Evolution of Technological Innovations, User Experiences, and Literacies

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Abstract
The advancement of computer-based innovations over the years has drastically altered the role of the end-user, from passive users of technology to active participants influencing technological development. Each major innovation, associated with preceding hardware and software milestones, has led to new understandings and skill sets required of end-users. This workshop position paper explores the technological progress from mainframe computers to personal computers, the internet, and the nascent age of artificial intelligence (AI) based on Large Language Models (LLMs). We examine how each technological leap has transformed the end-user experience, the evolving literacies demanded, and speculate how the evolution of user interaction with technology in the future might move in different directions and widen the technological gap.

Keywords
End-user, user literacy, evolution of technology, user experience, technological gap

1. Innovations driven by hardware, software, and users

Delving into the nature of innovations in hardware and software reveals noticeable patterns and interdependencies, shaped by their unique trajectories of evolution. Historically, as hardware evolved – shrinking in size while increasing in performance to become more portable and user-friendly – it has driven software advancements and influenced technology use. This evolution of technology allowed for interactive technology for everyone, the internet, and smartphones. Innovations in software have led to the internet enabling services like search engines and streaming, mobile apps, and artificial intelligence models that were trained on web-based content.

Over the years, the interaction and codesign [1], between hardware and software has transformed from a linear relationship into a complex, reciprocal dynamic process in a continuous change that shapes the user's interaction with technology. The distinguishing lines between hardware and software have blurred as both have become equally crucial in driving technological progression. For example, mainframes necessitated highly specialized skills, whereby end-users aquire expertise in complex command-line interfaces and

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programming languages. Personal computers (PCs) in the 1980s revolutionized this concept. PCs brought computing to homes, democratizing technology and drastically transforming the profile of end-users. Apple and Microsoft's graphical user interface (GUI) and GUI guidelines refocused end-user skills towards operating a mouse to move on a 2D screen, navigating the desktop environment, and managing files. Thus, basic computer literacy moved out of coding and command line prompts and into common business software like word processing and spreadsheets. In the last decade the Internet of Things (IoT), characterized by the interconnectivity of sensor-equipped embedded devices, has rapidly become a pivotal standard for low-power lossy networks (LLNs) with resource constraints, thanks to the proliferation of smart devices and the advancement of high-speed network infrastructure. This network paradigm enables a large array of "things" to communicate and share data across both private and public networks, marking a significant evolution in how digital networks are structured and utilized [2].

Future innovation will likely continue to rest upon this intricate interplay between hardware, software and user experiences. This will have implications for computational literacy, ethics, and inclusivity. With the emergence of AI and LLMs, new avenues for end-user experiences have begun to shape. As AI technologies evolve, they are fostering a less technical, but more intuitive environment for end-users. LLMs can communicate effectively with humans, generating text that mimics human-like interactions and they become part of the everyday tools we use. This development has set the stage for a new form of literacy: developing effective ways to interact with AI to obtain desired results.

However, understanding the sources of AI biases, ethical considerations associated with AI usage, critical thinking, the principles of machine learning, and AI-based decisions are also increasingly becoming part of users' computational literacy. This literacy now extends to prompt engineering, a nascent skillset focused on effectively communicating with AI systems. Prompt engineering involves crafting inputs that elicit the desired outputs from AI models, reflecting an interplay between the precise use of language and an understanding of the model's capabilities and limitations. Mastering this art form is quickly becoming an important competency, as it dictates the quality and applicability of AI-generated content. When it comes to critical thinking skills, it is important for end-users to separate knowledge-based information from nonsensical information, despite the latter's initially sounding plausible. Without the necessary background knowledge, including proficiencies in prompt engineering, users will struggle to appropriately command and critically evaluate AI outputs, potentially undermining the utility and benefits of AI technologies.

2. The evolving relationship between humans and computers: The paradox of the active user

In a seminal paper in human-computer interaction in 1987, Carrol & Rosson introduced the paradox of the active user [3]. This means that users tend to use computers without spending time learning about the system before they start using it. At the time the concept was introduced it meant that new users weren't reading the manuals provided with their computers. They would instead delve right into use mode, even if that meant using the system in suboptimal ways or ways that would lead to subsequent breakdown and repair.

Rosson and Carroll considered it a paradox, as they understood that users could enhance their computer experience significantly by initially investing time in understanding them, yet they also recognized that such behaviour was unlikely to occur in actual practice [3].

The active user paradox is prevalent in today's use of computers in the following way; as technology develops with a focus on enhancing end-user experiences, it simultaneously risks generating a digital divide. While technology promises to empower users, not all users might reap the benefits equally. For example, in the domain of AI in education, we as educators see a gap between two types of users, those users who seamlessly integrate AI generated text into their own writing and those who verbatim copies AI-generated text and put into own text without personal adaptation. The differentiation and potential discrimination between users are critical considerations in the development of future (AI-based) technology, leading us into complex societal and ethical territories, which goes beyond education.

