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Enhancing Metacognitive Competencies through Human-Centered AI: The Role of Custom-Trained Intelligent Agents in Workforce Upskilling

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1. Abstract

This editorial examines the integration of human-computer intelligent interaction (HCII), specifically through human-centered artificial intelligence (AI) and custom-trained intelligent agents, to foster metacognitive competencies critical for workforce upskilling. With 59% of the workforce projected to require substantial upskilling by 2030, developing personalized AI models tailored to individual cognitive and learning profiles presents an innovative pathway. These custom-trained agents leverage human-computer interaction (HCI) technologies and machine learning methodologies to enhance understanding of one's own learning processes-metacognition-thus empowering individuals to optimize their future learning and adaptability. This approach not only enhances the individual's ability to engage effectively with complex tasks in the workplace but also supports lifelong learning strategies mandated by contemporary labor markets. The editorial synthesizes current research findings and theoretical frameworks to explore the transformative potential of AI-driven metacognitive training in education and industry, proposing future directions and considerations for widespread implementation.

2. Keywords

Human-Centered AI, Metacognition, Workforce Upskilling, Custom-Trained Agents, Human-Computer Intelligent Interaction (HCII)

3. Introduction

The convergence of artificial intelligence and human-computer interaction has led to the emergence of human-computer intelligent interaction (HCII), significantly transforming education and workforce development.

As contemporary workplaces increasingly require advanced cognitive and adaptive capabilities, cultivating metacognitive skills-defined as individuals ability to recognize, understand, and regulate their cognitive processes-has become essential [1]. The anticipated need for extensive workforce upskilling, projected to affect approximately 59% of the global workforce by 2030, underscores the urgency to leverage advanced technological solutions to support this transition [2]. The rapid evolution and integration of artificial intelligence across various industries are expected to reshape the global economic landscape by 2030. According to the World Economic Forum, AI and automation will generate around 170 million new jobs while concurrently displacing

approximately 92 million roles, compelling organizations to rapidly adapt to these technological shifts [3]. Such significant labor-market transformations emphasize the critical necessity of workforce upskilling to meet the evolving demands of new job categories. Furthermore, the World Economic Forum's Reskilling Revolution initiative aims to deliver enhanced education, skill development, and employment opportunities to 1 billion people by 2030, reflecting the magnitude of the global upskilling imperative [4,5]. This initiative underscores the importance of equipping workers with essential competencies to succeed in an increasingly AI-driven economy.

Within this evolving context, metacognitive skills-including critical thinking, self-regulation, and the capacity to effectively manage one's own learning-become increasingly crucial. The OECD's Future of Education and Skills 2030 project highlights that as the technology advances, individuals will increasingly need to leverage inherently human attributes such as creativity and self-directed learning [6,7]. Strengthening these metacognitive capabilities will empower individuals to effectively adapt to technological innovations and successfully navigate the complexities of contemporary workplaces. Thus, fostering metacognitive skills is essential not only for individual career progression but also for sustaining economic competitiveness in an era fundamentally reshaped by emergent technologies.

4. Custom-Trained Intelligent Agents for Metacognitive Reflection

A compelling approach within HCII involves training custom intelligent agents specifically designed around individual cognitive and learning profiles. These tailored agents function not merely as facilitators for task completion but, importantly, as powerful instruments for enhancing metacognitive reflection. Through assisting users in recognizing their learning preferences, strengths, weaknesses, and cognitive strategies, these systems foster deeper self-awareness and self-regulated learning [8]. Effective customization of these models incorporates numerous individual variables such as personality traits, cultural contexts, and cognitive predispositions, thereby aligning closely with personalized learning processes [1]. Through continuous interactions and targeted feedback, these intelligent systems enable individuals to develop explicit knowledge and awareness of their cognitive strategies, directly contributing to lifelong learning and improved adaptability.

