Editorial: Building the future of education together: innovation, complexity, sustainability, interdisciplinary research and open science

María Soledad Ramírez-Montoya[1,2,3]*, M. A. Montoya[4],
Diana Hernández-Montoya[5]*, Genaro Zavala-Enríquez[1] and
Antonio Martínez-Arboleda[6]

[1]Institute for the Future of Education, Tecnológico de Monterrey, Monterrey, Mexico, [2]Benemérita
Escuela Normal de Coahuila, Saltillo, Mexico, [3]University of Desing, Innovation and Technology (UDIT),
Madrid, Spain, [4]Institute for the Future of Education, Bilbao, Spain, [5]Fab Lab Kä Träre, Vicerrectoría de
Investigación, Universidad Estatal a Distancia de Costa Rica, San José, Costa Rica, [6]School of
Languages, Cultures and Societies, University of Leeds, Leeds, United Kingdom

Editorial on the Research Topic
Building the future of education together: innovation, complexity,
sustainability, interdisciplinary research and open science

1 Introduction

On the eve of building the future of education, the need arises to seek unexplored paths toward an educational future built from the collective and for the collective. The United Nations Educational, Scientific and Cultural Organization (UNESCO), through its international commission, issued a report in which it invites us to reimagine the future of education, stating that education is a fundamental pillar for forging a common and shared future, connecting humanity in the face of global challenges such as climate change and disinformation (UNESCO, 2021a). UNESCO mobilized a major conference "Transforming Knowledge for a Just and Sustainable Future" on the occasion of the 30th anniversary of the UNITWIN/UNESCO Chairs Programme (UNESCO, 2022). Multiple declarations have also emerged to accompany that vision for the education: Recommendations for Open Educational Resources (OER; UNESCO, 2019), Recommendations for Open Science (UNESCO, 2021b), Common Principles for Future Generations (UNESCO, 2023), Guidance for Generative Artificial Intelligence in Education and Research (UNESCO, 2024a) and recently, the Dubai Declaration on OER (UNESCO, 2024b). Building the future of education involves mobilisations for transformation toward more just, resilient and universally shared learning horizons.

Achieving the above necessarily involves taking an interest in learning about, but above all in adapting, new educational practices characterized by innovation and complexity, not exclusively, but as a priority, in order to apply them in our contexts. Montesillo Cedillo (2025) argues that complex thinking could be a dominant paradigm for understanding life and current reality. This is not only relevant in educational settings but also when we think about integrating innovation into the practices, initiatives, projects, resources,

and experiences that we develop in educational settings and that we hope will impact not only students but also their families and communities. For their part, Andrade Salazar and Villela Cervantes (2024) highlight the enormous possibilities offered by complex thinking to promote more integrative and transdisciplinary visions in the construction of knowledge. And it is precisely these visions that are required to generate innovation that lasts, that is sustained over time but adapts to the times and contexts. The Voutilainen et al. (2024) in HundrED 2025 and ProFuturo (2024–2025) reports mention key innovations that are part of a complex vision of education: the use of artificial intelligence, the personalization of learning, the integration of sustainability and inclusion, among others. Many of these innovations are addressed in the various articles that form part of this Research Topic and showcase successful initiatives that integrate complexity and innovation in various contexts around the world, always prioritizing interdisciplinarity, co-creation, and openness to share what is being done and how it is being done.

In this era of reimagination and change, sustainability becomes a vital foundation for the future of education. It is not merely about raising environmental awareness but about developing an education system that is inherently resilient and adaptable. This involves boosting adaptive capacity, fostering critical thinking to tackle complex issues, and encouraging global collaboration, thereby equipping the next generation with the tools to create fair and prosperous societies in harmony with the planet. As ECLAC emphasizes, education is a strategic and wise investment, and various entities must ensure the financial sustainability of educational policies (Huepe, 2024). Simultaneously, it is crucial to speed up progress and close gaps in educational coverage and completion rates, as well as enhance their quality and relevance (Trucco, 2023). When education itself becomes sustainable, it acts as a powerful driver for a more equitable and sustainable future for all.

