in the AI Era

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List of Figures

List of Tables

Abstract:
The rapid diffusion of AI exemplified by Large Language Models (LLMs) has intensified long-standing tensions between automation-centric approaches and visions of human-centred empowerment. This paper argues that End-User Development (EUD) is no longer an optional enhancement, but a socio-technical necessity for coping with *wicked problems*. To address this challenge, the paper integrates *four complementary socio-technical frameworks* into a unified conceptual foundation for EUD in the AI era. Building on this synthesis, we introduce the *Mindsets-Cultures-Technologies (MCT)* model, which explains EUD outcomes as a function of alignment across these three dimensions. This model provides a principled account of why identical AI systems can either empower users or reinforce dependency. Using this integrative lens, the paper critically analyses both the opportunities and risks posed by LLMs for EUD. While LLMs can lower barriers to participation and support learning-on-demand, their unreflective use risks reinforcing consumer mindsets, reducing productive struggle, obscuring design trade-offs, and fostering overreliance on technology. We argue that these risks stem less from LLM capabilities than from how they are embedded in socio-technical environments. The paper concludes with a set of *design principles for AI-augmented EUD*, positioning EUD and the MCT model as foundational requirements for coping with wicked problems.

Keywords:

- End-user development (EUD); wicked problems; mindsets, cultures, and technologies (MCT)
- large language models (LLMs)
- AI era

Footnote:

This journal paper is a *substantially expanded* version of a conference paper [Fischer, 2025]. The extensions are specially focused on analyzing and exploring how EUD in the AI era exposes the need to make explicit how different frameworks interact and what conditions are required for them to be effective in practice.

1 Introduction

The overwhelming interest and broadly discussed attention in AI (particularly in large language models (LLMs)) has intensified long-standing debates about the relationship between humans and computational systems [Fischer, 2023]. Much of the current discourse frames this development in terms of increasing automation, efficiency, and autonomy, often suggesting that powerful AI systems can replace substantial aspects of human judgment, learning, and design. While such narratives highlight impressive technical capabilities, they risk obscuring a more fundamental question: *how can AI systems be designed to support and empower humans in complex, evolving problem situations rather than replacing them?*

This question becomes especially pressing when AI is applied to wicked problems (Section 2). In the context of these problems, End-User Development (EUD) (Section 3) treats systems not as finished products but conceptualizes them as evolving environments whose ongoing development is distributed among designers, users, and communities over time. In the presence of increasingly powerful AI systems, EUD becomes even more critical: without it, AI risks reinforcing fixed problem framings, reducing transparency, and undermining human responsibility.

The paper is a reflective synthesis drawing on 30 years of research in [Fischer, 2021], analyzed through the lens of wicked problems and socio-technical system design. It builds on four long-standing research frameworks that have guided work on EUD and socio-technical systems: *Lifelong Learning, Meta-Design, Intelligence Augmentation, and Cultures of Participation.*

To address this requirement, the paper introduces and elaborates an *integrative conceptual model of Mindsets, Cultures, and Technologies (MCT).* The central claim is that EUD succeeds or fails not primarily because of technical capabilities, but because of the alignment—or misalignment—among users' mindsets, social and organizational cultures, and the technologies they use.

The subsequent sections analyze how EUD is transformed in the AI era, with particular attention to LLMs. The paper critically examines how to avoid the *discontinuity* between passive system use and active system modifications, identifies potential blind spots of the EUD approach, derives design principles for AI-augmented EUD, and discusses future directions. It concludes by arguing that the central challenge for EUD in the AI era is not to make systems more autonomous, but to design socio-technical environments in which *human agency, learning, and participation remain central* despite rapidly advancing AI capabilities.

2 Wicked Problems

"Knowledge does not start from perceptions or observations or the collection of data or facts, but it starts, rather, from problems." — Karl R. Popper

Major problems societies are facing today include [United-Nations, 2024]:

- P-1: problems being *wicked, poorly understood,* and *ill-defined* that cannot be delegated and require the involvement of the owners of problems in cycles of improvement and refinement over time [Rittel & Webber, 1984];
- P-2: problems modeling *changing and unique worlds* being dependent on open, living information repositories and tools [Benkler, 2006];
- P-3: problems of a *magnitude* that individuals cannot solve [Sloman & Fernbach, 2017];
- P-4: problems of a *systemic nature* requiring the collaboration of many different minds from a variety of backgrounds [Brown & Duguid, 2000].

Taken together, these properties explain why wicked problems cannot be delegated to automation and why EUD is unavoidable.

Coping with wicked problems requires more than powerful technologies; it demands the co-evolution of (1) *mindsets* that embrace learning, (2) *cultures* that legitimize participation and disagreement, and (3) *technologies* that cope and support change. Wicked problems provide the fundamental rationale for EUD in the AI era because they cannot be solved *for* people, but only addressed *with* people and communities who are empowered to shape both the problems and the tools used to engage with them.

Urban Planning: a case study. *Urban Planning* [Arias, 1996] can serve as a case study (see Section 7) as it exhibits all the defining properties of a wicked problem [Rittel & Webber, 1984]. Planning challenges are *ill-defined*, with no single agreed-upon formulation: issues such as mobility, housing, sustainability, affordability, and equity are understood differently by different stakeholders. Because these stakeholders hold *conflicting values and priorities*, planning problems cannot be solved through technical optimization alone, but must be continuously negotiated. Interventions in urban systems have *cascading and unpredictable consequences***,** meaning that every proposed solution generates new problems and shifts the problem space itself.

These characteristics make urban planning a prototypical wicked problem requiring participatory, evolvable, and socio-technical environments such as the *"Envisionment and Discovery Collaboratory (EDC)"* [Arias et al., 2016] (see Figure 2).

3 End-User Development (EUD)

End-User Development (EUD) [Lieberman et al., 2006] refers to the ability of users—who are not professional system developers—to adapt, extend, and evolve computational systems to fit their own goals, contexts, and practices. Rather than treating systems as finished products, EUD conceptualizes them as open, evolving artifacts whose ongoing development is distributed across designers, users, and communities over time.

Given the properties of wicked problems (as outlined in the previous section), the necessity of EUD is not a normative preference but a structural requirement). While foundation models can generate competent outputs across many domains, they cannot anticipate local meanings, values, and contingencies. EUD enables users to remain active agents by shaping AI behavior through configuration, workflow composition, domain-specific knowledge integration, and reinterpretation of system outputs (Table 1).