Custom intelligent agents utilize advanced artificial intelligence techniques, including machine learning and data analytics, to personalize educational content and learning strategies effectively. These agents analyze comprehensive data sets derived from user interactions, preferences, and performance metrics to identify the most effective learning pathways, appropriately adjust task difficulty, and deliver precise feedback tailored to each user's unique learning style [9]. This customized approach significantly enhances user engagement and overall learning outcomes by aligning instruction closely with individual learner needs and pacing. Empirical evidence has demonstrated that such personalized learning systems substantially improve student performance through tailored instructional methods that resonate with diverse learner profiles [10,11]. Consequently, users benefit from optimized learning experiences that are both motivating and directly applicable to their cognitive and educational development [12].

Beyond content personalization, custom intelligent agents actively promote the development of critical metacognitive skills by prompting learners to engage in reflective thinking about their cognitive processes. These agents encourage users to assess their problem-solving strategies, recognize and rectify misunderstandings, and adjust learning approaches accordingly. Such reflective practice is instrumental in cultivating self-regulated learners capable of adapting to complex and evolving challenges in dynamic environments [13]. Studies consistently show that smart educational tools significantly increase student engagement in self-reflection, thereby enhancing their metacognitive capabilities and fostering higher-order thinking skills essential for lifelong learning [14,15]. Thus, these agents not only support immediate educational tasks but also equip learners with enduring cognitive competencies.

Furthermore, effective customization of intelligent agents necessitates careful consideration of individual differences, including personality traits, cultural backgrounds, and cognitive preferences. Through integrating these dimensions, intelligent agents provide learning experiences that are both culturally sensitive and emotionally relevant, thus maximizing educational impact and relevance. This holistic approach ensures learners experience academic support that respects their unique backgrounds, fostering a sense of personal validation and deeper engagement with learning content [16]. As a result, learners experience increased motivation and improved educational outcomes, making personalized learning not only effective academically but also enriching culturally and emotionally.

Continuous interaction between custom-trained intelligent agents and users enables the provision of timely and targeted feedback based on real-time data regarding user performance and engagement. This ongoing interaction allows learners to continuously refine their understanding of their cognitive processes, reinforcing effective learning strategies and promoting continuous improvement. For instance, agents capable of simulating coaching interactions can offer immediate, individualized guidance, providing learners with precise recommendations and support tailored to their current cognitive and educational needs [17]. Consequently, this approach fosters an ongoing cycle of reflective learning and sustained cognitive development, preparing individuals effectively for future educational and professional challenges.

Finally, the implementation of custom intelligent agents directly addresses critical issues of scalability and accessibility within educational and professional training contexts. Through the automation of personalized instructional support, these platforms significantly expand access to high-quality learning experiences, accommodating a larger and more diverse learner population without sacrificing instructional quality. This democratization of personalized learning opportunities is particularly valuable in resource-limited educational environments, where individualized attention and coaching are typically constrained. Recent developments in personalized coaching platforms exemplify this potential, making professional development and educational enrichment widely accessible, thus promoting equitable educational opportunities across diverse settings [18].

5. Importance of Metacognition in the Age of AI

Metacognition, defined as the active regulation and orchestration of one's cognitive processes, serves as a foundational element for effective learning and adaptability in rapidly changing environments. Maier and Triff [8] demonstrate that purposeful integration of intelligent tools into problem-solving activities substantially enhances cognitive self-regulation, enabling individuals to strategically plan, monitor, and assess their approaches to complex tasks. This reflective process, augmented by AI, aligns with the Council of Europe's "learning to learn" competence framework, which highlights lifelong learning as critical in adapting to evolving technological contexts [19]. Research further emphasizes that deliberate reflection facilitated by smart tools deepens learner understanding and enhances their problem-solving techniques, which are crucial for navigating successful transitions within the workforce [2]. Through customized cognitive scaffolding, these systems guide individuals towards adopting more efficient and effective learning strategies, thus improving both task performance and personal cognitive growth [1]. Nevertheless, recent studies also highlight potential pitfalls associated with such integration, notably the phenomenon of "metacognitive laziness". This occurs when users become excessively reliant on technology, consequently reducing their own engagement in essential self-reflection processes. For example, university students who received assistance exhibited enhanced task performance but simultaneously showed reduced engagement in self-regulated learning practices, underscoring the necessity for balanced incorporation into educational environments to sustain active metacognitive involvement [20].

