

Digital Competence, Cognitive Experience, and Perceived Value of Augmented Reality for Adult Education

Alexandru Bibic

“Ion Creangă” State Pedagogical
University of Chişinău
Chişinău, Republic of Moldova
alex_bibik@icloud.com

Mihail Terenti

MintViz, MANSiD Research
Center, Ştefan cel Mare
University of Suceava
Suceava, Romania
mihail.terenti@usm.ro

Andrei Braicov

“Ion Creangă” State Pedagogical
University of Chişinău
Chişinău, Republic of Moldova
braicov.andrei@upsc.md

ABSTRACT

Extended Reality (XR) technologies encompassing Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR), offer new perspectives for adult education in the digital era. This article examines the impact of AR applications on the development of adults' digital competence directly, targeting the five domains of the European DigComp 2.2 framework, and indirectly by reducing technology anxiety, lowering cognitive load, and increasing motivation for digital learning. Based on a literature review, we discuss reported benefits and limitations of AR technologies for digital competencies development. We then report results from a user study involving 20 participants representing medical professionals, who rated digital competence, cognitive experience, and perceived educational value for learning and education.

AUTHOR KEYWORDS

Augmented Reality; Digital competence; Adult education; DigComp 2.2; DigCompEdu; Continuing education.

DOI: 10.37789/icusi.2026.11

Introduction

The rapid development of digital technologies has increased the need for adults to acquire and continuously update digital competence, understood as a key condition for lifelong learning and participation in contemporary social, professional, and civic life [9]. However, many adults, especially those from older age groups or professionally underserved contexts, still lack basic digital skills [8]. This gap includes technical aspects, such as use of digital devices and broader competencies such as confidence, critical information processing, digital safety, problem solving, and the transfer of digital practices across learning, work, and everyday situations.

In recent years, AR technologies have been widely explored as tools for developing digital competencies among various groups of users. Such applications support the development of new competencies and skills by increasing user engagement, providing interactive visualizations and learning experiences. However, there are still challenges associated with the use of AR tools to develop digital competencies, including technical limitations and the need for appropriately dealing with cognitive load. In this context, it is important to examine both the educational potential of AR applications, and the challenges associated with their implementation. The aim of this paper is to examine the challenges and the benefits of AR applications, as part of XR technology, for developing digital competencies in adult users and how such tools can contribute to their development through the direct activation of the five

DigComp 2.2 domains and indirect cognitive effects, such as reduced technology-related anxiety and increased motivation to engage with digital tools [24]. We also report findings from a pilot study evaluating users' perceptions of the impact of an AR learning application on their digital competencies.

Impact of AR on the Development of Digital Competencies

In this section, we discuss the impact of AR applications on the development of digital competencies in adults. We summarize the main findings from previous studies and discuss the potential benefits and challenges of using AR technologies for developing digital competencies.

Direct Impact

The concept of digital competence includes a broad set of knowledge and skills that enable individuals to use digital technologies effectively, critically, responsibly, and confidently in different areas of life. As digital literacy is a multidimensional concept, we rely on the DigComp 2.2 framework as one of the most widely recognized frameworks for describing digital competence [24]. It divides digital competencies into five interrelated competence areas: information and data literacy, communication and collaboration, digital content creation, safety, and problem solving.

Research on the contribution of AR tools to the development of information and data literacy within the DigComp 2.2 framework remains limited. Existing studies mainly focus on teachers or specific professional fields rather than on the general public [1, 7]. Recent research has also explored the integration of Large Language Models (LLMs) as powerful tools for accessing and organizing personalized information. For example, Gao et al. [11] integrated LLMs into virtual learning environments to create personalized learning spaces and demonstrated that these environments can improve users' digital skills alongside learning outcomes.

Regarding communication and collaboration, AR technologies support shared virtual spaces for interaction, knowledge exchange, and teamwork. However, research in this area has mainly focused on specific professional contexts. For example, Olaosebikan et al. [16] developed a virtual collaborative environment for researchers that supported note-taking and information sharing among researchers. AR applications are still rarely designed specifically to develop digital communication and collaboration competences. In education, AR is increasingly used to support collaboration between teachers and students through more engaging learning environments [2, 15]. Although students and teachers show interest

in these technologies, a lack of technical skills among instructors remains one of the main challenge. Many online learning platforms now offer courses to improve digital communication skills and technology use.^{1,2}

AR applications are widely used to develop content creation competences because they allow users to visualize and present information in a more interactive way. AR content is often more engaging and interactive, but creating it requires technical skills from users. Studies show that positive learning outcomes motivate teachers to improve their digital content creation skills [1, 18]. Similar results are found in other fields, such as nursing education, where AR simulations help students practice clinical skills [7]. Merchant et al. [14] found that active participation in digital content creation is a strong factor in developing digital competences.