Table 1: Wicked problems are defined by properties that make EUD unavoidable

Characteristic of Wicked Problems	Consequence	Why EUD is necessary
No stable problem definition	Requirements change	Systems must be modifiable in use
No final solution	Continuous redesign	Users must be designers
Conflicting values	Negotiation, not optimization	Owner of problems must shape behavior
High context dependence	Local knowledge dominates	Centralized designs fail
expertise comes from a variety of backgrounds	Symmetry of ignorance	All stakeholders must be able to contribute knowledge

4 Four Frameworks Enabling and Supporting EUD

Our research characterizes and explores EUD not as a standalone technical feature but as an integrative socio-technical capability that emerges at the intersection of lifelong learning, meta-design, intelligence augmentation, and cultures of participation [Fischer, 2021]. Each of these frameworks addresses a necessary but insufficient condition for EUD; taken together, they explain why EUD is indispensable for addressing wicked problems with socio-technical environments (see Figure 1).

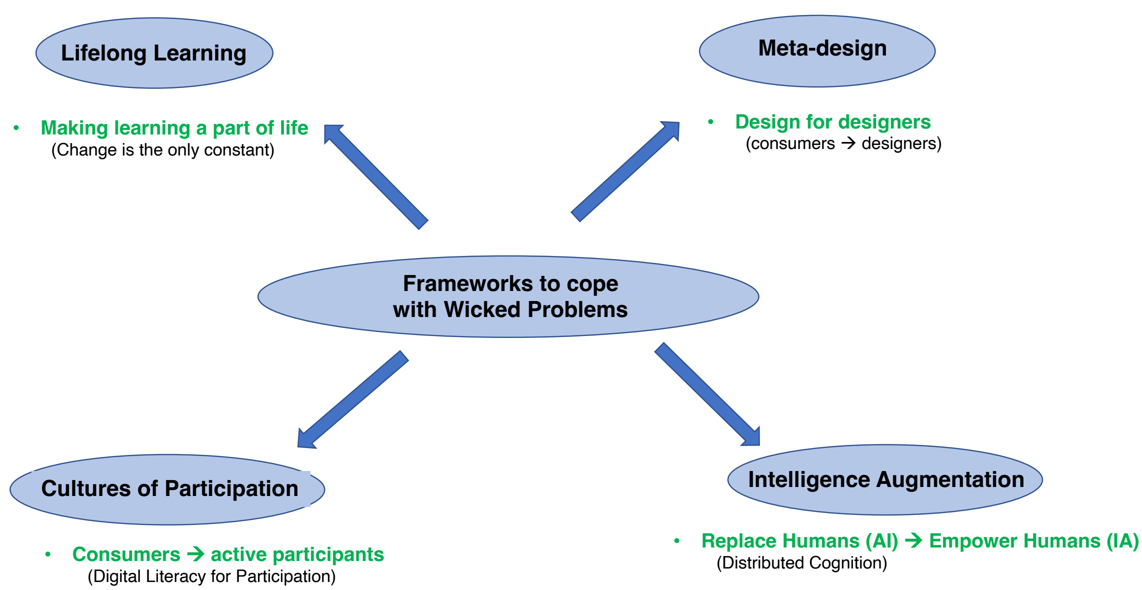

Figure 1: Research Themes and Frameworks to Cope with Wicked Problems

Description: The figure shows how four *complementary socio-technical frameworks* contribute to our framework.

From a *lifelong learning perspective* [Harvard-Business-Review, 2021] EUD operationalizes learning as an ongoing, situated activity rather than a preparatory phase preceding system use. Because users cannot anticipate all future requirements, EUD enables learning-in-use by allowing systems to be incrementally adapted in response to breakdowns, emerging goals, and changing contexts. Without such support, systems presuppose stable knowledge and fixed competencies, an assumption that is incompatible with real-world practice and especially problematic in the presence of wicked problems.

Meta-design [Fischer, 2021; Illich, 1973] provides the structural foundation for EUD by shifting the focus from designing complete systems to designing open systems that can be evolved by their users. Traditional *professional software* development is based on a developer-centric model where users are passive recipients of pre-designed solutions. This *model only works* (1) when problems and tasks are well-specified, (2) when goals are static, and (3) when environments are predictable — wicked problems violate all of these three requirements.

Meta-design complements and transcends professional design and participatory design [Ehn, 2008] by extending design time indefinitely. Meta-designers (being part of a design team at design time) can create contexts and design tools, and users (e.g., domain experts, engaged citizens) can act as co-creators, ensuring that the solutions are tailored to the specific situated needs and considerations [von Hippel, 2005]. The defining criteria of meta-design that support EUD and shift societal challenges from consumption-based productivity to participation and agency can be summarized as follows [Fischer et al., 2017; Susskind, 2020]: (1) creating a framework for change, (2) empowering end-users as co-designers, and (3) supporting sustainability and adaptability.

Intelligence augmentation [Engelbart, 1995; Fischer, 2023; Shneiderman, 2022] situates EUD within a theory of distributed cognition and human centered design. EUD enables users to shape the external representations, computational artifacts, and interaction mechanisms that in turn shape their reasoning and decision making. By supporting reflective interaction and incremental redesign, EUD ensures that intelligent systems augment rather than replace human judgment. Without this perspective, EUD risks degenerating into mere end-user programming, increasing cognitive burden rather than providing cognitive leverage.

Cultures of participation [Benkler, 2006; Fischer, 2011] provide the social infrastructures for collective action that makes EUD sustainable beyond individual use. Because knowledge and expertise are inherently distributed, EUD must be supported at the community level through mechanisms that make contributions visible, reusable, and open to critique. Cultures of participation transform isolated local adaptations into shared resources, enabling systems to evolve through collective intelligence rather than centralized control. Absent such cultures, EUD remains fragile, unscalable, and prone to abandonment.

5 MCT: An Integrative Conceptual Model

Our core assumption is that the integrative conceptual model *"Mindsets, Cultures, and Technologies (MCT)"* does not compete with or replace the four frameworks; rather, it provides an *explicit integrative lens* that clarifies *where* and *how* these frameworks exert leverage and *why* EUD succeeds or fails in practice.

The four frameworks articulate our current understanding of EUD; the MCT model provides the *integrative mechanism* and *conceptual glue* that binds Lifelong Learning, Meta-Design, Intelligence Augmentation, and Cultures of Participation into an actionable and future model for EUD in the AI age. Table 2 describes the mapping between the four frameworks and the MCT model. The third column provides forward pointers to the cases described later in the paper.