Advancing sustainability in the future of education requires not only rethinking what we teach but also how we generate and integrate knowledge across disciplines. Interdisciplinary research in education represents both a response to and a strategy for addressing complex, multifaceted challenges that transcend traditional disciplinary boundaries. As Julie Thompson Klein explains, interdisciplinarity entails more than the mere combination of disciplinary insights—it is a dynamic, context-dependent process that can stimulate methodological innovation, foster the co-construction of knowledge, and reshape both research and teaching practices in higher education (Thompson Klein and Philipp, 2023). Building on sociocultural theory, Hong et al. (2023) use a variety of visual representation techniques—including diagrams, event maps, and spatial activity models—to trace the intricate processes of collaborative inquiry in problem-based learning environments, highlighting the ways in which tools and discourse mediate learning in interdisciplinary teams. Complementing this, Vogel et al. (2023), based on a sociocognitive framework, examine transactivity—the process of learners building on one another's ideas—as a central mechanism of knowledge co-construction during collaborative problem-solving. Their findings suggest that alternating between novelty and reference in discourse enables deeper engagement and

more productive interdisciplinary collaboration. Together, these studies illustrate how interdisciplinarity not only provides a conceptual framework for educational transformation but also yields measurable impacts when operationalized through rigorous, multimodal research designs.

Interdisciplinary research naturally demands higher levels of openness than traditional, subject-based research. Open Science initiatives effectively address this requirement by breaking down informational barriers between disciplines, making research processes and outcomes transparent, accessible, and reusable across diverse fields (Scotti et al., 2025). Crucially, Open Science aims to cultivate meaningful relationships between researchers and the communities they serve (Leonelli, 2023). This explains the significant societal impact of Open Science, and particularly Citizen Science, in education and public awareness (Cole et al., 2024). Ultimately, the transformation of education depends on fostering a virtuous cycle underpinned by principles and practices designed to democratize knowledge.

This Research Topic arose from a motivation for the collective construction of new ideas and the dissemination of knowledge and practices essential for the future of education. The research community was invited to share original papers, reviews, theoretical cases and practical applications, with approaches that encompassed crucial elements to contribute to the future of education, digital education, lifelong learning and open science. In essence, it sought to explore complexity, sustainability, interdisciplinarity and social impact to redefine the educational landscape.

2 Presentation of article collection in the Research Topic

The Research Topic received valuable contributions that passed through at least two peer reviewers and after the review process, 19 papers were accepted, from 67 authors from five continents. We have organized the accepted contributions into a monograph according to the areas of practice and research covered under the call for research, linking it to the UNESCO guideline in its invitation to reimagine together the future of education. Thus, the sections of this section begin with an overview of what the theme means for the future of education, in order to present the articles that contribute to this theme.

2.1 Innovation

Educational innovation is crucial for the development of the competencies required in a changing world and to ensure that education maintains its relevance and transformative capacity. UNESCO (2021a) emphasizes the imperative need to reinvent education to address global challenges and catalyze social transformation. The report highlights the critical role of new pedagogies and technologies in expanding learning opportunities and fostering creativity, essential for shaping desirable futures. Ramírez-Montoya et al. (2022) emphasize the need for educational innovation to bring new products, services, processes and

knowledge, where the generation of new options involving the integration of novelties in problematic or challenging situations can support the improvement of educational processes. In this monograph, four articles stand out for their contribution to the area of innovation in the framework of building the future of education.

"AI in higher education: a systematic literature review," contributed by Castillo-Martínez et al. (Mexico), Daniel Flores-Bueno (Peru), Sonia M. Gómez-Puente (The Netherlands) and Victor O. Vite-León (Peru). This work is crucial in examining the integration of Artificial Intelligence (AI) in higher education, identifying its benefits and challenges. It provides guidance for institutions on how to implement AI effectively and ethically, optimizing learning and fostering skills such as critical thinking and creativity. It is essential for preparing an educational future that takes advantage of AI responsibly.

"Immersive learning platforms: analyzing virtual reality contribution to competence development in higher education—a systematic literature review," authored by Cabrera-Duffaut et al. (Ecuador), Ana María Pinto-Llorente (Spain) and Ana Iglesias-Rodríguez (Spain). This article provides an analysis of Virtual Reality (VR) in higher education as fundamental to understanding how immersive platforms can revolutionize the development of competencies. It shows the potential of VR to create experiential learning environments that foster interpersonal skills and the practical application of knowledge. Its study is vital to designing educational experiences that prepare students for the challenges of tomorrow.