Moreover, integrating these approaches into educational settings presents both opportunities and challenges for cultivating metacognitive capabilities. Although the agents provide personalized feedback and adaptive learning environments that support metacognitive development, a significant risk remains that learners may become passive recipients of generated information without critically evaluating its validity or relevance. Therefore, it becomes crucial to design systems that actively involve learners in metacognitive practices, prompting them to thoughtfully plan, monitor, and evaluate their learning strategies [21]. Within the context of workforce development, metacognitive competencies are indispensable for effective collaboration with these technologies. As these agents becomes more prevalent across professional fields, employees must proficiently manage and critically evaluate their interactions with such systems. This capability includes assessing generated recommendations, recognizing the limitations of technology, and synthesizing human judgment with AI-driven insights. Strengthening these metacognitive skills ensures that workers effectively harness the tools to enhance productivity while maintaining accountability and adhering to ethical standards [22].

6. Interdisciplinary Approaches and Technological Frameworks

The successful implementation of custom-trained intelligent agents necessitates an interdisciplinary approach integrating HCI, cognitive science, and advanced artificial intelligence technologies, including deep learning and natural language processing (NLP) [23]. This synergistic framework supports the development of systems capable of interpreting and responding to user interactions in ways that are both contextually appropriate and cognitively aligned with individual learning styles. Through leveraging insights from cognitive psychology, these systems can mimic human cognitive processes, enhancing user engagement and facilitating intuitive interactions. For instance, advanced deep learning algorithms have significantly improved gesture and speech recognition capabilities, enabling more natural and fluid human-computer dialogues and interactions [24].

In educational and workforce contexts, integrating intelligent agents serves a dual purpose: Providing immediate task assistance and fostering metacognitive development. Through engaging learners and employees in the active process of training these agents for specific tasks, individuals not only gain mastery over the relevant subject matter but also enhance critical self-regulation and reflective skills. This "learning by teaching" methodology requires users to explicitly reflect on their knowledge and problem-solving strategies, thereby promoting deeper metacognitive awareness and improved cognitive self-regulation [25,26]. Additionally, these agents can offer personalized feedback tailored to individual cognitive profiles, further reinforcing effective learning strategies and fostering greater self-awareness [23].

Effective human-computer collaboration through intelligent user interfaces (IUIs) further enables seamless integration of supported metacognitive strategies into everyday professional activities. Such integration transforms workplaces into environments where continuous learning and cognitive reflection naturally occur, thus contributing to sustained individual growth and adaptability. These systems with advanced NLP capabilities, for instance, facilitate natural conversational interactions, enabling users to clearly articulate their cognitive processes and receive contextually relevant feedback. This process not only enhances task performance but also actively encourages the practice of metacognitive reflection [27]. Thus, the interdisciplinary convergence of HCI, cognitive science, and AI is critical for developing intelligent agents that both streamline task completion and cultivate metacognitive skills essential for lifelong adaptability. Through actively involving learners and workers in training these agents and embedding reflective practices into IUIs, systems can effectively support both immediate productivity and long-term cognitive development. Such holistic integration underscores the transformative potential of the technologies to enhance human intelligence rather than merely automate routine tasks [28].

7. Future Directions and Implementation Considerations

Looking forward, the integration of custom-trained intelligent agents into educational curricula and workforce training programs promises transformative impacts. These systems can potentially bridge critical skill gaps, preparing individuals for the cognitive demands of future labor markets. Nevertheless, significant implementation challenges remain, including ensuring ethical standards, transparency, and explainability of AI-driven decisions, along with addressing diverse user acceptance and trust issues [1]. Of course, widespread adoption of these intelligent systems will require collaborative efforts across academia, industry, and policymakers to create supportive frameworks that facilitate ethical, effective, and accessible use of agents for

metacognitive enhancement. The strategic use of custom-trained intelligent agents represents a significant advancement in fostering metacognitive competencies critical for future workforce readiness. Embracing these technologies within human-centered agentic frameworks positions individuals not merely as passive consumers but as empowered agents of their cognitive growth, driving sustainable lifelong learning practices essential in the age of AI.

8. References

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