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Research Article

Communicating educational innovation projects in Latin America mediated by the scaling of complex thinking: Contribution of the UNESCO-ICDE Chair in Mexico

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ABSTRACT

The United Nations Educational, Scientific and Cultural Organization (UNESCO) Chair in the open educational movement for Latin America aims to promote scientific, technological, entrepreneurial, and innovative development. In Mexico, face-to-face bootcamps occur every two years, where prototypes of high-value solutions for education are developed using design and active learning methodologies, with the aim of scaling complex thinking and sustainable development. In the 2023 edition, 94 academicians from 12 countries participated (Argentina, Bolivia, Chile, Colombia, Ecuador, Germany, Guatemala, Mexico, Peru, Spain, the Dominican Republic, and the United Kingdom). Experts from Tecnológico de Monterrey, the Open University, the University of Leeds, and Siemens Stiftung supervised the process. This article presents the prototyped proposals and the results of applying the Play2Train4C methodology, enabling participants to develop educational innovation projects under the paradigm of complex thinking. The results indicate that (1) the participants managed to prototype ten proposals validated by experts and (2) their perceptions of their systemic, critical, scientific, and innovative thinking (sub-competencies of complex thinking) improved by the end of the bootcamp. The conclusion was that the UNESCO Chair boosted solution-building skills for the complex problems arising in Latin America and enabled key agents in education to improve their complex thinking skills for quality education, as promulgated by sustainable development goal 4.

Keywords: educational innovation, higher education, complex thinking, science communication

INTRODUCTION

The United Nations Educational, Scientific and Cultural Organization (UNESCO) Chair is an initiative of UNESCO that aims to promote collaboration and excellence in education and research and the dissemination of knowledge in areas of importance for UNESCO. These areas often are education, science, culture, human rights, and sustainable development (United Nations, 2015). The chairs are promoted in academic institutions and research centers worldwide to create programs and activities for quality education, human resource development, interdisciplinary research, and the dissemination of knowledge in which interdisciplinary experts and academicians collaborate to address global challenges and exchange ideas, and share knowledge (Marujo & Casais, 2021).

The UNESCO Chairs program, created in 1992, had more than 700 chairs by 2017 in a wide range of disciplines and hundreds of inter-university networks (UNITWIN) in 128 countries (Michelsen & Wells, 2017). These chairs focus on teaching and conducting research on topics that promote the UN Sustainable Development Goals through international inter-university cooperation, networks among researchers and institutions, and knowledge exchange (UNESCO, 2017).

The UNESCO Chairs offer the possibility to create opportunities for international collaboration (Letseka, 2020) and collaborative environments to produce initiatives that favor the development of quality education (UNITWIN/UNESCO, 2017). In Mexico, various chairs have emerged whose objective is to form research networks to generate new knowledge and train new researchers. The following list highlights some of the most relevant chairs in this country:

- UNESCO Chair of Education for Social Justice–Autonomous University of Mexico (UNAM).
- UNESCO Chair of Education in Human Rights and Democracy–National University of Distance Education (UNED) and National Human Rights Commission (CNDH).
- UNESCO Chair on Youth, Education and Society–Autonomous University of Mexico City (UACM).
- UNESCO Chair of Health Anthropology–Metropolitan Autonomous University (UAM).
- UNESCO Chair of Intercultural Communication and Human Rights–Iberoamerican University (UIA).
- UNESCO Chair for Research in Communication and Culture of Peace–Autonomous University of Baja California (UABC).
- UNESCO Chair of Cultural Diversity and Interreligious Dialogue–University of Guadalajara (UDG).
- UNESCO Chair of Sustainability–Tecnológico de Monterrey (ITESM).
- UNESCO Chair in the Open Education Movement for Latin America–Tecnológico de Monterrey (ITESM).

The UNESCO Chair in the Open Education Movement for Latin America was created in 2014 to promote open access to knowledge in Latin America through networks and working groups that enable the production, visibility, dissemination, mobilization of knowledge and academic and scientific production through training practices to reduce the educational gap in teaching and teacher training (Tecnológico de Monterrey, 2022).

Tecnológico de Monterrey has established numerous collaborations and projects in the field of education and technology (Cruz-Sandoval et al., 2022; George-Reyes & Glasserman, 2022; George-Reyes et al., 2023a; Ramírez-Montoya, 2020). They have partnered with UNESCO in initiatives for open education, participated in open education projects in Latin America, and promoted equitable access and participation in education through the use of open educational resources (OERs), open technologies, and open pedagogical practices (Ramírez-Montoya, 2019). These resources and practices enable students to freely access, use, adapt, and share educational materials, thus promoting collaboration and innovation in teaching and learning (Patiño et al., 2023).

The activities carried out by the Chairs include the training of teachers, students, and lifelong learners in the use, design, development, and promotion of OERs, research on their implementation, the organization of conferences and events, and the development of regional alliances and collaborative networks (González-Pérez et al., 2022). Through workshops, diploma courses, seminars, and academic and postdoctoral stays, the chairs contribute to strengthening the open educational movement in Latin America through integrated academic networks, together with collaborative research and development projects that jointly create solutions to the continents' developmental problems, aligning with UNESCO objectives for sustainable development (Ramírez-Montoya, 2021).