Table 2: Mapping the Four Frameworks onto Mindsets, Cultures, and Technologies

Four Frameworks	**MCT Mindsets, Cultures, and Technologies**	**Illustrations with Cases**
Lifelong Learning	*Mindsets:* shift from "learning is preparation" to "learning is integral to use" *Cultures:* legitimize learning during work and support exploratory tinkering *Technologies:* support learning on demand	Student-1 and Student-2
Meta-Design	Mindset: Shift from consumer to active contributors Cultures: adaptation and reinterpretation rather than rigid compliance. *Technologies:* open architectures, tailorable representations,	Sim-City → EDC
Intelligence Augmentation	*Mindsets:* embrace distributed cognition *Cultures:* automation-centric cultures undermine EUD *Technologies:* control and co-construction	Geo-Scientist
Cultures of Participation	*Mindsets:* cultivate identities as contributors, learners, and co-designers. *Cultures:* shared ownership *Technologies:* lower thresholds for contributions	Sim-City → EDC

6 Mindsets for End-User Development

A *mindset* [Dweck, 2007] in the context of this paper is the collection of beliefs, attitudes, and assumptions we hold about ourselves and the world. Mindsets are responsible for how we are framing wicked problems, how we interpret situations, and determine our subsequent actions and reactions. Mindsets are not only taught, but the tools we use (e.g.: SimCity versus the EDC; see Table 3) create and support the development of mindsets. _

To illustrate, identify, and classify mindsets with examples, we provide empirical data by contrasting two fundamentally different responses from students evaluating a course that we taught for advanced undergraduate and graduate students at our university. The design and the objectives of the course were framed by the following ideas [dePaula et al., 2001; Fischer et al., 2020]:

(1) the teacher should serve as a "guide on the side" and not as "sage on the stage";
(2) the teacher provides a seed for the course that should be enriched by the interests and participation of the students;
(3) the students should have opportunities to engage in interest-driven and active learning;
(4) the course was based on objectives derived from the "flipped classroom" model using in-person class time for increased engagement and flexibility.

This approach is analogous to the EUD approach supported by meta-design (see Figure 3) with the students being active contributors and co-designers.
The students' assessments for this course resulted in a bipolar distribution indicating fundamentally different mindsets among students: students were either enthusiastically positive (rating it with A's on the faculty course questionnaire), or totally negative (rating it with F's).

The following two responses are representative examples showing the different reactions. The two students exhibit *fundamentally different mindsets* toward learning: one driven by a preference for structure, control, and external guidance, and the other by curiosity, autonomy, and growth.

Comment by Student-1: Indication of a passive, consumer-oriented mindset (from [Fischer, 2025])

Student-1 Response
"I will not ever take a course of this nature again in my undergraduate career, and I hope to find a more structured graduate program with an adviser that is more forthcoming. I will reinforce my strengths by continuing to study in the method

that I have developed over the past 15 years, I will redirect my weaknesses by avoiding unstructured class environments. I believe that the type of self-directed learning that this class wished to promote is better done during independent studies and thesis work.”

This response exemplifies a passive, consumer-oriented mindset in which learners expect knowledge to be delivered rather than co-constructed. It highlights how deeply established habits of formal education can impede the development of agency, curiosity, and reflective practice—precisely the dispositions required for EUD, for navigating wicked problems, and for engaging productively with AI-augmented design environments.

A fundamentally different mindset is documented by another student’s reaction to the same course.

Comment by Student-2: Indication of an EUD Compatible Mindset (from [Fischer, 2025])

Student-2 Response
“*When I signed up for this class, I had no idea what it was going to be about. Once I started understanding the material, however, I was extremely thrilled and interested to be a part of one of the most progressive courses on campus. I'm not sure what specifically to say except that I rank this class in the top three that I've taken at CU Boulder. The self-directed nature of the work ensured that I wouldn't be bored or unchallenged, and the interplay between all of us was a lot of fun. After four and a half years in college, I can honestly say that this is one of the first courses where I was treated as an adult, a fact which means more to me than I can describe.”*

In contrast to consumer-oriented learning expectations of Student-1, this student embraced the open-ended structure and reported that the self-directed nature of the work was both motivating and intellectually challenging. He described the course as "one of the most progressive on campus" and valued the "interplay between all of us," emphasizing collaboration, agency, and responsibility. Most notably, he reflected that this was "one of the first courses where I was treated as an adult," underscoring the role of trust, autonomy, and shared ownership in enabling learners to transition from passive recipients of instruction to active participants and co-designers of their learning environment. This case provides strong empirical evidence for the argument that EUD requires not only appropriate tools but also the cultivation of mindsets and cultures that support agency, participation, and co-evolution—qualities that will be even more essential in AI-supported design environments.

The lessons learned from these data points provided the foundations for developments to avoid the "Big Switch", which are elaborated in Section 10,2 describing our objectives, how LLM-enriched models can support the transition of consumer mindsets to EUD mindsets.

7 Cultures for End-User Development

A fundamental challenge for cultures supporting EUD is to conceptualize, create, and evolve socio-technical environments that not only enable and support users' participation but also successfully encourage it [Benkler, 2006; Jenkins, 2006]. Participation is determined by numerous factors, including engaging in personally meaningful problems, problem framing, control, motivation, and reward structures. We will use another specific example to illustrate the objective of our paper.

Case Study: Transcending the Limitations of SimCity. The focus of this research project was based on our assessment of SimCity (http://www.simcity.com) by exploring the question: "why were these systems not used in urban planning?" The primary reason that we found in discussions with urban planners (see Section 2) was that planning addresses *open-ended problems* in real-world contexts and that SimCity represented a *closed system*: it did not allow the introduction of elements into the simulation that were not part of SimCity's designers' conception of the problem and made such systems difficult to use in wicked design settings [Rittel & Webber, 1984]

To address the shortcomings of SimCity, we engaged in the long-term development of the *Envisionment and Discovery Collaboratory (EDC*), a socio-technical system that explores EUD frameworks for social creativity and democratizes design in the context of framing and resolving complex urban planning problems [Arias et al., 2016]. Figure 2 shows how stakeholders engage with the EDC System in an urban planning task.

Figure 2: The Envisionment and Discovery Collaboratory (EDC)

Description: The figure shows a tabletop computing environment. The table display presents a detailed view of an urban area (and represents the "action" space). The two upright displays in the program represent the "reflection space" in which context-relevant information related to the actions is displayed.

Table 3 summarizes the finding and lessons learned supporting the objectives pursued with our research to support EUD in the context of wicked problems (with column 4 mentioning themes and challenges for "EUD in the AI Age" that are further explored in later sections).

Table 3: SimCity versus. EDC for Urban Planning

Dimension	SimCity	EDC	AI-Augmented EUD
Design Orientation	closed, simulation platform	open, participatory meta-design environment	serve as a sparring partner for scenario generation
Problem Framing	predefined by the game designers	emergent, co-constructed, collective evolution	exploration of alternative framings
Transparency	assumptions about possibilities and actions are fixed ("blackbox")	inspectable models modifiable by all users	infer the source for arguments
Collaboration	minimal; mostly single player	central (e.g.: supported with boundary objects)	support for negotiation among different viewpoints
Agency	users learn and interact with the system model created by the designers	users construct situation models based on their own interests	suffer from the risk to make interactions more passive

Learning opportunities	engage with existing systems by learning existing rules	critiquing approaches exploit mistakes are learning opportunities	being exposed to alternative ideas
EUD support	minimal	core design objective for the system	user control is essential to avoid automation induced passivity

8 Technologies for End-User Development

This article is grounded in the basic assumption that technologies are necessary but not sufficient for supporting EUD in the context of wicked problems. As described in the previous section, the EDC integrates innovative technological developments including tabletop computing environments, sketching support, GIS systems, Google Earth, and visualization software [Arias et al., 2016]. AI's influence on creativity and critical thinking is not predetermined by technological capability but emerges from the alignment between mindsets, cultures, and technologies (as further explored in Section 11.2).

