

REVIEW ARTICLE

Artificial intelligence literacy in design intelligence: A review

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Abstract

The integration of artificial intelligence (AI) and design has given rise to “design intelligence (DI),” an ecosystem encompassing both AI applications in design (AI for design) and the intelligent design of AI systems (design for AI). Despite growing interest in AI and design, existing studies often address these two perspectives separately, creating a significant gap in the literature. This evolving field highlights the pivotal role of AI literacy in ensuring the responsible use and development of AI-driven design technologies. This article presents a comprehensive literature review synthesizing research across AI literacy, AI-driven design for design (AiDD) and DI. Drawing on educational research, design thinking, and AI implementation studies, this review proposes a novel layered framework for AI literacy, tailored to the DI context. The findings identify AI literacy as a foundational element for effective engagement with these AI-driven design frameworks. Enhancing AI literacy among diverse stakeholders could improve understanding, adoption, and ethical application of these technologies. The analysis reveals a reciprocal relationship between AI for design and design for AI, which together form the core of the AiDD paradigm. In addition, AI literacy is shown to be multidimensional, encompassing technical competence, ethical reasoning, critical evaluation, creative application, and adaptive learning. This review further emphasizes the role of AI literacy in fostering human–AI collaboration, maintaining quality and effectiveness, promoting responsible use, and supporting democratized access to advanced design tools. Overall, strengthening AI literacy is essential for empowering society to harness intelligent systems responsibly and effectively, supporting the sustainable development and integration of AI into evolving design practices.

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1. Introduction

Artificial intelligence (AI) is utilized in virtually every aspect of design practice, encompassing a wide range of disciplines, including graphics, film production, technical writing, drug discovery, and DNA sequencing.¹⁻⁷ This extensive integration exemplifies the “AI for design” paradigm, in which AI tools act as powerful instruments to augment human creativity and analytical capabilities.⁸⁻¹⁰ By automating routine tasks and enabling the exploration of complex problem spaces, AI empowers designers to push

the boundaries of innovation and efficiency across diverse sectors.^{11,12} This paradigm not only accelerates the design process but also facilitates the generation of novel and high-quality solutions that are challenging to achieve using traditional methods alone.

Concurrently, the field observes the parallel evolution of “design for AI,” where AI systems are intentionally crafted to embody advanced design principles, making them more intelligent, adaptable, and capable of surpassing human cognitive abilities within specialized domains.^{13,14} This approach prioritizes the creation of AI architectures that can learn, generalize, and optimize their performance autonomously, thereby enhancing the utility and robustness of the AI models. The convergence of these two paradigms has given rise to the concept of “AI-driven design for design (AiDD),” an innovative ecosystem in which intelligent systems both utilize and are continuously shaped by design methodologies. AiDD embodies a recursive cycle akin to the concept of machines building machines, which has historically been a key driver of technological progress in human civilization.¹⁵ The critical distinction in this AI-driven cycle is its unprecedented speed and scale, significantly outpacing previous expert expectations.¹⁶ This rapid acceleration fosters a dynamic co-evolution of design and AI, driving both human creativity and AI capabilities in tandem and heralding a transformative era in technological and creative innovation.¹⁷

Understanding AiDD is now critical, as it embodies a recursive ecosystem where AI systems are both shaped by and actively contribute to design processes, accelerating innovation at unprecedented speed and scale, thereby affecting society, individuals, and the environment. This emerging field necessitates the development of a new form of literacy, specifically AI literacy in design intelligence (DI), which encompasses the essential competencies required to effectively navigate, critically evaluate, and proficiently utilize sophisticated human–AI collaborative systems. As AI technologies become increasingly integrated into design workflows, this literacy involves understanding the technical functionalities of AI tools and recognizing their implications for creativity, decision-making, and ethical considerations within the design process. Mastery of AI literacy in DI enables designers and stakeholders to engage with AI systems as active collaborators, optimizing their potential to enhance innovation while maintaining human-centered values.

Moreover, given that AI systems are fundamentally human-designed constructs, emphasis should be placed on empowering individuals and society at large to harness their capabilities responsibly and creatively, rather than imposing restrictive limitations on their development.

This empowerment involves fostering interdisciplinary education, promoting critical thinking about AI’s role in design, and encouraging adaptive learning strategies to keep pace with rapid technological advancements. By cultivating AI literacy in DI, the design community can ensure that AI serves as a catalyst for expanding human creativity and problem-solving capacity, ultimately driving a more inclusive, innovative, and ethically grounded future in design practices.

In achieving these goals, we propose a framework that offers an original and integrative contribution by bridging the previously fragmented perspectives of applied AI in design and the intentional design for AI systems within a unified conceptual model of DI. Unlike existing studies that treat these paradigms separately, this framework synthesizes technical, ethical, creative, and adaptive competencies into a layered structure tailored specifically for the complex and recursive ecosystem of human–AI collaboration in design. It uniquely emphasizes the multidimensional nature of AI literacy as foundational to effective engagement with DI systems, advancing beyond traditional notions of technical proficiency to include critical evaluation, ethical reasoning, and design-thinking methodologies. By doing so, the framework not only guides practitioners and educators in developing comprehensive AI literacy but also supports the sustainable and responsible integration of AI into design workflows, fostering innovation, inclusivity, and adherence to ethical standards across educational, professional, and societal domains. This holistic approach positions the framework as a pioneering tool for navigating the evolving challenges and opportunities at the intersection of AI and design.