"Learning manufacturing computer vision systems using tiny YOLOv4" from the contribution of Medina et al. (Mexico), Russel Bradley (United States), Wenhao Xu (United States), Pedro Ponce (Mexico), Brian Anthony (United States) and Arturo Molina (Mexico). This article proposes an innovative project-based teaching methodology for machine vision systems in manufacturing contexts. It is essential to bridge the gap between academic training and the demands of Industry 4.0, equipping students with advanced technological skills. It proposes an active learning model that promotes problem solving and adaptability in the face of emerging technological challenges.

"Enhancing STEAM education through augmented reality: the EduAR open platform experience" contributed by Velarde-Camaqui et al. (Mexico/Peru), Rosario Celaya-Ramirez (Mexico), Yéssica Contreras-Fuentes (Mexico) and Sanabria-Z et al. (Mexico). This study introduces EduAR, an open access Augmented Reality platform that seeks to transform STEAM education. Its value lies in democratizing access to quality educational resources, promoting critical thinking and problem solving in an interactive way. It is a concrete example of how technology can innovate pedagogy and make it more inclusive and attractive to all students.

2.2 Complexity

Education must cultivate complex thinking, critical, scientific, systemic and innovative reasoning, to foster the ability to navigate ambiguity. The report UNESCO (2021a) stresses that we live in a world characterized by increasing complexity, uncertainty and precariousness, facing interconnected crises. Ramírez-Montoya et al. (2025b) highlight the importance of promoting learning scenarios, educational models and learning environments in line with the demands of complex problem solving, to promote high capabilities and engagement with real-world challenges in a meaningful way. This will enable individuals to understand intricate systems, collaboratively address multifaceted challenges, and develop innovative solutions that respond to the interconnectedness of global phenomena, preparing people for an uncertain future. In this monograph four articles stand out for their contribution to the area of complexity to contribute to the future of education.

"Financial literacy to develop complex thinking skills: quantitative measurement in Mexican women entrepreneurs" by Bayly-Castaneda et al. (Mexico), María Soledad Ramírez-Montoya (Mexico), Arturo Erdély-Ruiz (Mexico) and Miguel Angel Montoya-Bayardo (Mexico/Spain). This article is valuable for its focus on the intersection of financial literacy and complex thinking. It demonstrates how the development of financial skills, especially in entrepreneurs, requires a deep understanding of interrelated systems. It contributes to education by demonstrating that practical skills are enhanced when integrated with complex reasoning skills, crucial for informed decision-making in a world of economic uncertainty.

"Developing the skills for complex thinking research: a case study using social robotics to produce scientific papers" is the contribution of Lopez-Caudana et al. (Mexico), Carlos Enrique George-Reyes (Mexico) and Raidell Avello-Martínez (Ecuador). The study demonstrates how social robotics can be an innovative tool to scale complex thinking and strengthen academic research skills. Its relevance lies in training researchers capable of addressing multifaceted problems and generating knowledge in dynamic contexts. Its technological focus is fundamental to cultivate the capacity for analysis and synthesis, preparing students for rigorous scientific work.

"eComplexity: validation of a complex thinking instrument from a structural equation model" authored by Vázquez-Parra, Henao-Rodriguez et al. (Mexico), Linda Carolina Henao-Rodriguez (Colombia), Jenny Paola Lis-Gutiérrez (Colombia), Castillo-Martínez et al. (Mexico) and Paloma Suarez-Brito (Mexico). This work validates the "eComplexity" instrument, crucial for measuring complex thinking and its subcompetencies in university students. Its importance lies in providing a robust tool to assess the development of this fundamental competence, allowing educational institutions to design and adjust pedagogical interventions. It is essential to strengthen students' ability to face and solve complex problems in the future.

"Complex thinking and profile of Colombian university teachers" by Vázquez-Parra et al. (Mexico), Luz Elena Malagón-Castro (Colombia), Paloma Suarez-Brito (Mexico) and Gloria Clemencia Valencia-González (Colombia). This article examines the self-perception of competence in complex thinking among Colombian university teachers. It is vital because it underscores the need for educators to possess and cultivate these skills in order to effectively guide their students in a complex world. Identifying these competencies is critical for the design of teacher education programmes and for ensuring that education prepares students for the complexity of today's world.