The example in Table 4 documents an interview with a geo-scientist. His mindset aligns with that of interdisciplinary professionals who prioritize utility over mastery and view tools as a means to achieve domain-specific goals. He sees himself primarily as a scientist, with software development as a supplementary skillset that enhances his research. His focus on autonomy, problem-solving, and scientific rigor (exhibiting a similar mindset as Student-2) empowers him in addressing immediate challenges but may limit his ability to collaborate with domain experts in software development.

The geo-scientist's experience exemplifies the *meta-design* principle that systems must be open and evolvable, because user needs change as understanding deepens. His inability to articulate precise requirements in advance and his insistence on inspecting correctness directly reflect the epistemic characteristics of wicked problems, where problem framing and solution construction co-evolve. His self-directed learning aligns with *lifelong learning* and *learning on demand*, while his statement that "even if a developer sits next to me, it would not help" reveals the *symmetry of ignorance* [Rittel & Webber, 1984] that cultures of participation must address. Finally, his pragmatic use of coding as an externalization that "talks back" illustrates *intelligence augmentation*: tools become cognitive partners that support reflection, critique, and scientific reasoning.

Table 4 [Fischer et al., 2009] documents in the left column the statements made by the domain expert, and the right column interprets his underlying mindset and the implications for enriching the understanding of EUD. The example illustrates our central claim: *EUD flourishes when mindsets, cultures, and technologies align to empower users in navigating wicked problems and co-evolving their digital environments.* It also identifies the requirements for designing AI systems that empower end-users to remain active co-designers in their evolving digital environments.

Table 4: Software development as an essential task for domain experts
(adapted from [Fischer, 2025])

Statements by the Geo-Scientist	Relevance for Deepening the Concept of 'End User'	AI-Supported EUD
I spend in average an hour every day developing software for myself to analyze the data I collected because there is not any available software	No software exists (despite 1.5 Mio Apps) or a potentially useful app is unknown to the user	AI can accelerate learning-on-demand
Even if there is a software developer sitting next to me, it would not be of much help because my needs vary as my research progresses	Change is a constant and software needs to evolve	can produce initial prototypes or partial models that users can appropriate, critique, and evolve
I cannot clearly explain what I want to do at any moment	Poorly understood, ill-defined problems cannot be delegated, and the owners of problems must have the "authority" to change the problem	AI can lower barriers to articulating wicked problems
If the software developer can manage to write a program for me, I will not know if he or she has done it right without looking at the code	Externalizations need to "talk back" to the owners of the problems	AI-supported EUD requires inspectable, explainable, manipulable outputs
I spent three months to gain enough programming knowledge to get by	Personally meaningful activities will encourage interest-driven learning	AI can contextualize information and provide examples
Software development has now become an essential task of my research, but I do not consider myself a software developer and I don't know many other things about software development.	End-users engage in programming because they want to get their work done and programming is a mean rather than an end for them	AI can share contribution and reduce work loads

9 Interactions Among Mindsets, Cultures, and Technologies

The reaction of Student-1 to an open-ended, self-directed course environment vividly illustrates how the triad of mindsets, cultures, and technologies shapes the viability of EUD. The quote reflects a consumer-oriented mindset characterized by a preference for instructor-provided structure and a reluctance to engage with ambiguity or self-directed inquiry. Culturally, it reveals the lingering influence of traditional educational environments [Collins & Halverson, 2009] that reward compliance, correctness, and stability rather than exploration, reflection, and participation—precisely the cultural foundations needed for EUD. Technologically, the student expresses discomfort with underdesigned or flexible environments, highlighting the need for tools that scaffold learners into more open-ended modes of engagement.

Table 5 summarizes and interprets this empirical data with MCT Model and Column 3 derives initial implications and requirements for AI-supported EUD further elaborated in Section 11.4.

Table 5: Mapping the Consumer-Oriented Student-1 Answers onto the MCT Model

Dimension	Manifestation in the Student Quote	Interpretation for EUD	Implications for AI-Supported EUD
Mindsets	Desire for structure; resistance to ambiguity; rejection of self-directed learning; reliance on established habits	Indicates a *consumer mindset* expecting knowledge delivery rather than co-construction	AI tools must *foster* agency and reflection, not reinforce passivity; LLMs must encourage exploration rather than provide turnkey answers
Cultures	Expectation that teachers "be forthcoming"; avoidance of "unstructured environments"	Reveals a traditional educational culture that rewards correctness, compliance, and structure	AI-supported EUD must scaffold collaborative learning cultures and normalize exploration, critique, and shared authorship
Technologies	Prefers environments where tools and tasks are predefined and controlled by others. Shows discomfort with underdesign or open-ended systems	Suggests difficulties engaging with evolvable, underdesigned systems central to EUD. Highlights the need for scaffolding interfaces that gradually open complexity.	AI systems must make openness *manageable*: explainable outputs, transparent reasoning, adjustable granularity, and modifiable artifacts

The Student-1/Student-2 contrast also provides the conceptual key for understanding how the same LLM will produce fundamentally different outcomes for different users.

- A student with Student-1's consumer orientation will interact with LLMs through what we term *Behavior-1*: accepting whatever the system generates as a finished product, delegating judgment to the technology, and deepening dependency with each use.
- A student with Student-2's EUD-compatible orientation will interact through *Behavior-2*: treating LLM outputs as material to evaluate, appropriate, and rewrite in light of their own knowledge and experience.

The technology is identical; the MCT conditions surrounding its use are not. Section 10.3 develops this distinction in full, and it is further elaborated as an organising thread through the design principles of Section 11.4 and the conclusions of Section 12.

10 End-User Development in the AI Era

10.1 Extending our four Frameworks

While LLMs offer unprecedented generative and analytic power, they are deployed as centrally trained, opaque, and largely non-modifiable artifacts. This design orientation intensifies long-standing tensions between powerful computational systems and user agency, making the role of EUD more essential. The following paragraphs provide some details on the issues documented in Figure 3.