The remainder of this paper is organized as follows: Section 2 provides a comprehensive review of AI literacy, outlining its evolution, key dimensions, and relevance across educational, professional, and societal contexts. Section 3 examines the concept of AiDD, exploring the integration of AI and design thinking, its transformative impact on creative practices, and the challenges it poses. Section 4 focuses on the intersection of AI literacy and AiDD, presenting a layered framework that highlights the technical, creative, ethical, and adaptive competencies required for effective engagement with DI systems. Section 5 discusses the critical importance of AI literacy in DI, emphasizing its role in enhancing human–AI collaboration, ensuring quality, promoting ethical use, fostering innovation, supporting professional competence, democratizing access, facilitating organizational transformation, and contributing to societal benefit. Finally, Section 6 summarizes the key findings, highlights the need for developing comprehensive AI literacy frameworks in

DI, and outlines recommendations for future research and educational initiatives.

2. AI literacy

The concept of AI literacy has evolved significantly over the past decade, reflecting the use of AI technologies in educational, professional, and social contexts. A comprehensive bibliometric analysis of research from 2014 to 2024 revealed that AI literacy education research has experienced exponential growth, mapping the current landscape, tracing its evolution, and identifying key themes through a systematic analysis of 335 relevant articles.¹⁸ The foundational understanding of AI literacy encompasses multiple dimensions that extend far beyond technical competencies.

AI literacy, as synthesized from various literature surveys in the selected text, can be defined as a multifaceted competency encompassing the knowledge, skills, and critical understanding necessary to effectively engage with AI technologies across educational, professional, and societal contexts. It extends beyond mere technical proficiency to include ethical reasoning, critical evaluation, creative application, and adaptive learning.

Recent systematic literature reviews indicate that AI literacy represents both a pedagogical and cognitive challenge, particularly at the K-12 level, where education systems must prepare students to live in a society characterized by ubiquitous human-AI interaction,^{19,20} more so than the influence of the Internet. The scope of AI literacy has been conceptualized using several frameworks. Contemporary research identifies AI literacy as encompassing education, ethics, and applications, with systematic reviews of 323 research studies revealing thematic trends that emphasize the relevance and complexity of AI literacy in the current era.²¹ This multifaceted approach recognizes that AI literacy encompasses not only technical understanding but also critical thinking, ethical reasoning, and practical applications.²² AI technologies may be the first human-made systems that could surpass human cognitive capabilities, perhaps not in behavioral and societal aspects.

Educational research emphasizes that AI literacy integration requires comprehensive educator training and curriculum adaptation to align with societal needs, focusing on personalized learning and support for diverse educational requirements.²³ The transformation of educational paradigms necessitates the adoption of new pedagogical approaches. AI literacy is increasingly recognized as a crucial aspect of media and information literacy, regarded not only as a human right but also as a fundamental competency for digital citizenship.²⁴ This perspective elevates AI literacy

from a specialized skill to a universal requirement for effective participation in contemporary society.

Primary education research demonstrates that AI literacy education requires evidence-based approaches to inform educators and researchers about appropriate content, including theoretical frameworks, pedagogical strategies, learning tools, and assessment methods.^{25,26} The systematic approach to AI literacy development emphasizes the importance of age-appropriate and context-sensitive educational design. Recent systematic reviews spanning 2019–2023 have revealed that AI literacy conceptualization involves complex constructs that require sophisticated implementation and assessment efforts across multiple domains and academic levels.²⁷

Technology education perspectives highlight that interest in AI literacy has intensified due to technological advances in AI, creating new imperatives for educational systems.²⁸ The promotion of AI curriculum integration in K-12 education reflects governmental and institutional recognition that students must develop AI literacy for digital citizenship, future career preparation, and daily living needs.²³ Contemporary research emphasizes empowering students to become creators, designers, and producers of AI technologies rather than passive consumers, indicating a shift toward more active and participatory forms of AI literacy.^{29,30}

In professional practice, technical competence, encompassing proficiency in AI tools, an understanding of machine learning principles, and effective data management, is closely tied to ethical reasoning.³¹ Professionals must not only master AI functionalities but also critically assess the ethical implications of its applications. This includes accountability for AI outputs, intellectual property rights, bias mitigation, and social impact considerations.³²

In a practical context, ethical competence ensures the responsible application of technical skills. For example, while technical proficiency enables the deployment of AI-driven design tools, ethical reasoning guides decisions regarding fairness, inclusivity, and transparency.³³ This dual competence prevents misuse or harm arising from AI-generated content and fosters trust in professional outputs.³⁴

It is essential to possess critical evaluation skills that bridge the technical and ethical domains. Professionals use these skills to validate AI outputs, detect biases or errors, and assess the appropriateness of AI applications in specific contexts.³⁵ This evaluative capacity supports the continuous improvement and ethical oversight of AI-augmented workflows.³⁶

The rapidly evolving AI landscape necessitates that professionals engage in lifelong learning to continually update their technical knowledge and ethical frameworks.³⁷ In this case, adaptive learning enables practitioners to respond to the emerging ethical challenges posed by new AI capabilities and regulatory environments, ensuring the ongoing responsible use of AI.³⁸

In brief, this review examines various aspects of AI literacy, with a primary focus on areas related to AI in education, including high school, higher education, professional practice, and societal engagement. The dimensions of AI literacy across contexts are summarized in Table 1. The dimensions are rooted in technical competence, ethical reasoning, critical evaluation, creative application, and adaptive learning.