2.3 Sustainability

Sustainability is key to cultivating a conscious global citizenry committed to the collective wellbeing and preservation of our environment for future generations. Tariq et al. (2024) give examples of how by incorporating advanced AI-based tools to optimize energy consumption, educational facilities can become interactive learning centers that encourage students to engage with sustainability concepts in their everyday environment. The report UNESCO (2021a) positions education at the center of efforts to forge more just and sustainable futures for humanity and the planet. This work explicitly calls for education to be more responsive to pressing challenges such as climate change and unsustainable development, integrating environmental sustainability and promoting an ethic of care, reciprocity and solidarity. In this monograph, four articles stand out for their contribution to the area of sustainability with contributions for the future of education.

"HUMETAV model for citizen science initiatives: designing socio-ecological projects to foster awareness" is a contribution built in international collectivity by Sanabria-Z et al. (Mexico), Eduardo Santana-Castellón (Mexico), Pamela Olivo (Mexico), José Martín Molina-Espinosa (Mexico), Inna Artemova (Mexico/Russia), Terry Irwin (USA), Gideon Kossoff (United States), David Sánchez-Ruano (Mexico), Laura Succini (Italy), Velarde-Camaqui et al. (Mexico), Néstor Gabriel Platero-Fernández (Mexico), Lorena Quintero (Mexico), Inés Alvarez-Icaza Longoria (Mexico), Cléa Montanari (France), Luis Valle (Mexico) and Lisset Abril Sánchez-Salgado (Mexico). This work is fundamental in proposing a citizen science model to sensitize young people to socio-ecological importance. Its focus on the co-created, interdisciplinary design of projects that address real problems contributes directly to forming active and aware citizens. It promotes civic participation in the search for sustainable solutions, essential to address the contemporary environmental and social crisis.

"Children's learning for sustainability in social studies education: a case study from Taiwanese elementary school" authored by Shih (Taiwan). This article presents a case in Taiwan that illustrates how sustainability education can be effectively integrated into the social studies curriculum at the elementary level. It is crucial because it demonstrates the importance of cultivating environmental awareness and civic responsibility from an early age. It provides a practical model for educating future generations on how to actively contribute to more sustainable development, laying the foundation for lasting cultural change.

"Education 4.0 framework for sustainable entrepreneurship through transdisciplinary and abductive thinking: a case study" is a contribution by Torres-Sánchez et al. (Mexico), Antonio Marcelo Juárez (Mexico) and Jhonattan Miranda (Mexico). This article provides a valuable framework for promoting sustainable entrepreneurship through transdisciplinary thinking in the context of Education 4.0. It is vital because it emphasizes the identification and resolution of contemporary problems, such as water scarcity, encouraging creative and responsible solutions. It prepares students to be agents of change with a holistic vision, key to sustainable economic and social development.

"Entrepreneurial thinking and Education 4.0 in communities with development gaps: an approach through the Sustainable Development Goals" with contributions by Leiva-Lugo et al. (Mexico), Inés Álvarez-Icaza (Mexico), Francisco Javier López-Hernández (Mexico) and Jhonattan Miranda (Mexico). This paper argues for a training model based on Education 4.0 to develop entrepreneurial thinking in disadvantaged communities, using the Sustainable Development Goals (SDGs) as a central axis. Its relevance lies in the promotion of local solutions and the reduction of gaps in access to training, contributing to a more equitable development. It is fundamental to empowering individuals to create a more just and sustainable future for their own communities.

2.4 Interdisciplinary research

Interdisciplinary approaches foster holistic understanding, critical thinking, and the ability to synthesize knowledge from diverse fields. The report UNESCO (2021a) calls for curricula that prioritize ecological, intercultural, and interdisciplinary learning, recognizing that complex global challenges cannot be solved from a single discipline. Advances in science, technology and digital forms of communication have created new social dynamics that demand alternative analyses and perspectives to understand the complexities of the modern world; therefore, disciplines must leave aside their watertight compartments and initiate a dialogue "between sciences" to begin to develop shared methodologies capable of analyzing and evaluating current social realities in an innovative way (Ramírez-Montoya et al., 2025a). Interdisciplinary visions prepare citizens to collaborate in shared purposes and address real-world problems effectively, building a future where knowledge is generated and applied in an integrated manner. In this monograph four articles contribute from the area of interdisciplinary research to promote the future of education.