Within the digital safety domain, virtual tools and simulations show promising results in improving awareness of online risks and users' ability to respond to security threats. For example, phishing simulation studies [12, 13] indicate that interactive training can increase attack-recognition rates by 35-40% compared to conventional approaches. Similarly, Vishwanath [23] reported that trained employees reduced phishing click-through rates from 18% to 4%, while conventional training reduced rates from 17% to only 11%. Similar positive results have been reported in the problem-solving domain, where AR technologies support experimentation, critical thinking, and practical digital skills development.

The European Silver VR project³ followed adults over 65 who participated in weekly VR sessions over 12 weeks. Participants achieved an average 28% increase in digital competence scores (DigComp-based assessment), compared with 11% in the control group. Notably, 73% of participants continued autonomous use of digital tools after the end of the program.

Indirect Impact

In addition to helping adults develop digital skills directly, AR applications can also contribute to digital competence in indirect ways. Instead of teaching digital skills explicitly, AR creates learning experiences that can improve learners' perception of technology, increase their motivation, positively impact perceived cognitive load [5], and encourage them to use digital tools more often [24]. These changes can support the development of digital competence over time, especially among adults who may initially have limited confidence in using technology.

One important indirect effect of AR is the reduction of technology anxiety. Technophobia, defined as fear or anxiety related to the use of computerized technology [6], is widely reported as a major barrier to digital competence development among older adults [20]. This is compounded by a substantial digital skills gap: only 33% of EU citizens aged 65-74 possessed at least basic digital skills in 2025, compared to approximately 75% among those aged 16-34.⁴ AR applications may help reduce this anxiety because they rely on more natural interactions, such as gestures and voice commands, instead of complex menus or text-based commands. Structured, gradual exposure to immersive technologies through short guided

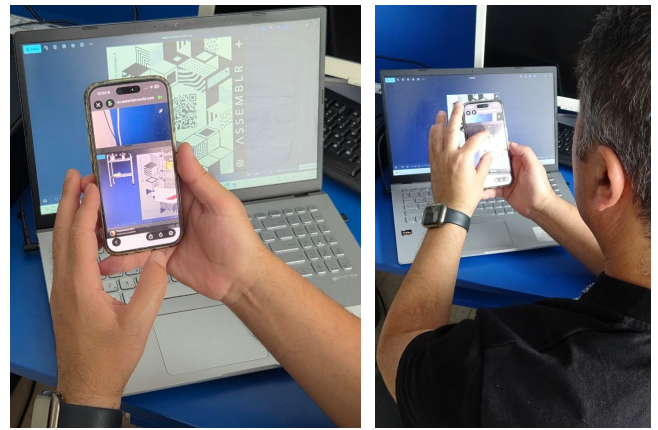


Figure 1: Pilot study participants interacting with the AR application using a smartphone.

programs has been shown to support higher levels of technology acceptance and reduced apprehension among older adults, even after relatively brief periods of engagement. This research also showed that participants became more willing to use other digital technologies.

AR applications may also increase motivation to engage with digital technologies. Their immersive and interactive nature can create “flow,” an experience described by Csikszentmihalyi [10], helping learners stay focused and engaged in learning activities. Ryan and Deci [19] explain this effect through Self-Determination Theory, arguing that motivation increases when the needs for competence, autonomy, and relatedness are satisfied. As adults become more confident when using AR applications, they may also become more willing to explore other digital technologies, supporting the gradual development of digital competence.

Interacting with AR applications can also develop cognitive skills via cognitive augmentation [21]. Exploring three-dimensional virtual environments helps developing spatial reasoning, which has been linked to more effective use of complex digital interfaces [5, 22]. A recent instrument for assessing cognitive extension in XR environments, XR-CES [3], supports evaluation of cognitive extension across seven dimensions. Its evaluation revealed statistically significant differences across groups of learners based on exposure, e.g., higher perceived attention, thinking, cognitive integration, and cognitive sustainability extension from 20 to 40 minutes of exposure to the virtual environment in a mobile AR application. Follow-up confirmation on a larger sample [4] further strengthened the theoretical model of XR-CES.

Study

Procedure

We conducted a user study to evaluate an educational mobile AR application designed for first-aid training. The application guided participants step-by-step through a wound-care procedure. First, participants received a brief introduction to the first-aid procedure by watching a video incorporated into the AR environment (Figure 1). They then completed an AR demonstration, following the required steps through visual and audio guidance. After the practical activity, participants completed a short knowledge quiz to evaluate the retention of the presented information.