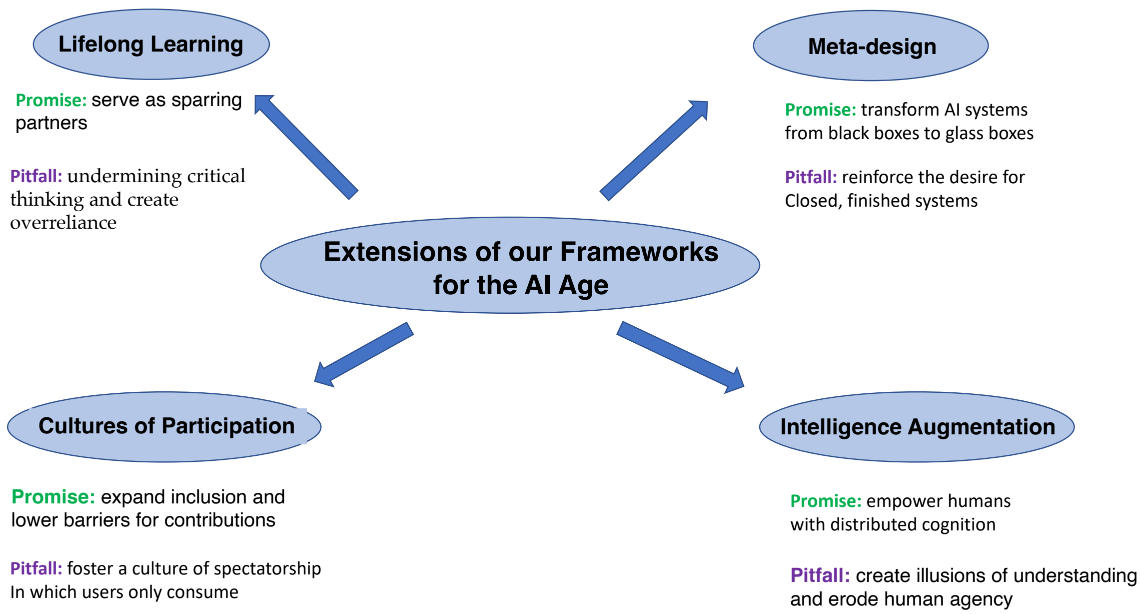

Figure 3: Extensions of our Frameworks for the AI Age: Comparing Opportunities for Empowerment with Risk of Dependency

Description: Figure 3 provides an overview of the extensions to our original four frameworks (see Figure 1) in the AI era by associating possible promises (see Section 11.2) and pitfalls (see Section 11.1) associated with LLMs.

Lifelong Learning Perspectives can avoid that LLM-based systems risk reinforcing use-oriented dependency if they primarily support immediate problem solving without fostering learning-in-use. Foundation models embed vast amounts of generalized knowledge, but they do not support users in incrementally appropriating, restructuring, or extending that knowledge in response to situated breakdowns. EUD counteracts this tendency by enabling users to adapt systems over time, transforming interaction with LLMs from episodic consultation into an ongoing learning process.

Without EUD, LLMs may accelerate performance while simultaneously eroding users' capacity to learn, judge, and act independently. As Section 10.3 illustrates, this risk is not theoretical: it is instantiated every time a user accepts a generated output without engaging with it (Behavior-1) rather than treating it as a starting point for active appropriation and rewriting (Behavior-2).

Meta-design is required for addressing the inherent closure of foundation models. Because end users cannot realistically modify model parameters or training regimes, the locus of EUD must shift to other possibilities. Meta-designed environments embed LLMs within open architectures that support user-driven configuration, extension, and reinterpretation through mechanisms such as external knowledge integration, and domain-specific scaffolding.

In this context, the success of an LLM-based system is determined less by model quality alone than by the degree to which it enables users to become co-designers of the surrounding environment. Behavior-2 enacts this co-designer role at the level of individual interactions — treating each generated output as an open, unfinished artefact to be inspected, critiqued, and evolved; Behavior-1 forecloses it by treating the same output as a closed, finished product.

Intelligence augmentation reframes the role of LLMs away from automation towards distributed cognition. Without EUD, the contributions of LLMs can be restricted to authoritative answer generators, encouraging uncritical acceptance and obscuring uncertainty. EUD enables users to shape how LLM outputs are generated, contextualized, and represented, thereby preserving human judgment and supporting reflection-in-action.

By allowing users to modify the artefacts that mediate their interaction with LLMs, EUD ensures that intelligence is distributed across humans and systems rather than centralised within the model. Behavior-1 inverts this: the user who submits a prompt and accepts the result without evaluation has ceded their cognitive role entirely, producing what the paper identifies as the Intelligence Augmentation Pitfall — an illusion of competence substituting for genuine understanding.

Cultures of participation address the social dimension that foundation models alone cannot support. Although LLMs dramatically lower the threshold for access to sophisticated computational capabilities, they do little to raise the ceiling for meaningful participation in system evolution. EUD-oriented infrastructures are required to make user contributions persistent, shareable, and open to critique, transforming isolated prompt-based interactions into collective resources.

Cultures of participation enable communities to appropriate LLMs collaboratively, embedding them within shared practices rather than treating them as externally provided services. Only Behavior-2 users generate the situated, personal, experience-laden contributions that participatory cultures require: a Behavior-1 user, having accepted a generic LLM output unchanged, has nothing distinctively their own to contribute to a shared knowledge community.

10.2 Exploring the Use of LLMs to Avoid the Fallacy of the "Big Switch"

One of the challenges in EUD is the *abrupt discontinuity* between passive system use and active system modification. Traditional environments force users to cross a conceptual chasm: they must shift from a consumer's mindset ("following the rules") to an EUD mindset ("changing the rules.") This Big Switch (illustrated by the red curve in Figure 4) demands new skills (reflection, abstraction, articulation), new mindsets (agency, curiosity), and new cultural expectations (legitimacy of contribution).
Being exposed to a consumer mindset [Fischer, 2002] for many years, research [Dweck, 2007] has shown that humans are likely to be strongly influenced by the values they have learned from and practiced in their previous experiences. If learners in educational environments are exposed to a consumer mindset (one indication being the response of Student-1 in Table 2), it will require a "big switch" to eventually acquire an EUD mindset to cope with the wicked problems of the digital age (see issues mentioned in Section 2).