3. AI-driven design for design

The emergence of AiDD represents a sophisticated evolution in the relationship between AI and creative practice, in which AI systems leverage and embody design principles.¹¹ Information system's research has increasingly adopted a design perspective on AI, with researchers prescribing solutions to problems using AI approaches rather than merely analyzing existing systems.³⁹ This paradigm shift indicates a fundamental transformation in the conceptualization of AI in design.

Systematic literature reviews examining the synergy between design thinking and AI reveal complex interactions that have profound implications for the design sector.^{40,41} The integration of design thinking methodologies with AI capabilities creates hybrid approaches that enhance human creativity and machine intelligence. Research demonstrates that AI is fundamentally transforming the design paradigm across multiple industries, creating unprecedented opportunities while introducing complex challenges through deep integration.⁴² This transformation extends beyond simple tool adoption to the fundamental reimagining of the design processes and outcomes. The impact is not only limited to the individual but also to the company.⁴³

Generative AI in creative contexts has garnered significant attention from the literature and organizations, particularly due to advances in machine learning techniques. However, research in this area remains in its early stages, with limited attempts to synthesize existing knowledge.⁹ The rapid evolution of generative AI technologies has outpaced comprehensive academic analyses, creating gaps in our understanding of optimal integration. Multiple studies have explored the impact of AI on the graphic design industry, examining how AI transforms creativity and efficiency within design practices.⁴⁴

Research on AI-generated image tools reveals significant impacts on both professional and non-professional users in the art and design fields, highlighting the democratization of design capabilities while raising questions about professional expertise.⁴¹ This democratization effect represents a double-edged phenomenon that expands creative access while potentially disrupting the established professional hierarchies. The advent of generative AI has led to a resurgence in design methods, promoting new research paradigms characterized by significant intersection and integration.⁴⁵

Critical interpretive synthesis approaches have revealed that AI applications in graphic design are reshaping design processes, creating opportunities and challenges that require systematic examination.⁴⁶ The complexity of these transformations necessitates sophisticated analytical frameworks that can capture both their positive potential and the emerging difficulties. Contemporary research indicates that AiDD encompasses multiple levels of integration: AI as a tool for designers, AI as a collaborative partner in design processes, AI as a generator of design solutions, and AI systems designed with human-centered design principles.⁴⁷

The literature reveals that successful AiDD implementation requires careful consideration of human-AI interaction patterns, ethical implications of automated design decisions, and preservation of human agency within AI-augmented creative processes.⁴⁸ Research emphasizes that effective AiDD systems must strike a

Table 1. Dimensions of artificial intelligence literacy across context

Dimension	Education (K-12, higher education)	Professional practice	Societal participation
Technical competence	Coding basics, machine learning concepts	Tool proficiency, data use	Understanding AI in daily life
Ethical reasoning	Fairness, inclusivity	Accountability, intellectual property rights	Social impact, bias awareness
Critical evaluation	Assessing AI tools	Validation of AI outputs	Media and AI literacy
Creative application	Maker projects, generative AI	Design prototyping, automation	Democratized creativity
Adaptive learning	Curriculum integration	Lifelong upskilling	Civic adaptability

Abbreviation: AI: Artificial intelligence.

balance between automation and human control, ensuring that AI capabilities augment rather than replace human creativity and judgment.⁴⁹

The three overlapping parts in [Figure 1](#) define the interdisciplinary space of DI, wherein AI literacy, design thinking, and AI-driven design converge to facilitate effective human–AI collaboration and innovation. The intersection of AI literacy and design thinking represents the integration of AI knowledge and design methodologies, where competencies include the critical assessment of AI tools within the design process, the application of ethical considerations to AI-augmented decisions, and the strategic use of AI capabilities to enhance creative problem-solving. It embodies the ability to navigate both technical AI concepts and human-centered design principles, fostering informed, responsible, and innovative design practices that leverage AI as a transformative resource for the future.

The intersection of AI literacy and design for AI focuses on the technical and ethical expertise required to develop and utilize AI systems specifically tailored for design tasks. It encompasses understanding the functional ties and constraints of AI, critically evaluating AI-generated outputs, and ensuring the responsible deployment of AI in automating or supporting the design workflow. This overlap highlights the necessity of proficiency in both AI system design and ethical stewardship to optimize AI's role as a design enabler.

The intersection of design thinking and design for AI encapsulates the fusion of human-centered design approaches with AI-driven design technologies. It emphasizes collaborative frameworks in which AI serves as

a creative partner or tool, complementing human ingenuity through generative and analytical capabilities. The focus lies on co-creative processes that combine empathetic design thinking with AI's computational strengths to produce innovative, user-centric design solutions.

4. AI literacy in AI-driven design for design

The intersection of AI literacy and AiDD represents an emerging field that requires specialized competencies that combine technical understanding, design thinking, and ethical reasoning. While direct research specifically addressing AI literacy in AiDD remains limited, several converging research streams provide insights into this critical area. The literature reveals that this intersection requires novel frameworks that address the unique challenges of AI–human collaboration in creative contexts.^{11,50} [Figure 1](#) outlines the overlap between AI literacy, design thinking, and AiDD within DI.

Educational research indicates that AI literacy in creative contexts requires enhanced critical thinking skills and comprehensive training approaches that align with diverse educational and professional requirements.^{18,23,51} The application of AI literacy principles to design intelligent contexts requires sophisticated pedagogical approaches that can address both the technical and creative competencies of learners. Bibliometric analyses reveal that AI literacy research has identified key themes, including educational applications, ethical considerations, and practical implementations, suggesting frameworks applicable to the DI context.¹⁸ One aspect that has not been addressed is the competency of AI design.