¹<https://www.coursera.org/learn/augmented-reality>

²<https://epale.ec.europa.eu/ro/online-course-catalogue>

³<https://www.silvergrow.eu/menu/project/digital-skills-virtual-reality>

⁴https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Skills_for_the_digital_age

Participants. The study involved 20 adult participants aged between 18 and 61 years. Of these, 16 self-identified as female and 4 as male. Most participants reported little or no prior experience with AR/VR technologies, making the sample representative of typical adult learners encountering immersive technologies for the first time.

Measurements. Participants completed a questionnaire using a five-point Likert scale, from 1 (strongly disagree) to 5 (strongly agree). The questionnaire was designed to evaluate four aspects of the user's perception of interaction with the AR application, as follows:

- Digital competence was evaluated through self-reported digital competence, technical confidence and technology-related stress;
- Interaction with the AR app regarding navigation, accessibility, task execution, and task understanding;
- Cognitive experience during AR interaction evaluating processing multimodal information, distributed attention, and cognitive overload;
- Perceived educational value for learning, content understanding and retention, educational potential.

For each of the four measurements, a score was calculated by averaging the values of the contributing dimensions. Before calculating the average, the negatively connotated dimensions were reverse-scored by subtracting their values from 6, resulting in scores ranging from 1 to 5. The negatively connotated dimensions were the technology-related stress dimension from the Participants' Digital Competence measurement and the cognitive overload dimension from the cognitive experience ratings. After the study, a short informal interview was conducted to explore participants' experiences with the AR application and their perceptions of its potential impact on the development of digital competencies.

Results

The results indicate a positive perception of AR application and the learning experience. Participants reported a relatively high level of digital competence, with an average of 4.10 ($SD = 0.65$). Among the contributing dimensions, the participants reported an average score of perceived technical confidence of 4.30 ($SD = 0.86$) and for self-reported digital competence an average of 4.10 ($SD = 0.91$). The self-reported level of stress when using new technologies was evaluated with an average score of 2.10 ($SD = 1.29$). Although most participants had little or no prior experience with AR/VR technologies, they generally considered themselves digitally competent, expressed confidence in solving simple technical issues. They also reported openness to explore new technologies and reported low to moderate levels of stress when interacting with them.

The interaction with the AR application received a high average score of 4.53 ($SD = 0.64$). Overall, participants found the application easy to navigate, appropriate for their level of digital skills, and they were able to follow the proposed workflow. The contributing dimensions also received high ratings, with mean scores of 4.40 ($SD = 0.75$) for navigation, 4.65 ($SD = 0.67$) for accessibility, 4.60 ($SD = 0.75$) for task understanding, and 4.45 ($SD = 1.10$) for task execution. The overall feedback remained positive, and most participants were able to complete the tasks successfully, yet a small number of participants experienced some navigation difficulties.

For instance, P_{15} commented that they experienced difficulties following the application's instructions because they had to move the smartphone around to locate and view the virtual elements. However, after becoming familiar with the application, they recognized that it positively changed their perception of new technologies and expressed interest in using similar applications in the future. This suggests that unfamiliar interaction methods in AR may initially present challenges for users with limited technological experience, but the interactive nature of AR experiences can help users overcome these difficulties and develop confidence and acquire new digital competencies.

Regarding the cognitive experience, participants reported a positive evaluation, with an overall average score of 4.00 ($SD = 0.57$). Overall, they indicated that they were able to process the simultaneous audio and visual guidance, manage multiple sources of information, and maintain their attention throughout the activity. The individual dimensions also received positive ratings, with average scores of 4.60 ($SD = 0.68$) for processing multimodal information and 4.60 ($SD = 0.68$) for perceived improvement in distributed attention. In contrast, the feeling of being overwhelmed received an average score of 3.20 ($SD = 1.70$), indicating that participants felt a slightly to moderately overload during the activity.

The perceived educational value of the application received the highest overall rating, with an average score of 4.79 ($SD = 0.42$). Participants considered the application useful for learning, with an average score of 4.80 ($SD = 0.52$), and reported that the content was easy to understand, with an average score of 4.75 ($SD = 0.44$), and easy to remember, rated with 4.75 ($SD = 0.55$). They also recognized the educational potential of the application, which received the highest score among the contributing dimensions, with an average of 4.85 ($SD = 0.37$). In addition, participants expressed a willingness to use similar AR applications in the future and indicated that they would recommend the application to other users.