"Teaching dynamics to enhance critical thinking and knowledge socialization in the mathematics classroom" by Dominguez (Mexico/Chile). This article highlights the application of active learning strategies in the mathematics classroom to foster critical thinking and knowledge socialization. It is fundamental because it transcends traditional teaching, connecting mathematics with argumentation and the democratization of learning. It promotes an interdisciplinary approach by integrating communication and collaboration skills, preparing students to apply mathematical reasoning in diverse contexts.

'Bridging the gap: bioinspired robotics as catalyst for interdisciplinary education' is an article by Cayetano-Jiménez et al. (Mexico), Rogelio Bustamante-Bello (Mexico) and Miguel Ramírez-Cadena (Mexico). This article explores bio-inspired robotics as a powerful catalyst for interdisciplinary education. It is valuable because it fuses biology, robotics and engineering, promoting critical thinking and collaborative problem solving in university students. It demonstrates how the integration of diverse disciplines can enrich learning, preparing students to approach complex challenges from multiple perspectives.

"Exploring educational simulation platform features for addressing complexity in Industry 4.0: a qualitative analysis

of insights from logistics experts" by Pacheco-Velazquez et al. (Mexico), Virginia Rodes-Paragarino (Mexico/Uruguay) and Alberto Marquez-Uribe (United States). This study examines how simulation platforms can help manage the complexity inherent in Industry 4.0 in the logistics domain. It is relevant because it addresses the need to train professionals with advanced skills in highly interconnected environments. It highlights the importance of tools that enable the understanding of complex systems and informed decision-making, essential for innovation and efficiency in an evolving industrial future that spans multiple fields of knowledge.

"The social innovation profile in students as a transformation strategy: structural equation modeling" is a contribution by Glasserman-Morales et al. (Mexico), Carolina Alcantar-Nieblas (Mexico) and Sergio Nava-Lara (Canada). This article analyses the profile of social innovation in students as a transformative strategy. It is crucial for the future of education because social innovation, by nature, requires an interdisciplinary approach to solve complex problems that cross social, economic and technological boundaries. It promotes the development of competences that empower students to be agents of change and to design innovative solutions.

2.5 Open science

Reimagining the future of education requires envisioning the collective efforts of science for the common good, promoting collaboration and knowledge sharing. UNESCO's (2021b) open science statement delineates it as the combination of diverse movements and practices in order to make multilingual scientific knowledge openly available, accessible and reusable by all, to increase scientific collaborations and information sharing for the benefit of science and society, and to open the processes of creation, evaluation and communication of scientific knowledge to social actors beyond the traditional scientific community. Ramírez-Montoya (2023) visualizes open science as the possibility of opening the universe toward a limitless horizon, where scientific data open an infinite number of possibilities to build new strategies, ideas and projects. It starts from the principles of openness by advocating equitable access to knowledge, collaborative learning and shared responsibility in the construction of inclusive and just futures. In this monograph three articles contribute from the area of open science to contribute to the future of education.

"Scale to measure student perception in collaborative online international learning experiences: design and validation" co-authored by Rozo-García et al. (Colombia), Carolina Alcantar-Nieblas (Mexico) and María Soledad Ramírez-Montoya (Mexico). This article contributes to the future of education by validating a scale to measure student perception in collaborative international online learning (COIL) experiences. These experiences, being collaborative and online, embody principles of openness and accessibility. The study is vital for evaluating and improving the design of programmes that promote knowledge sharing and transnational collaboration,

breaking down geographical barriers and fostering a global learning community.

"MAICC model: development of complex thinking through citizen science project evaluation" article by Olivo-Montaño et al. (Mexico), Sanabria-Z et al. (Mexico), José Martín Molina-Espinosa (Mexico), Lorena Quintero-Gámez (Mexico), Velarde-Camaqui et al. (Mexico/Peru), Lisset Abril Sánchez-Salgado (Mexico), Miguel Gonzalez-Mendoza (Mexico), Adriana Breda (Spain), Luisa Morales-Maure (Panama) and Inés Alvarez-Icaza (Mexico). This paper introduces the MAICC model, which links complex thinking with the evaluation of citizen science projects. Its relevance to open science is significant, as citizen science is a pillar of this movement, democratizing research and promoting public participation in knowledge generation. The article is fundamental for the formation of citizens capable of actively contributing to scientific research and progress.