Systematic reviews emphasizing the relevance and complexity of AI literacy in recent contexts provide a foundation for understanding how AI literacy principles can be applied to the design of intelligent systems.²¹ The complexity of designing intelligent systems requires AI literacy frameworks that can address multilayered human–AI interactions and dynamic, creative processes. Research on design thinking and AI synergies suggests that AI literacy in design contexts must encompass an understanding of both technological capabilities and design methodologies.⁴⁰ The worst-case scenario is that both the technology and methodology are designed by AI.

Studies on the impact of AI-generated image tools on professional and non-professional users highlight the importance of AI literacy in ensuring the effective utilization of DI systems across different skill levels.⁴¹ This study suggests that AI literacy in design contexts must be scalable and adaptable to diverse user backgrounds and needs. Research on generative AI in creative contexts reveals that effective utilization requires a sophisticated

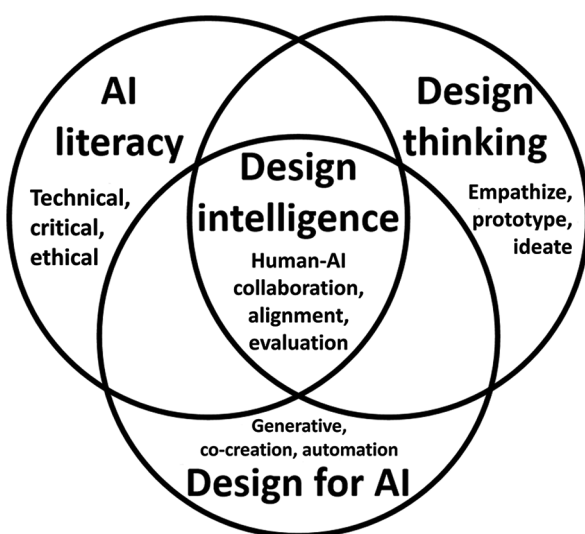


Figure 1. Venn diagram showing the overlap of artificial intelligence (AI) literacy, design thinking, and design for AI

understanding of both AI capabilities and creative processes.^{9,46} In this context, filming a movie, writing a novel, and painting an artistic piece have been significantly democratized.⁵²

The recognition of AI literacy as a fundamental aspect of media and information literacy suggests that AI literacy in DI contexts must address the broader issues of digital citizenship and social responsibility.²⁴ The application of AI literacy to DI requires an understanding of how these systems affect society, culture, and professional practice. Systematic reviews of AI literacy conceptualization reveal complex constructs that require sophisticated implementation approaches, indicating that AI literacy in DI contexts requires similarly nuanced frameworks.²⁷

Research on AI's transformation of design paradigms across multiple industries suggests that AI literacy in DI must address both the opportunities and challenges created by the deep integration of AI and design practices.^{42,45} Studies of new design paradigms characterized by AI integration indicate that AI literacy in these contexts must encompass an understanding of hybrid human-AI creative processes.⁴⁷ Critical interpretive synthesis approaches to AI in design suggest that AI literacy in DI requires a systematic understanding of how AI reshapes design processes and outcomes.⁴⁶

Emerging literature suggests that AI literacy in design must encompass several key domains: technical understanding of AI capabilities and limitations in creative contexts, design thinking competencies that enable effective human-AI collaboration, ethical reasoning about the implications of AI-generated design solutions, critical evaluation skills for assessing AI-assisted design outputs, and adaptive learning capabilities that enable continuous engagement with evolving AI technologies.^{28,29} This specialized form of AI literacy requires the integration of technical, creative, and ethical competencies that enable individuals and organizations to effectively navigate the complex landscape of DI systems.^{48,49}

The practical implementation of AI into existing workflows presents several challenges that must be addressed to ensure effective integration.⁵³ Organizations often face difficulties aligning AI-driven design tools with established processes,⁵⁴ requiring adjustments to accommodate new interaction patterns between human designers and AI systems.⁵⁵ This includes defining clear roles and responsibilities to balance automation and human oversight, as well as developing appropriate prompts and evaluation mechanisms to effectively guide AI outputs.⁵⁶ In addition, integrating AI demands technical infrastructure capable of supporting complex AI models alongside design tools, which may necessitate investments

in computing resources and data management.^{57,58} Resistance to change and varying levels of AI literacy among users can further complicate adoption, highlighting the need for comprehensive training and ongoing support to build proficiency and confidence.⁵⁹ Moreover, ethical considerations and quality assurance must be embedded within workflows to prevent misuse, bias, privacy issues, and overreliance on AI-generated content.^{60,61} Therefore, successful implementation requires a holistic and interdisciplinary approach that combines technical readiness, human-centered design thinking, organizational policy development, and adaptive learning strategies to foster the sustainable and responsible integration of AI into professional design environments.^{62,63}

The convergence of AI literacy and DI remains underexplored. The layered challenges include understanding AI capabilities and limitations, applying design thinking methodologies in AI-augmented contexts, navigating the ethical and professional implications of AI-generated content, and continuously adapting to evolving AI technologies.