Discussion

The existing research on using AR to develop adults' digital competencies suggests that they can have direct and indirect impacts. Directly, AR applications support the development of practical digital skills, especially in the area of digital content creation, as defined by the DigComp 2.2 framework. Through interaction with AR environments, users practice using digital tools, learn new ways of interacting with technology and gain experience in creating and working with digital content. Indirectly, AR applications can support the development of digital competencies by increasing users' motivation, confidence, and willingness to engage with digital technologies. Another important impact of AR applications is related to learning processes. AR learning applications encourage users to spend more time interacting with educational content, but the wider implementation of AR technologies remains challenging, as limited digital skills among some adult learners may create difficulties in using these applications effectively.

The results of our user study support findings reported in previous research. Participants showed interest in interacting with AR applications, and even users without previous experience were able to quickly learn the basic navigation and interaction methods. Participants recognized the educational potential of AR applications and their value in learning contexts, which received the highest evaluation score in the study. They are consistent with previous studies that reported the

educational benefits of AR applications and their positive impact on learners' motivation [24]. Our findings complement this research by providing insights into users' perceptions of how AR applications can support the development of their cognitive abilities and digital competencies. However, it is important to distinguish between perceived learning outcomes, which were measured in our study, and actual learning outcomes. The integration of AR tools into education and digital competence development should be carefully designed and evaluated to avoid creating an illusion of improvement [17] compared to traditional methods.

Conclusion

AR applications represent a promising approach for supporting adults in developing digital competencies addressing direct skill development and with positive changes in users' perception of technology and cognitive augmentation. Our findings indicate that, despite initial challenges related to unfamiliar interaction methods and limited digital experience, AR can create motivating learning experiences that encourage adults to engage more with digital technologies.

ACKNOWLEDGMENTS

This work was supported by a grant of the Ministry of Education and Research, CCCDI-UEFISCDI, project number PN-IV-PCB-RO-MD-2024-0130, within PNCDI IV.