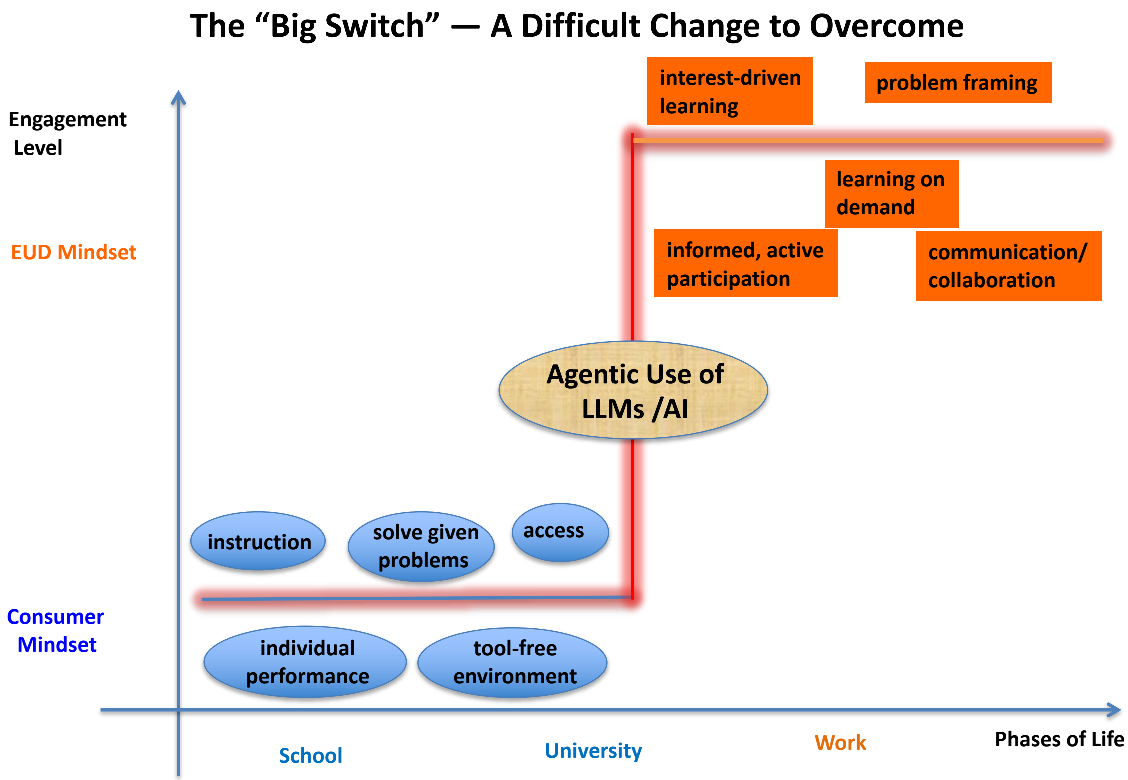

Figure 4. The Fallacy of the "Big Switch" indicated by the Red Curve
(adapted from [Fischer, 2025])

Description: The figure illustrates how the agentic use of LLMs and AI will require a "big switch" from consumer to an EUD mindset.

To avoid that stakeholders have to master the "big switch" mindset change, learners and users should be exposed from an early age to artifacts and participatory cultures [Resnick, 2017]. The green bubbles in Figure 5 are specific approaches and developments supporting the green curve, leading to a *gradual acquisition* of an EUD mindset, thereby avoiding the big switch.
LLMs have the potential to reduce the "Big Switch" from consumer to co-designer by our extended four basic frameworks. The green curve enables learners and users to *gradually* move from a consumer mindset to a EUD mindset.

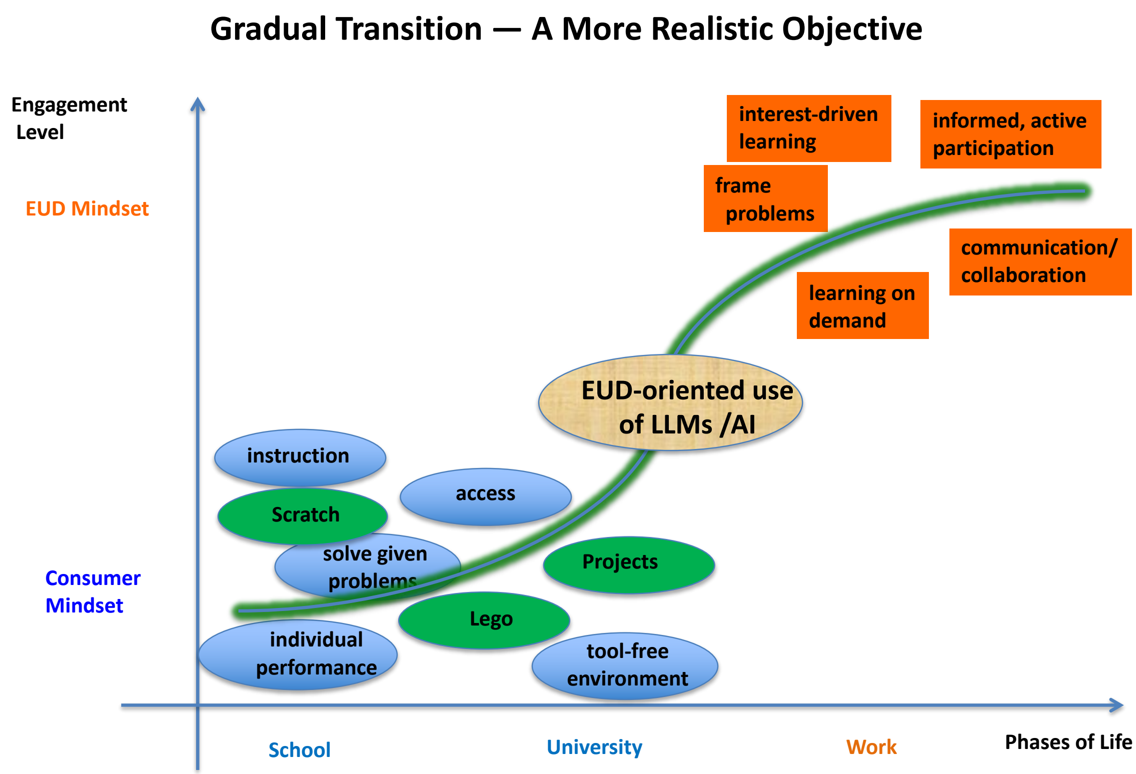

Figure 5. Gradual Transition to an EUD Mindset indicated by the Green Curve (adapted from [Fischer, 2025])

Description: The figure illustrates how the "big switch" can be avoided by supporting EUD with LLMs.

10.3 A Narrative Supporting the Claim for LLMs: "It is not the Tool — It is how it is Used"

We developed a narrative to illustrate that LLMs can be *used* in fundamentally different ways as a "*Personal Speechwriter*". High-level politicians, industry leaders, and other decision-makers are using human speechwriters to assist them in giving presentations. If speechwriters provide a text and the "important person" delivers the speech by reading the given text literally to an audience, the "important person" (with the biggest salary) engages in the least demanding activity: all they need to be able to do is read. What the listeners of the speech hope for and expect is that the "important person" superimpose her/his own ideas based on the ideas provided by the speech writers.

The same argument can be made that asking students to create an essay as a homework assignment will not provide a meaningful learning activity when the student submits the essay question to a LLM, which creates the answer that the student returns to the teacher as it is not even looking at it.

Most students writing an essay as a homework assignment, or workers writing a job application, cannot afford to have a human as a personal speech writer. They can use LLMs as their "personal speech writer" in the following two fundamentally different ways:

- *Behavior-1:* they use the text created by a LLM as their final product (governed by a passive consumer mindset);

or

- *Behavior-2:* they can use ChatGPT to generate a first draft and then rewrite the text to reflect their own voices and experiences (governed by an EUD mindset).