The proposed layered framework of AI literacy in DI is illustrated in [Figure 2](#), which corresponds to [Table 1](#). This framework is also closely related to AiDD, where foundations, AI literacy competencies, and human-AI collaboration are directly derived from AI design competencies. AI design competencies within the context of AI literacy in AiDD encompass a specialized set of skills and knowledge that enable individuals to effectively create, evaluate, and refine AI systems tailored for design applications. These competencies require a deep understanding of AI functionalities, including algorithmic processes, machine learning models, and data management, combined with proficiency in design thinking methodologies to ensure that AI tools are human-centered, adaptable, and ethically aligned. Practitioners must be capable of critically assessing AI-generated outputs, identifying biases or limitations, and iteratively improving AI designs to meet their creative and functional objectives. Furthermore, AI design competencies involve

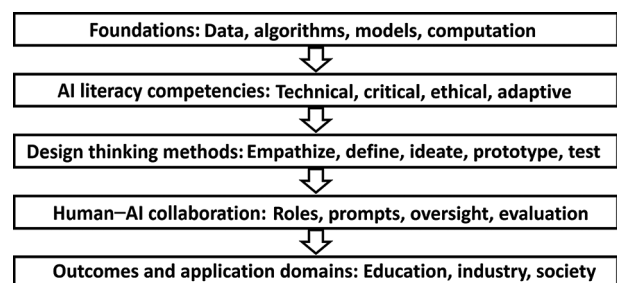


Figure 2. Layered framework of artificial intelligence literacy in design intelligence

ethical reasoning to navigate issues such as authorship, cultural sensitivity, and social impact, thereby ensuring responsible innovation. Adaptive learning is also crucial, as designers must continually update their skills to keep pace with the rapidly evolving AI technologies and integrate emerging capabilities into their design workflows. Together, these competencies form the foundation for developing AI systems that augment human creativity and foster effective, transparent, and collaborative human–AI partnerships within the AiDD ecosystem.

In short, the framework can be arranged into five layers (Figure 2). The first layer represents the foundation: data, algorithms, models, and computation. The foundational layer of DI is built on core components, including data, algorithms, models, and computing infrastructure. Data serve as essential inputs, capturing the diverse and complex information necessary for AI systems to learn and operate. Algorithms provide the procedural logic that drives AI decision-making and pattern recognition, whereas models represent the structured abstractions that AI systems use to interpret data and generate outputs. High-performance computing resources enable the processing and training of these models at scale, thereby facilitating rapid iteration and refinement. Together, these elements form the technical backbone that supports the development and deployment of AI technologies in DI frameworks.

The second layer represents AI literacy competencies: technical, critical, ethical, and adaptive competencies. AI literacy in DI encompasses a spectrum of competencies that enable effective and responsible engagement with AI systems. Technical competence encompasses understanding AI functionality, fundamental coding concepts, and machine learning principles. Critical skills focus on evaluating AI output, recognizing bias, and assessing the reliability of tools. Ethical reasoning addresses the fairness, inclusivity, accountability, and social implications of AI-generated content. Adaptive learning emphasizes continuous skill development to keep pace with evolving AI technologies and changing design contexts. These integrated competencies empower users to navigate the complexities of AI-enhanced design, ensuring quality, creativity, and ethical responsibility.

The third layer comprises design thinking methods, such as empathize, define, ideate, prototype, and test. Design thinking offers a human-centered methodology critical to DI, guiding the creative process through iterative stages. The empathize phase involves understanding user needs and contexts and ensuring that AI integration aligns with real-world problems. Define focuses on framing clear design challenges based on the gathered insights.

Ideate encourages the generation of diverse and innovative solutions, often by leveraging AI's generative capabilities. Prototyping involves creating tangible representations of ideas, allowing for exploration and refinement. Finally, the test phase evaluates prototypes with users and stakeholders, providing feedback to inform subsequent iterations. This cyclical process facilitates effective collaboration between human designers and AI systems, fostering innovation based on user experience.

The fourth layer is human–AI collaboration, which includes roles, prompts, oversight, and evaluation. Effective human–AI collaboration within DI requires clearly defined roles and interactions. Humans act as initiators, interpreters, and ethical overseers, guiding AI systems through well-crafted prompts that direct AI behavior toward desired outcomes. Oversight mechanisms ensure accountability and quality control, preventing overreliance on automation, and mitigating risks, such as bias or error propagation. Continuous evaluation of AI outputs by human collaborators enables iterative improvement, contextual adaptation, and alignment with professional and ethical guidelines. This balanced partnership leverages the complementary strengths of human creativity and AI computation to enhance the design processes and outcomes.

The fifth and final layer is outcomes and application domains, comprising education, industry, and society. The integration of AI literacy and DI manifests across multiple domains, producing diverse and impactful outcomes. In education, it fosters the development of critical competencies and adaptive learning strategies that prepare learners for a future shaped by human–AI collaboration. Within the industry, DI drives innovation, efficiency, and new business models by augmenting design workflows and enabling rapid prototyping and customization. Societally, it supports democratized access to creative tools, promotes inclusive design practices, and addresses ethical and cultural considerations, contributing to equitable and responsible technological advancement. These application domains illustrate the broad relevance and transformative potential of AI literacy in the DI ecosystem.