Technological advances throughout the decades has consistently revolved around a user-centric (HCI) paradigm. Early computer systems, while not explicitly end-user-focused, laid the groundwork for the transition to personal computers, which represented a leap towards a democratization of technology. No longer confined to mathematicians and engineers, computers began to serve business professionals, avid hobbyists, and enthusiasts in fields ranging from gaming to scientific research. This shift gradually turned technology from being a tool designed for advanced specialists into a utility for the masses, explicitly designed around end-user functionality. Furthermore, this shift realigned the nature of our interaction with technology. Rather than solely facilitating task execution, machines evolved to augment our cognitive processes, thereby improving our efficiency and effectiveness in performing those tasks. Now, the focus has shifted again, moving beyond individual user engagement to collaborative and community-centric processes, underscoring the importance of shared technological experiences and collective intelligence [4]. In all the various shifts in tool use and task reorientation the importance of end-users has come to the forefront, a trend that continued to intensify with subsequent innovations like the Internet, smartphones and social media. Each wave of technology did not only amplify functionality, but added layers of complexity with intricate user interfaces for different user groups, levels of systems functionality and task structures. While yesterday's challenge focused on crafting an impressive text for a conference, tomorrow's objective might involve addressing societal and global issues.

However, the rapid pace of technological change has arguably left behind segments of the population who have been unable to keep abreast, thus, exacerbating technological inequalities. This dichotomy sharpens, particularly as we move into the era of AI and LLMs, which while designed to increase user empowerment, might exclude those lacking sufficient computational literacy. We have already mentioned education; another example of the digital divide is the elderly population. Innovations like online banking and digital ticketing, intended to simplify life, can, paradoxically, complicate it for seniors or anyone not tech-savvy. If they do not have a smartphone or lack the necessary skills to operate these devices, they might find themselves unable to perform everyday tasks consumers take for granted in society.

The dilemma extends beyond age-related concerns, affecting different sectors of society. Rural versus urban, rich versus poor, educated versus uneducated, high-achievers vs. low-achievers – all these societal and educational divisions can steer the development of user experience and accessibility of innovation into unchartered territory. The digital divide poses a risk of creating a society segregated by a digitally privileged class versus a digitally deprived one.

The paradox of the active user might lead to widening of the technological gap and must be an area of critical reflection for all stakeholders involved in the design and implementation of technology, including those involved in developing computational literacy programs in schools, higher education, workplaces and elsewhere. Not only should developers continue to optimize intuition and ease-of-use in their user interface designs, but there must also be inclusive strategies to uplift the sections of society at risk of being left behind. This effort could include implementing user-friendly designs for the elderly, offering accessible training programs, and ensuring affordable internet connectivity and device availability for socio-economically disadvantaged users.

The field spanning technology development and comprehension balances delicately on the brink of promise and the contradiction associated with the paradox of the active user. As technological evolution and its story continue to unfold, the role of end-users will undoubtedly remain central, influencing not only the course of future technological evolution in hardware and software, but also society's shape in the digital age.

In summary, we suggest focusing on end-user development as this is a field that can balance the challenges of developing technology that cater to the masses, from domain expert users to learners, to novices, and disadvantaged users. EUD provides methods and techniques that can balance the separate fields we covered in this position paper exposition. We place EUD in the context of how technological evolution has transformed the end-user experience, requiring new literacies. We speculate how the evolution of user interaction with technology in the future might move in different directions and widen the technological gap

3. The future trajectory of systems for end-user development

We propose that the future trajectory of systems for end-user development is twofold; on the one hand, a focus on more intuitive, user-empowering AI technologies, and on the other, a necessity for concurrently enhancing computational literacy across the full spectrum of end-users. The former is mainly in the realm of computer science and HCI and the latter in the social sciences and education.

3.1. User-adaptable AI technologies

End-users' ability to articulate their needs and desires influences innovation. The advent of AI and chatbots presents a transformative shift in the relationship between technology and end-users. The traditional boundaries between applications and platforms are becoming increasingly fluid, as AI-driven interfaces like Gemini, Copilot and related AI technologies begin to act as intermediaries between the user and a constellation of services.

This evolution towards a centralized, conversational interface eliminates the need for users to interact directly with specific programs or applications for different. We envision, a user who needs to compose and send a letter might simply dictate the contents to their digital assistant, which then handles the intricacies of document creation, formatting, and dispatching via email or print. This scenario was already envisioned in a 1987 video by Apple whereby a butler agent performed well defined tasks for a domain expert user (a professor) [5]. This environment which was far from realisable at that time (1987) is much close to realization today, at least for demonstration purpose. The layer of abstraction provided by advanced AI models means that the underlying software becomes transparent to the user, streamlining their experience and reducing the complexity of day-to-day digital interactions.

For developers, this shift has profound implications. If AI interfaces continue to serve as the primary point of contact for technology users, developers might indeed begin to view those interfaces as their primary 'end-users.' In doing so, they would need to optimize their software and services for compatibility and seamless integration with these AI platforms, rather than for human user interaction. However, it's essential to consider whether developers can afford to limit their conception of the end-user to the interface alone. After all, the human end-user is not the interface, but the person relying on the interface to carry out their intentions and accomplish their goals, and this include novices as well as experts, disadvantaged users as well fully functioning ones. The paradox of the active user tells us that end-users tend to use such systems without thinking about the consequences in terms of what they should know before using it. In educational setting (K12 + higher education) this is paramount as AI systems must be used with great caution, as the enabling of learning (not optimization of workflow) is the primary mission and raison d'etre of educational institutions.