"The impact of large language models on higher education: exploring the connection between AI and Education 4.0" contribución de Peláez-Sánchez et al. (México), Velarde-Camaqui et al. (México/Perú) y Glasserman-Morales et al. (México). This article analyzes the influence of Large Language Models (LLMs) on higher education, in the context of Education 4.0. It is vital because it addresses how these technologies can enhance autonomous and collaborative learning, which aligns with the democratization of access to knowledge. It highlights the need to address ethical issues and human oversight, promoting responsible use of tools that can expand the reach of information and research in an open manner.

3 Conclusion and new avenues

Commitment, responsibility and collaboration are perhaps the most necessary actions or behaviors in today's society. Individualism has distanced us from dialogues where we talk, listen, learn and grow, those spaces that allow us to contrast different perspectives that would lead us to innovative ways of interpreting reality. This is perhaps the starting point to provoke the generation of useful knowledge, to stop and reflect for a few moments and to be able to transform ourselves into human beings committed to ourselves and to the environment, where dialogue and attentive listening enable us to begin to find innovative solutions as citizens committed to society.

With these foundations, and focusing on the importance of the "most objective possible" research, we will be able to expand our knowledge and practices in the framework of the future of education. A future that is not understood as remote, but rather, although our gaze is set on the years to come, actions and practices must focus on the present, which requires us to be challenged with a social impact that continues in the process of reducing the social gap and in the construction of a socially committed citizenship.

The tools and the means are at our fingertips, since through open science and interdisciplinarity we will be able to reach a greater number of people from diverse geographies to make education as democratic as possible. Building the future of education together implies an intersection of knowledge, collectivities, openness and shared vision for the common good. This monograph is an invitation to continue searching for

possibilities that allow us to contribute, from research and innovation, new ways for education and society.

Author contributions

MR-M: Conceptualization, Investigation, Supervision, Writing – original draft, Writing – review & editing. MM: Writing – original draft, Writing – review & editing. DH-M: Writing – original draft, Writing – review & editing. GZ-E: Writing – original draft, Writing – review & editing. AM-A: Writing – original draft, Writing – review & editing.

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References

Andrade Salazar, J. A., and Villela Cervantes, C. E. (2024). El pensamiento complejo y la construcción de conocimiento: una perspectiva Moriniana. *Revista Vida* 6, 33–50. doi: 10.36314/revistavida.v6i1.41

Cole, N. L., Kormann, E., Klebel, T., Apartis, S., and Ross-Hellauer, T. (2024). The societal impact of open science: a scoping review. *R. Soc. Open Sci.* 11:240286. doi: 10.1098/rsos.240286

Hong, D., Chakraburty, S., Zou, X., Chen, Y., and Hmelo-Silver, C. E. (2023). Visual representations for studying collaborative inquiry. *Interdiscip. J. Probl.-Based Learn.* 17, 1–3. doi: 10.14434/ijpbl.v17i2.35901

Huepe, M. (2024). *El desafío de la sostenibilidad financiera de la educación en América Latina y el Caribe*. Documentos de Proyectos (LC/TS.2024/1), Santiago, Comisión Económica para América Latina y el Caribe (CEPAL)/Banco Mundial/Fundación Ford/Organización de las Naciones Unidas para la Educación, la Ciencia y la Cultura (UNESCO).

Leonelli, S. (2023). *Philosophy of Open Science*. Cambridge: Cambridge University Press. doi: 10.1017/9781009416368

Montesillo Cedillo, J. L. (2025). Síntesis del pensamiento complejo. *Cienc. Lat. Rev. Cienc. Multidiscip.* 9, 12136–12150. doi: 10.37811/cl_rcm.v9i1.16784

ProFuturo (2024–2025). *10 innovaciones que transformarán la educación en 2025*. Available online at: https://profuturo.education/observatorio/soluciones-innovadoras/10-innovaciones-que-transformaran-la-educacion-en-2025/ (Accessed July 8, 2025).

Ramírez-Montoya, M. S. (2023). *Ciencia abierta, una alfombra mágica*. TecScience. Tecnológico de Monterrey. Available online at: https://tecscience.tec.mx/es/humano-social/ciencia-abierta (Accessed July 17, 2025).