5. The importance of AI literacy in DI

The critical importance of AI literacy in AiDD stems from the transformative nature of DI systems and their profound impact on creative practice, professional development, and societal outcomes. Rather than constraining the development of AI technologies, AI literacy serves as an enabling framework that empowers individuals and organizations to fully utilize DI.⁶⁴

5.1. Enhancing human–AI collaboration

AI literacy in DI contexts plays a fundamental role in enabling more effective and seamless human–AI collaboration by equipping users with the necessary expertise, proficiency, and competencies to fully comprehend AI capabilities, recognize its limitations, and identify the most suitable points of integration within creative workflows.⁶⁵ This comprehensive understanding allows users to develop collaborative processes in which human creativity and AI's computational power function synergistically, each complementing the other's strengths.⁶⁶

Users with strong AI literacy are better positioned to discern the appropriate applications for various AI tools, knowing when automation can enhance efficiency and when human judgment and intervention are essential to ensure quality, contextual relevance, and adherence to ethical considerations.⁶⁷ This skillful balance optimizes the creative process by leveraging AI's ability to handle complex computations, generate novel ideas, and automate repetitive tasks while preserving the nuanced decision-making, intuition, and critical thinking that are unique to human designers.⁶⁸

Furthermore, AI literacy fosters the design and implementation of workflows that integrate AI tools to enhance productivity without undermining human agency and creativity.⁶⁹ It encourages users to actively engage with AI outputs, critically evaluate suggestions, and iteratively refine the results to ensure that the final outcomes meet professional, esthetic, and functional standards. This collaborative dynamic also supports adaptability, as users can modify their approaches in response to evolving AI capabilities and project requirements.⁷⁰

In addition, understanding the limitations of AI helps prevent overreliance on automated systems, thereby reducing the risks associated with errors, biases, or the inappropriate application of AI-generated content.⁷¹ AI-literate users can anticipate potential pitfalls and implement safeguards, such as human oversight checkpoints or ethical review processes, to maintain control over the design process and uphold accountability.

In short, cultivating AI literacy within DI contexts empowers users to strike an optimal balance between automation and human control, fostering innovation while safeguarding quality and ethical issues. This balanced integration enhances creative outcomes and contributes to the sustainable development and broader acceptance of AI-assisted design practices in the field.

5.2. Ensuring quality and effectiveness

DI systems generate outputs that are not final products but require careful human evaluation, refinement,

and adaptation to specific contexts before they can be effectively utilized. AI literacy equips users with essential critical thinking skills, enabling them to thoroughly assess AI-generated design solutions and discern their strengths and weaknesses.⁷² This includes identifying potential biases embedded within the outputs, recognizing the limitations inherent to AI models, and evaluating whether the results align with the intended professional, esthetic, and functional standards.

Such informed judgment is crucial to prevent the uncritical acceptance of AI outputs, which may lead to suboptimal or inappropriate design decisions. Users must apply their domain expertise to interpret AI suggestions, adjust or improve them as necessary, and ensure that the final design solutions are contextually relevant and ethically valid.⁷³ This process also involves continuous monitoring and validation to maintain quality control and uphold industry standards.

Moreover, AI literacy fosters an understanding of the collaborative nature between human designers and AI tools, emphasizing that AI serves as an aid rather than a replacement for human creativity and expertise. By developing these evaluative competencies, users can better integrate AI-generated content into their workflows, enhancing innovation while safeguarding against errors, biases, and misapplications.⁷⁴

In summary, the ability to critically engage with AI outputs ensures that DI systems contribute positively to design practices, producing outcomes that are not only technically proficient but also culturally sensitive, socially responsible, and aligned with users' needs and expectations. This human-in-the-loop approach is fundamental for maximizing the benefits of AI-assisted design and sustaining trust in emerging technologies.

5.3. Promoting ethical and responsible use

The integration of AI into design contexts introduces a range of critical ethical considerations that must be carefully addressed to ensure responsible and equitable use of these technologies. Central to these concerns are questions of authorship and originality, as AI-generated content challenges traditional notions of creative ownership and intellectual property. Users must understand how to appropriately attribute contributions when AI tools assist or autonomously generate design elements, striking a balance between innovation and respect for the rights of creators.⁷⁵

Cultural sensitivity is another vital ethical dimension, as AI systems can inadvertently perpetuate biases or misrepresent diverse cultural values if they are not properly designed and evaluated.⁷⁶ AI literacy equips users

with the knowledge to critically assess and mitigate such biases, fostering inclusive design practices that honor and reflect the richness of diverse cultural perspectives and experiences. This awareness helps prevent the reinforcement of stereotypes and the marginalization of underrepresented groups in AI-assisted design outputs.

Furthermore, the social impact of AI-driven design decisions requires careful consideration by designers. Designers and organizations must assess the impact of deploying AI technologies on communities, social equity, and society.⁷⁷ AI literacy provides frameworks for moral reasoning and ethical decision-making, enabling users to anticipate potential consequences, promote fairness, and align design outcomes with societal well-being.

Understanding these ethical challenges involves recognizing the limitations and responsibilities inherent in the use of AI. This includes transparency regarding AI involvement in the creative process, accountability for the generated outputs, and adherence to ethical standards that safeguard individual rights and public trust.⁷⁸ By fostering comprehensive ethical awareness, AI literacy empowers users to navigate the complex moral landscape of AI integration in design, ensuring that technological advancements contribute positively and justly to the cultural and social fabric of society.

Cultivating ethical competence through AI literacy is essential for guiding the development and application of AI in design fields. It encourages proactive engagement with ethical dilemmas, supports the creation of equitable and respectful design solutions, and reinforces the role of human judgment as a critical complement to AI capabilities in the design process. This integrated ethical approach helps secure the legitimacy and sustainability of AI-enhanced design practices in an increasingly interconnected and diverse world.