In developing AI-integrated applications, developers face a double-edged sword: they must ensure seamless operation and AI compatibility while preserving user autonomy. The key is to allow personalized experiences with adaptable interfaces for user adaptation, requiring developers to continuously refine EUD tools and understand user behaviours – often inferred from AI interactions. This approach, known as meta-design [6], is crucial for enabling user-tailored modifications within AI environments.

3.2. End-user literacy skills

The ability to adapt technology and continuously learn new digital skills is another crucial aspect of computational literacy for end-users. On that basis, we provide suggestions for relevant computational literacy skills.

We assume that users in the future will interact with some type of human-centred AI (HCAI) tools. Generative AI (GAI) and LLMs provide the basic structure for these technologies and specialized tools have gradually started to appear in all areas. For instance, a company may implement an automated help desk to assist customers with their accounts or to help new employees with onboarding. In the past, this functionality was supported by simpler AI-based chatbots based on a fixed set of responses and knowledge management (KM) systems. Contemporary chatbots built on GAI and LLMs capitalize on web-sourced data, hereunder Wikipedia, to improve upon outdated technologies. These platforms, starting from a robust base, are rapidly integrated within all sectors, especially business and education, harnessing predecessors' advancements in NLP. Generative systems can be tailored for domain-specific tasks with simple re-configurations or domain-focused training. Experts with fundamental computational skills, nurtured from K-12 to higher education, can adapt customize these LLMs for specialized use cases.

What are the essential computational literacy skills that should be integrated into education curricula to ensure domain-expert users excel in their respective fields? Specifically, how can skills development leverage GAI and LLMs to boost productivity in business and health care, improve elder care, and facilitate adaptive learning in education? Key skills, as we raise – but not limited to, are basic programming knowledge, data literacy, a fundamental understanding of AI – its application and limitations, digital ethics and privacy, Human-AI interaction and critical thinking.

Teachers should be perceived as meta-designers, enabling students to tailor learning technologies to their personal needs for use in specific domains. This empowers students to use digital resources in classrooms or for homework assignments, stimulating interest, adapting assignments to individual ability levels, and meeting learning objectives. The end goal of GAI tools in teaching and learning, as we envision it, is to promote human-machine joint understandings and achievements, where the collaborative efforts of humans and machines exceed what each entity can accomplish independently

4. Summary and open issues for discussion

In this position paper we have adressed two themes in the call for papers, namely: *"How will the increasing integration of AI into daily life and digital tools redefine the roles of end-users as both consumers and contributors?"* and *"how can we foster a 'holistic symbiotic design' that not only addresses the functionality of AI technology but also the ethical, societal, and inclusivity concerns?"*

The history of technological evolution toward today's AI technologies showcases a complex interplay between hardware and software, each setting the stage for the next leap of promise and disappointment. Each major advancement has prompted corresponding changes in end-users' digital skill sets and literacies. Starting from highly specialized skills for a the advanced end-user to the current shift in interactive skills "for all" with AI, digital literacy has seen a tremendous transformation. As AI deepens its roots in various spheres of life, the lines between end-users as consumers and contributors will further blur and redefining the aspect of end-user interaction and end-user development with technology.

In the spirit of fostering a structured and productive discussion at the workshop, we ask:

- How might AI technologies change the way users contribute to and participate in digital platforms and everyday actvities?
- How can we prepare end-users to adapt to the changing landscape of AI integration, ensuring they have the skills needed to both utilize, modify, and critique these systems?
- In what ways can educators adapt their teaching strategies to incorporate AI literacy, addressing the challenges and opportunities that AI presents within an educational context?

The increasingly user-centric design of technology represents a double-edged sword, with the potential to both empower and exclude. The paradox of the active user seems to create a digital divide, between those who with flourish in the digital society and those who don't. For the latter, compulsory AI literacy skills may be required to cope with the nuanced relationship between consumers and active users, from being-shaped-by technology to becoming end-user developer [7]. Furthermore, end-users should serve as a reminder of the larger ethical, societal, and inclusive considerations that must underpin our shared digital future, building on the lessons learned from past use of digital technologies where end-users were defined by their background in specific domains to become everyone who need to be trained to develop a new skill set. Therefore, developers will need to envision and design for a future where they are catering to both the AI interface – the immediate end-user – and the human end-user who needs prerequisite knowledge, whose diverse needs continue to propel the evolution of technology. The mutual learning requirements of AI interfaces and human users herald a new era of 'holistic symbiotic design', where understanding multiple layers of complexity beyond the 'conventional' user interface become vital. Furthermore, we suggest the following topics for discussion:

- What frameworks can be developed to ensure that ethical considerations are integral to the design process of AI systems from the outset?
- How can interdisciplinary collaboration be strengthened to bring together computer scientists, social scientists, designers, educators, ethicists, and end-users in creating AI solutions that serve the common good?

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