References

- [1] Ngr Putu Raka Novandra Asta, Setiawan Setiawan, Memed Saputra, Najmuddin Najmuddin, and Kddour Guettaoi Bedra. 2024. Integrating Augmented Reality with Management Information Systems for Enhanced Data Visualization in Retail. *J. Soc. Sci. Utilizing Technol.* 2, 2 (2024). doi:10.70177/jssut.v2i2.964
- [2] Jose Belda-Medina and José Ramón Calvo-Ferrer. 2022. Integrating Augmented Reality in Language Learning: Pre-Service Teachers' Digital Competence and Attitudes Through the TPACK Framework. *Education and Information Technologies* 27, 9 (2022). doi:10.1007/s10639-022-11123-3
- [3] Andrei Braicov, Tatiana Veverita, Ilona Popovici, Mihail Terenti, and Radu-Daniel Vatavu. 2026. XRCES: A Multidimensional Instrument for Assessing Cognitive Extension in Extended Reality. In *Proceedings of the 5th IEEE International Conference on Metrology for eXtended Reality, Artificial Intelligence and Neural Engineering (MetroXRINE '26)*. IEEE, USA, 6 pages.
- [4] Andrei Braicov, Tatiana Veverita, Ilona Popovici, Mihail Terenti, and Radu-Daniel Vatavu. 2026. Assessing Cognitive Extension in Extended Reality: Initial Evidence from a Confirmatory Factor Analysis. In *Proceedings of the ACM Symposium on Spatial User Interaction (SUI '26)*. ACM, New York, NY, USA, 3 pages. https://doi.org/10.1145/3822518.3839317
- [5] Andrei Braicov, Tatiana Veverita, Mihail Terenti, and Ivan Budanaev. 2026. Evaluating User Experience and Cognitive Load in AR-supported STEM Education. In *2026 International Conference on Development and Application Systems (DAS)*. 304–309. doi:10.1109/DAS69882.2026.11553320
- [6] Mark J. Brosnan. 1998. *Technophobia: The Psychological Impact of Information Technology* (1st ed.). Routledge, London. https://doi.org/10.4324/9780203436707
- [7] Pao-Ju Chen. 2025. Enhancing the Digital Competence of Nurses Through a Project-Based Augmented Reality Approach in Continuing Education. *The Journal of Continuing Education in Nursing* 56, 9 (2025), 364–371. doi:10.3928/00220124-20250619-01
- [8] European Commission. 2023. Standard Eurobarometer 99 - Spring 2023. https://europa.eu/eurobarometer/surveys/detail/3052
- [9] European Commission. 2025. Council Recommendation on Key Competences for Lifelong Learning. https://education.ec.europa.eu/focus-topics/improving-quality/key-competences
- [10] Mihaly Csikszentmihalyi. 1988. *The Flow Experience and its Significance for Human Psychology*. Cambridge University Press, 15–35. https://doi.org/10.1017/CBO9780511621956.002
- [11] Hong Gao, Haochuan Huai, Sena Yildiz-Degirmenci, Maria Bannert, and Enkelejda Kasneci. 2024. DataliVR: Transformation of Data Literacy Education through Virtual Reality with ChatGPT-Powered Enhancements. In *2024 IEEE International Symposium on Mixed and Augmented Reality (ISMAR)*. 120–129. doi:10.1109/ISMAR62088.2024.00026
- [12] Mina C. Johnson-Glenberg. 2018. Immersive VR and Education: Embodied Design Principles that Include Gesture and Hand Controls. *Frontiers in Robotics and AI* 5 (2018). doi:10.3389/frobt.2018.00081
- [13] Benedikt Lebek, Jörg Uffen, Markus Neumann, Bernd Hohler, and Michael H. Breitner. 2014. Information Security Awareness and Behavior: A Theory-Based Literature Review. *Management Research Review* 37, 12 (11 2014), 1049–1092. doi:10.1108/MRR-04-2013-0085
- [14] Zahira Merchant, Ernest T. Goetz, Lauren Cifuentes, Wendy Keeney-Kennicutt, and Trina J. Davis. 2014. Effectiveness of Virtual Reality-Based Instruction on Students' Learning Outcomes in K-12 and Higher Education: A Meta-Analysis. *Computers & Education* 70 (2014). doi:10.1016/j.compedu.2013.07.033
- [15] Stavros A Nikou, Maria Perifanou, and Anastasios A Economides. 2024. Exploring teachers' competences to integrate augmented reality in education: Results from an international study. *TechTrends* 68, 6 (2024), 1208–1221. doi:10.1007/s11528-024-01014-4
- [16] Monsurat Olaosebikan, Claudia Aranda Barrios, Lenore Cowen, and Orit Shaer. 2022. Embodied Notes: A Cognitive Support Tool For Remote Scientific Collaboration in VR. In *Extended Abstracts of the 2022 CHI Conference (CHI EA '22)*. ACM, New York, NY, USA, Article 279, 6 pages. doi:10.1145/3491101.3519664
- [17] Jocelyn Parong and Richard E. Mayer. 2018. Learning Science in Immersive Virtual Reality. *Journal of Educational Psychology* 110, 6 (2018), 785–797. doi:10.1037/edu0000241
- [18] Marco Romano, Paloma Díaz, and Ignacio Aedo. 2023. Empowering Teachers to Create Augmented Reality Experiences: The Effects on the Educational Experience. *Interactive Learning Environments* 31, 3 (2023), 1546–1563. doi:10.1080/10494820.2020.1851727
- [19] Richard M. Ryan and Edward L. Deci. 2017. *Self-Determination Theory: Basic Psychological Needs in Motivation, Development, and Wellness*. Guilford Publications. https://doi.org/10.1521/978.14625/28806
- [20] Xiaofang Song, Shasha Li, Liying Dong, Yue Li, Xinyu Yang, Jianyi Bao, Shufang Liao, Yingxue Xi, and Guojing Guo. 2025. Technophobia in Digital Health Contexts: A Systematic Review and Meta-Analysis With a Focus on Older Adults. *Digital Health* 11 (2025). doi:10.1177/20552076251374218
- [21] Mihail Terenti, Laura-Bianca Bilius, Andrei Braicov, Tatiana Veverita, Ilona Popovici, and Radu-Daniel Vatavu. 2026. Mapping Technological Dimensions of XR-based Cognitive Augmentation Systems. In *Proceedings of the 18th International Conference on Development and Application Systems (DAS '26)*. IEEE, USA, 298–303. https://doi.org/10.1109/DAS69882.2026.11553363
- [22] David H. Uttal, Nathaniel G. Meadow, Elizabeth Tipton, Linda L. Hand, Alison R. Alden, Christopher Warren, and Nora S. Newcombe. 2013. The Malleability of Spatial Skills: A Meta-Analysis of Training Studies. *Psychological bulletin* 139, 2 (2013), 352–402. doi:10.1037/a0028446
- [23] Arun Vishwanath. 2015. Examining the Distinct Antecedents of E-Mail Habits and its Influence on the Outcomes of a Phishing Attack. *Journal of Computer-Mediated Communication* 20, 5 (09 2015), 570–584. doi:10.1111/jcc4.12126
- [24] R. Vuorikari, S. Kluzer, and Y. Punie. 2022. *Digcomp 2.2, the Digital Competence Framework for Citizens – With New Examples of Knowledge, Skills and Attitudes*. Publications Office of the European Union. doi:10.2760/115376