5.4. Fostering innovation and creativity

AI literacy in DI contexts plays a pivotal role in significantly enhancing innovative capacity by broadening the spectrum of creative possibilities available to users.⁷⁹ Far from limiting creativity, a strong foundation in AI literacy equips individuals with the skills and understanding necessary to fully harness the diverse functionalities of AI tools. This enables users to experiment more freely and effectively during the design process, exploring new techniques and approaches that were previously inaccessible or unimaginable to them.

With advanced AI literacy, users can identify unique and novel applications of AI technologies, pushing beyond conventional boundaries and venturing into uncharted territories of creative problem-solving. This capability

empowers designers to generate innovative ideas, iterate rapidly, and refine their concepts through dynamic, AI-assisted workflows.⁸⁰ Thus, the integration of AI tools has become a catalyst for creativity, providing new methods for ideation, prototyping, and evaluation that complement human intuition and expertise.¹²

Moreover, AI literacy fosters a nuanced understanding of how human-AI collaboration can be optimized to produce original and impactful outcomes. Users learn to recognize the strengths and limitations of AI systems, enabling them to strategically integrate these technologies in ways that amplify human creativity rather than replacing it.⁸¹ This synergy fosters a more dynamic and iterative design process, where AI serves as an enabler and co-creator, generating ideas that are both innovative and contextually relevant.

The enhanced creative capacity resulting from AI literacy also contributes directly to the ongoing evolution and refinement of DI systems. As users experiment and innovate, their insights and novel applications provide valuable feedback to developers and researchers, informing the improvements and adaptations of AI models and tools.⁸² This continuous cycle of innovation ensures that DI technologies remain responsive to emerging creative needs and challenges, fostering a vibrant ecosystem of design and technological advancement that is constantly evolving.

In addition, AI literacy supports the development of more inclusive and diverse creative practices by enabling a wider range of users from different cultural, social, and professional backgrounds to engage meaningfully with DI tools.⁸³ This inclusivity enriches the design landscape with varied perspectives and ideas, further driving innovation and expanding the possibilities of what can be achieved through DI design. By democratizing access to advanced creative capabilities, AI literacy helps break down traditional barriers and opens new pathways for collaboration and expression.

Ultimately, cultivating AI literacy within DI contexts empowers users to harness the creative potential of AI technologies, fostering a collaborative environment where human creativity and machine intelligence intersect. This intersection not only leads to groundbreaking and impactful design outcomes but also drives the sustainable growth and continuous improvement of DI systems, ensuring their relevance and effectiveness in addressing complex and evolving challenges.

5.5. Building adaptive professional competence

The rapid evolution of AI technologies requires professionals to consistently update their skills and adapt to emerging tools and methodologies.⁸⁴ AI literacy serves

as a crucial foundation by providing essential knowledge about AI concepts, applications, and frameworks for continuous learning and skill development in the dynamic context of DI. This ongoing adaptability is crucial for professionals to maintain their relevance, competence, and effectiveness in the face of rapidly advancing AI technologies.

Moreover, AI literacy enables individuals to critically evaluate new AI tools and approaches, discerning their potential benefits and limitations in specific domains. This critical perspective fosters informed decision-making and strategic adoption of AI technologies, ensuring that professionals can integrate these tools in ways that enhance their work without compromising the quality or ethical standards of the work.⁸⁴

The capacity for lifelong learning, supported by AI literacy, also encourages innovation and resilience.^{85,86} As AI technologies evolve, professionals who continually educate themselves are better positioned to anticipate changes, respond proactively, and leverage new capabilities to address complex problems in their field. This adaptability benefits individual career growth and contributes to the broader organizational and societal capacity to harness AI for positive and sustainable impact.

In summary, AI literacy is essential for cultivating a professional workforce that can navigate the complexities of rapid technological change, maintain high performance, and drive responsible innovation in the digital era.

5.6. Supporting democratic access and participation

AI literacy plays a crucial role in democratizing access to advanced design capabilities by empowering a wider range of individuals and communities to use DI tools effectively.^{87,88} This democratization process helps lower traditional barriers to creative participation, allowing more people, regardless of their background or prior technical expertise, to engage in innovative design activities. By expanding the user base of DI technologies, new opportunities for entrepreneurship emerge, fostering economic growth and enabling diverse voices to contribute to the design landscape.

Moreover, democratizing access to DI tools encourages inclusive design practices that reflect a broader spectrum of cultural, social, and individual perspectives. This inclusivity is essential for creating products and solutions that better serve diverse populations and address complex societal challenges.⁸⁸ However, simply making these tools available is not sufficient. Effective democratization requires comprehensive education and ongoing support systems to ensure that users understand how to apply DI technologies responsibly and skillfully.⁸⁹ Without such guidance, the

risk of misuse, misunderstanding, or underutilization of these powerful tools increases significantly.

Educational initiatives should focus not only on technical training but also on fostering awareness of ethical considerations, social impact, and cultural sensitivity in design.^{90,91} Support mechanisms, such as community forums, mentorship programs, and accessible resources, can further enhance user confidence and competence. Together, these efforts help build a foundation in which DI technologies contribute positively to innovation, diversity, and equitable access in design.