In using LLMs as indicated by Behavior-2, the technology can contribute to making learners and workers more creative and to developing critical thinking skills by blending computational power with human intuition and expertise. Understanding why requires mapping each Behavior onto the MCT model.

- *Behavior-1* (accepting the generated output as a final product) instantiates all four Pitfalls of Figure 3 simultaneously. It produces overreliance and undermines critical thinking (Lifelong Learning Pitfall) because no learning occurs when engagement is zero. It reinforces the desire for closed, finished systems (Meta-Design Pitfall) because every satisfactory Behavior-1 outcome confirms that the right relationship to LLMs is consumptive rather than co-creative. It creates an illusion of understanding and erodes agency (Intelligence Augmentation Pitfall) because the submitted output performs competence the user does not possess. And it fosters a culture of spectatorship (Cultures of Participation Pitfall) because a generic LLM output, carrying no personal voice or situated experience, contributes nothing distinctive to any shared knowledge community.
- *Behavior-2* (treating the generated output as a first draft to be rewritten in one's own voice) instantiates all four Promises. The act of rewriting is learning-in-use (Lifelong Learning Promise: the LLM as sparring partner). Treating the draft as open and unfinished is the glass-box orientation in practice (Meta-Design Promise). The rewritten text reflects distributed cognition — LLM capability combined with human judgment, voice, and experience (Intelligence Augmentation Promise). And the result, carrying situated personal knowledge, is the kind of contribution that participatory cultures require (Cultures of Participation Promise).

The MCT model explains why these two Behaviors are not simply different choices a person makes in the moment — they are expressions of deeper alignments or misalignments among mindsets, cultures, and technologies. A study [Ashkinaze et al., 2025] found that passive AI exposure can increase idea diversity, while active reliance can decrease it, providing an empirical basis for the paper's Behavior-1 / Behavior-2 distinction. A user with Student-1's consumer mindset operating in a culture that rewards compliance and using a system that presents itself as an authority will reliably produce Behavior-1. A user with Student-2's EUD-compatible mindset, in a culture that legitimizes active contribution and using a system designed to expose its reasoning and invite critique, will reliably produce Behavior-2. The design implication is direct: changing the Behavior requires changing the MCT conditions that produce it, not merely exhorting users to engage more actively.

The integration of EUD and LLMs therefore opens two diverging possibilities: (1) LLMs embedded in Behavior-1 cultures accelerate passive consumption, deepening dependency while appearing to enhance productivity; (2) LLMs embedded in Behavior-2 cultures become genuine supertools — generating initial content that frees users to focus on creative, high-level tasks, while preserving and developing the human judgment that

EUD requires. The Design Principles in Section 11.4 specify the conditions under which the second trajectory rather than the first becomes the norm.

10.4 Contrasting Agentic AI and EUD-oriented approaches

Agentic AI and EUD-oriented AI represent *two diverging trajectories* for the future of AI. Agentic AI seeks to minimize human involvement by increasing machine autonomy whereas the framework described and analyzed in this article seeks to empower **humans as primary agents** in socio-technical systems. More specific differentiations:

- *problem framing activities*: Agentic AI frameworks and developments are grounded in the assumption that goals can be specified, and success criteria can be operationalized, whereas in EUD goals are negotiated and repeatedly revised, and success criteria are contextualized. This differentiation has separated the use of computers in education for a long time: intelligent tutoring systems (focused on instructionism) corresponding to Agentic AI and interactive learning environments (focused on constructionism) [Papert, 1980] corresponding to EUD-oriented approaches.

- *mindset formation*: Agentic AI promotes a mindset of relying on system authority (or teacher competence as the Student-1 does), whereas the EUD framework is grounded in learning-oriented engagement and shared responsibility for the framing and ongoing re-framing of problems (as demonstrated by Student-2 in Section 6).

This differentiation represents a specific example for supporting the general claim AI without EUD centralizes power and is applicable for tame problems, whereas AI with EUD distributes intelligence and can cope with wicked problems The paper by [Kumar et al., 2025] demonstrates that while LLM assistance provides an immediate, short-term boost to creativity, it can hinder unassisted, independent creative performance and cause a *"homogenization effect"*, where LLM exposure reduces the originality and diversity of future human ideas.

11 Future Directions for Mindsets, Cultures, and Technologies for EUD

11.1 Pitfalls and risks of LLMs for EUD

Figure 3 identified four framework-level pitfalls — the failure modes that each of the four frameworks was designed to prevent. The following mechanism-level pitfalls specify how, in practice, LLMs bring those failures about:

Overreliance on technology. The socio-technical impact of AI and automation includes concerns that reliance on automated tools can lead to unreflective use displacing rather than augmenting human capabilities [Brynjolfsson & McAfee, 2014].

Loss of friction in coping with wicked problems. Productive struggles where stakeholders engage with challenging tasks requiring effort and reflection are indispensable for mindsets engaged in EUD and critical thinking, thereby serving as a source for human potential in coping with wicked problems [Dweck, 2007].

Limited support for asking questions and framing problems. Despite their impressive performance in answering well-formed queries, LLMs provide only limited support for the upstream cognitive work of asking questions and framing problems [Simon, 1996].

Fluency as an illusion of understanding. *The fluency of LLMs* [Bender et al., 2021] stems from the combination of massive amounts of data, immense computing power, and novel processing techniques, encouraging a consumer mindset that will disempower users.

Hallucinates and wrong answers. Research on *Explainable AI (XAI)* [Shneiderman, 2022] establishes that many LLM models lack transparency about their internal reasoning processes, creating a "black box" problem, making it difficult for humans to scrutinize the answer produced.

Erosion of contributor identity and participatory culture. Beyond individual cognitive harms, the unreflective use of LLMs produces a collective cultural shift: from communities of active co-designers to populations of passive consumers [Fischer et al., 2020] When LLMs routinely deliver competent outputs without requiring users to articulate, negotiate, or defend their knowledge, the social conditions that legitimise contribution — shared ownership, visible effort, mutual critique — erode quietly. This is the Cultures of Participation pitfall of Figure 3: not a failure of any individual user but a systemic drift in what participation means and whether it is expected

These six pitfalls are consequences of deploying LLMs as automation-centric system components, and they map onto Figure 3's pitfalls as follows:

- Overreliance and loss of productive struggle produce the Lifelong Learning pitfall of undermined critical thinking;
- *Limited support for framing problems* and fluency-as-finishedness reinforce the Meta-Design pitfall of closed-system;
- Fluency-as-illusion and hallucination together produce the Intelligence Augmentation pitfall of illusory understanding;
- Erosion of participatory cultures leads to populations of passive consumers**.**

11.2 The Importance of the MCT Model for EUD in the LLM Era

LLMs dramatically strengthen the *technology* dimension while leaving mindsets and cultures underspecified**.** Interpreted through the four frameworks *and* MCT, LLMs have the potential to become: **(1)** Lifelong learning supertools and sparring partners**,** not knowledge dispensers; **(2)** Meta-design environments, not supplier of finished products,

(3) Intelligence Augmentation amplifiers, not replacements for human intelligence; and
(4) Catalysts for participation, not central authorities where participation is reduced to feedback rather than co-design.