Ramírez-Montoya, M. S., McGreal, R., and y Obiageli Agbu, J. F. (2022). Complex digital horizons in the future of education 4.0: insights from UNESCO recommendations. *RIED-Revista Iberoamericana de Educación a Distancia* 25, 9–21. doi: 10.5944/ried.25.2.33843

Ramírez-Montoya, M. S., Montoya, M. A., Zavala-Enríquez, G., and Martínez-Arboleda, A. (2025a). *Advances in Interdisciplinary Research: Pioneering Innovations and Sustainable Practices Towards Open Science*. New York, NY: Routledge. doi: 10.4324/9781003625391

Ramírez-Montoya, M. S., Portuguez-Castro, M., and Mendoza-Urdiales, R. A. (2025b). Redefining education: educational trajectories for complex thinking skills. *Humanit. Soc. Sci. Commun.* 12:958. doi: 10.1057/s41599-025-04929-2

Scotti, K. L., Jiao, C., Gainey, M. A., Bongiovanni, E. A., and Slayton, E. R. (2025). Charting open science landscapes: a systematized review of US academic libraries' engagement in open research practices. *J. Acad. Librariansh.* 51:103054. doi: 10.1016/j.acalib.2025.103054

Tariq, R., Mohammed, A., Alshibani, A., and Ramírez Montoya, M. S. (2024). Complex artificial intelligence models for energy sustainability in educational buildings. *Sci. Rep.* 14:15020. doi: 10.1038/s41598-024-65727-5

Thompson Klein, J., and Philipp, T. (2023). "Interdisciplinarity," in *Handbook Transdisciplinary Learning*, eds. T. Philipp and T. Schmohl (Bielefeld: Transcript Verlag), 195–204. doi: 10.1515/9783839463475-021

Trucco, D. (2023). *Mejorar la educación es crucial para un desarrollo social y económico inclusivo y sostenible*. Comisión Económica para América Latina y el Caribe (CEPAL). doi: 10.18356/16820908-2023-141-11

UNESCO (2019). *The 2019 UNESCO Recommendation on Open Educational Resources (OER): Supporting Universal Access to Information Through Quality Open Learning Materials*. Available online at: https://unesdoc.unesco.org/ark:/48223/pf0000383205 (Accessed July 6, 2025).

UNESCO (2021a). *Reimagining Our Futures Together: A New Social Contract for Education. Report from the International Commission on the Futures of Education*. Available online at: https://unesdoc.unesco.org/ark:/48223/pf0000379707 (Accessed July 6, 2025).

UNESCO (2021b). *UNESCO Recommendation on Open Science*. Available online at: https://unesdoc.unesco.org/ark:/48223/pf0000379949 (Accessed July 6, 2025).

UNESCO (2022). *Transforming knowledge for just and sustainable futures. An international conference to mark the 30th anniversary of the UNITWIN/UNESCO Chairs Programme*. Available online at: https://www.unesco.org/en/transforming-knowledge-just-and-sustainable-futures (Accessed July 6, 2025).

UNESCO (2023). *United Nations System Common Principles on Future Generations*. Available online at: https://unsceb.org/united-nations-system-common-principles-future-generations (Accessed July 6, 2025).

UNESCO (2024a). *Guidance for Generative AI in Education and Research.* Available online at: https://unesdoc.unesco.org/ark:/48223/pf0000386693 (Accessed July 6, 2025).

UNESCO (2024b). *Declaración de Dubái sobre los recursos educativos abiertos (REA): Bienes Públicos Digitales Y Tecnologías Emergentes Al Servicio De Un Acceso Equitativo E Inclusivo Al Conocimiento.* Available online at: https://unesdoc.unesco.org/ark:/48223/pf0000392271_spa (Accessed July 6, 2025).

Vogel, F., Weinberger, A., Hong, D., Wang, T., Glazewski, K., Hmelo-Silver, C. E., et al. (2023). "Transactivity and knowledge co-construction in collaborative problem solving," in *Proceedings of the International Conference on Computer-supported for Collaborative Learning, Proceedings of the 16th International Conference on Computer-Supported Collaborative Learning—CSCL 2023* (Japón: International Society of the Learning Sciences), 337–346. doi: 10.22318/cscl2023.646214

Voutilainen, M. M., Gonchigdorj, A., and Warren, C. G. F. (2024). *Colección Global HundrED 2025.* Helsinki: HundrED.