5.7. Facilitating organizational transformation

Organizations integrating DI systems require a workforce equipped with comprehensive AI literacy to effectively manage and navigate the complex transformation processes that these technologies bring.⁹²

This involves a thorough understanding of how AI tools can be seamlessly incorporated into existing workflows, ensuring that their capabilities are leveraged to enhance productivity and innovation without disrupting established practices.⁹³ In addition, organizations must identify the appropriate applications of DI systems, recognizing both their potential benefits and inherent limitations, to avoid misuse or overreliance.⁹⁴

Developing clear organizational policies and practices that support effective human–AI collaboration is another key aspect of AI literacy.^{95,96} Such policies help define roles, responsibilities, and ethical guidelines, fostering an environment in which AI technologies complement human expertise rather than replacing it entirely. At the managerial level, AI literacy enables leaders to make informed decisions about the adoption and scaling of DI technologies, aligning them with broader organizational goals and ensuring sustainable integration.⁹⁷

Organizations undergoing AI-mediated transformation provide concrete examples of how DI systems reshape workflows and culture. For instance, a global automotive company implemented AI-driven generative design tools to accelerate product development, enabling engineers and designers to collaboratively explore thousands of design alternatives rapidly, reducing prototyping cycles, and fostering innovation.⁹⁸ Similarly, a multinational architecture firm integrated AI-powered project management platforms that analyzed real-time data to optimize resource allocation and predict project risks, enhancing operational efficiency and decision-making.^{99,100} In the creative marketing sector, agencies have adopted AI-assisted content generation and client engagement systems that automate routine tasks, allowing human teams to focus on strategic and creative aspects. This

transformation of roles and increased productivity^{101,102} enables agencies to streamline their operations. These examples demonstrate that AI literacy is essential for managing new human–AI interaction patterns, developing appropriate governance policies, and fostering adaptive learning cultures that support the sustainable and responsible integration of AI technologies within organizations.

Moreover, fostering AI literacy across all organizational levels promotes a culture of continuous learning and adaptability, which is essential, given the rapid evolution of AI capabilities in recent years. This cultural shift encourages proactive problem-solving, critical evaluation of AI outputs, and responsible innovation. Ultimately, AI literacy within organizations not only facilitates successful technological adoption but also ensures that DI systems contribute positively to operational efficiency, employee engagement, and long-term organizational success.

5.8. Contributing to societal benefit

The broader societal impact of DI systems is significantly influenced by the extent to which diverse stakeholders comprehend and effectively utilize these technologies.¹⁰³ Achieving meaningful benefits from AI and DI systems requires more than just technical proficiency; it calls for a deep and widespread understanding of AI literacy across society. This literacy ensures that DI capabilities are applied thoughtfully and strategically to address genuine societal needs rather than being misused or deployed inappropriately.¹⁰⁴ Moreover, it is essential that these systems are designed and implemented in ways that respect and honor cultural diversity, acknowledging different values and perspectives to avoid biases and unintended harm.¹⁰⁵ In addition to technical knowledge, stakeholders must cultivate strong social and ethical awareness.

This broader understanding guides the development and use of DI systems toward outcomes that are innovative, socially beneficial, and equitable. Ethical obligations include transparency, fairness, accountability, and protection of individual rights, which are crucial for maintaining public trust and ensuring that the deployment of DI technologies contributes positively to social welfare. Ultimately, the positive societal effects of DI systems depend on an integrated approach that combines technical expertise with a commitment to ethical principles and cultural sensitivity, fostering inclusive progress and sustainable impact.

In short, AI literacy is not a constraint on AI development; it is an enabler of responsible, innovative, and inclusive DI.

6. Conclusion

AI literacy in DI represents a critical competency for integrating human–AI collaboration in creative and analytical contexts. The literature reveals that this specialized form of literacy encompasses technical understanding, design thinking, ethical reasoning, and adaptive learning skills. Rather than constraining AI development, AI literacy serves as an enabling framework that empowers individuals and organizations to effectively harness the potential of DI systems while addressing associated challenges and responsibilities. The importance of AI literacy in this context extends beyond individual professional development to encompass broader societal implications, including democratic access to creative tools, ethical deployment of AI capabilities, and responsible innovation in design practice. As DI systems continue to evolve, the need for sophisticated AI literacy frameworks that can address the complex intersection of technology, creativity, and human values becomes increasingly urgent and important.

Immediate actions include developing comprehensive educational frameworks in DI contexts, investigating practical pedagogical approaches for diverse audiences, and exploring the long-term implications of human–AI collaboration in creative practice. For instance, longitudinal studies in graphic design, architecture, or digital media should be conducted to evaluate how DI impacts creative outcomes and collaboration effectiveness. Meanwhile, exploring case studies of human–AI collaboration in advertising or design can help understand ethical decision-making and adaptive learning in real-world settings. Using the proposed framework, we can examine the societal implications of DI in public-facing creative sectors, such as museum curation and interactive storytelling, focusing on democratic access and responsible innovation. Simultaneously, we should investigate pedagogical interventions in design education and industrial design programs to identify the best practices for teaching AI literacy tailored to these disciplines.

The successful integration of DI into society requires not only technological advancement but also the cultivation of human competencies that enable effective, ethical, and creative engagement with these systems. The cultivation of AI literacy in DI should be viewed as an investment in human potential rather than a constraint on technological progress. By empowering individuals and organizations with DI systems, we can ensure that these technologies enhance human creativity, improve design quality, and make a positive contribution to society. This approach recognizes that design does not replace human creativity with AI but is a sophisticated collaboration between

human insight and AI capabilities, guided by informed, ethical, and creative judgment.

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