Using LLMs in this way (see Figure 3) will create the following promises for MCTs:

- they will change our minds about how we think, learn, and work and what *human creativity* really is [Csikszentmihalyi, 1996];
- they will enrich our understanding and increase the support for *"distributed cognition"* frameworks [Hollan et al., 2001];
- they will support the "productive struggle" [Dweck, 2007; Vygotsky, 1978] required in the context of challenging tasks by encouraging persistence and transforming mistakes into learning opportunities;
- they will contribute to the development of 21st Century Skills, including the 4 Cs Creativity, Critical Thinking, Communication, and Collaboration [National-Library-of-Medicine, 2023].

The approach to EUD discussed in this paper is grounded in *incremental redesign* and supported by the MCT model. An alternative approach is pursued with "Vibe Coding" [Williams, 2025] which regenerates code based on natural language prompts. This approach represents an alternative and is at odds with EUD when regeneration replaces the reflective evaluation that incremental redesign was always meant to produce. How successful the two approaches are in specific applications remains an open empirical question and a productive direction for future research."

11.3 Blind Spots: Challenges for our frameworks in the current AI discourse

As "EUD in the Era" is a wicked problem, there are no "decontextualized sweetspots" and no best solutions [Simon, 1996]. Future research should explore the following themes, which are design trade-offs to the objectives articulated by this paper:

- *claim-1:* Not everyone wants to design — this is especially the case for problems that specific users consider *personally irrelevant*.
- *claim-2*: in specific situations, there is competence without understanding — if AI systems deliver acceptable outcomes without user understanding, the need to EUD erodes and learning-on-demand can be replaced by using-on-demand.
- *claim-3:* human involvement is not always beneficial — boundaries need to be created to determine what must remain in human heads. What can safely be externalized, and how these boundaries shift dynamically across domains.
- *claim-4:* structural inequalities require different approaches — background knowledge, time, confidence, and institutional support can have a major impact who can realistically engage in EUD

11.4 Design Principles (DPs) for AI-Augmented EUD

The principles (grounded in the themes and research of this article) described in this section should be combined with principles from other research efforts to collectively reframe and explore the future of EUD in the AI age.

DP-1: Lifelong Learning — Support Learning-in-Use Rather Than Use-Only Interaction

> LLM interactions should create opportunities for users to learn while acting, rather than merely delivering answers. Systems should externalize assumptions, intermediate reasoning, and alternative perspectives so that breakdowns become triggers for reflection and redesign.

DP-2: Meta-Design — Design for Evolvability

> LLM systems should be conceived as open, unfinished environments rather than finalized solutions. Because foundation models are inherently closed at the parameter level, evolvability must be provided through higher-level mechanisms that allow users to incrementally adapt systems in response to emerging needs. Success is measured by users' capacity to evolve the system during use, not by the completeness of initial functionality.

DP-3: **Intelligence Augmentation (IA) — Augment Human Capabilities, Do not Replace them**

> LLMs should be positioned as supertools rather than authoritative decision makers. EUD-oriented systems must encourage critique, comparison, and reinterpretation of model outputs. Users should be able to employ different "prompt engineering" techniques [Gadesha, 2026] to shape how outputs are generated and represented so that human judgment remains central and accountable.
>
> Our IA approach is focused less on *"Will AI replace*?", but explores from an EUD perspective the question "*Will 'humans not using AI' be 'replaced by humans using AI'"?* as the more important research direction to pursue.

DP-4: Cultures of Participation — Encourage and Support Communities

> End-user adaptations should persist beyond individual sessions and be shareable within communities. Support for sharing innovations will transform isolated local innovations into collective resources, enabling systems to evolve through shared community practices.

What to Avoid. DP-1 to DP-4 are formulated as requirements *"what to do"* — another formulation of design requirements could be *"what to avoid"* because these developments would be detrimental to EUD in the AI Age. The following objectives should be avoided:

- LLMs that make learning or understanding obsolete by replacing "learning on demand" with "using on demand" (alternative formulation to DP-1);
- Black-box systems that undermine user control and interpretability (alternative formulation to DP-2);
- Automation-first AI developments replacing humans instead of empowering them (alternative formulation to DP-3);
- Technology-centric narratives ignoring cultural impacts (alternative formulation to DP-4).

11.5 Complementing Empirical Work

An increasing number of recent empirical studies [Klingbeil et al., 2024; Shin et al., 2025] provide important evidence for the risks of overreliance, limited scrutiny, framing deficits, hallucinations, and the loss of productive struggle in current LLM use. These studies largely document *what goes wrong* in isolated tasks or interaction settings, without offering an integrative framework that explains *why* these failures recur across domains or *how* they can be addressed systematically through design [Fogli et al., 2020]. The study reported in [Stadler et al., 2024] found that using LLMs in student scientific inquiry significantly reduces cognitive load and effort, but at the cost of lower-quality and less deep reasoning and argumentation

Our paper advances beyond prior empirical work by synthesizing these fragmented findings through the lens of *EUD* and by integrating them into the coherent *MCT* model. Rather than proposing incremental interface fixes or improved prompting strategies, the paper reframes the problem as a structural design challenge: how AI systems must be embedded within open, evolvable environments that preserve human agency in the presence of wicked problems. The contribution is therefore not another empirical demonstration of LLM limitations, but a theoretically grounded design framework that explains the persistence of limitations and derives *explicit design principles* for AI-augmented systems.

12 Conclusions

This paper is grounded in the basic assumption that the central challenge of AI in the presence of wicked problems is not technical capability but the preservation of human agency. The argumentation and analysis have highlighted enduring design tensions that must be navigated rather than eliminated by balancing user autonomy with scaffolding and guidance.

Situated in the context of the AI and LLM era, the paper has emphasized that emerging technologies intensify both the opportunities and the risks associated with EUD. While LLMs can substantially lower barriers to participation and support learning-on-demand, they can equally reinforce automation-centric approaches that deskill users and obscure critical design decisions. Whether AI becomes a catalyst for empowerment, or a driver of dependency depends on how it is embedded within socio-technical environments shaped by appropriate mindsets, cultures, and technologies.

Grounded in multiple perspectives on the desirability and feasibility of EUD and informed by long-term empirical and design-based research, this article contributes to advancing both the theoretical foundations and the practical design space of EUD. Looking forward, EUD will flourish only when mindsets, cultures, and technologies are intentionally aligned to support users and communities in framing wicked problems, negotiating design trade-offs, and co-evolving their digital environments. In this sense, EUD is not merely an option for the future of AI-enhanced systems—it is a prerequisite for sustaining human agency, learning, and collective intelligence in an increasingly complex digital world.

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