The first Bootcamp held at the Tecnológico de Monterrey was held in 2015 and had the participation of five professors from various Latin American countries (three from Mexico, three from Ecuador, two from Peru, one from Colombia, and one from Chile), this event has been held every two years. In 2023, the 5th edition of the bootcamp was held, where 53 women and 41 men from 12 countries met (54 from Mexico, eight from Guatemala, eight from Peru, six from Colombia, four from Spain, four from Argentina, two from Venezuela, two from the Dominican Republic, two from England, two from Germany, and two from Chile).

In the 2023 Chair in Mexico, the work was strengthened by scaling the complex thinking competency. This competency has been exploited on different occasions to promote the development of research projects by

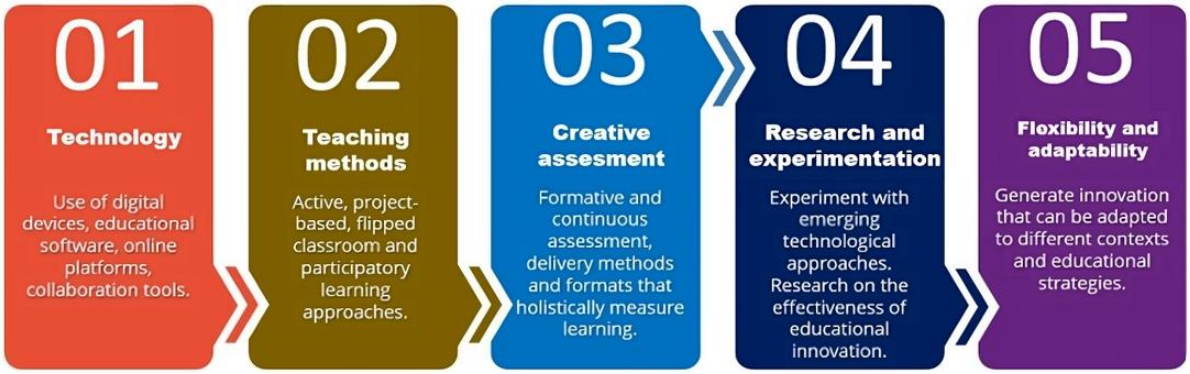

Figure 1. Essential elements of educational innovation (Source: Authors)

improving critical, scientific, systemic, and innovative thinking skills (Romero-Rodríguez et al., 2022; Suárez-Brito et al., 2022). Therefore, this article reports the results of the Chair and its incidence in forming the participants' complex thinking competency.

Educational Innovation & Skills Development

Education is continuously evolving, mainly due to the widespread use of the Internet and the availability and access to digital technology in educational institutions (Francom, 2020). Digital technology has become necessary for teaching and learning in the post-COVID-19 educational environments (Trust & Whalen, 2021). Developing competencies has become fundamental in this scenario to prepare teachers and students with the theoretical knowledge and practical skills necessary to address the challenges of an increasingly digitalized world (IEEE Standards Association, 2020).

As a starting point, it must be defined that innovation entails a novel idea, method, strategy, or practice that streamlines processes to generate and disseminate knowledge quickly (Ramírez-Montoya, 2020). The addition of technologies leads to technological innovations (Howard et al., 2021) that can improve education through its added value, obtaining better results due to the emergence of new teaching-learning approaches (Stumbrienė, 2023) and the successful transfer of learning (Gautam & Basnet, 2020).

Educational innovation implies adopting approaches, methodologies, and technologies beyond traditional teaching to transmit information (Leoste et al., 2021). It requires learning strategies derived from complex pedagogical skills in project-based learning, personalized learning, and the use of technology in the classroom to produce active, participatory, and relevant learning environments (Gilbert et al., 2021). Its components may vary according to the scenarios, where it is designed and implemented; however, various researchers (Gallardo-Córdova et al., 2029; López-Larios et al., 2022; Noor & Crossley, 2013; Parejo et al., 2022;Ramírez-Montoya, 2020) conclude that it consists of at least five essential elements:

(1) technology,

(2) teaching-learning methods,

(3) creative evaluation,

(4) research and experimentation, and

(5) flexibility and adaptability (**Figure1**).

Educational innovation aims to transform education through strategies and methodologies that effectively develop core competencies such as complex thinking (Ramírez-Montoya et al., 2022). However, some researchers have confirmed that teacher competencies related to change and improvement in education vary considerably (Lavidas et al., 2022; Sánchez-Cruzado et al., 2021; Scherer et al., 2021). Some research has reported the influencers of innovation: the teacher, the institution, colleagues, students, and the teaching environment (Gilbert et al., 2021) and that sometimes the emergence of educational innovation occurs in periods of forced innovation, as was the case with the application of digital technologies that allowed the continuity of teaching during COVID-19 (González et al., 2023).

The above represents an opportunity to create and promote training experiences for innovative use of technologies and educational practices that improve disciplinary and transversal competencies (Jevsikova et

al., 2021). Such "disruptive" educational practices require training in new teaching skills and a broad understanding of the correlation between using digital technologies and improving disciplinary and transversal skills in face-to-face, mixed, and remote teaching scenarios (Myry et al., 2022).

Educational innovation and the development of competencies are interconnected because both seek to improve education (Portuguez & Gómez-Zermeño, 2021). Educational innovation provides the tools and approaches to create a more effective learning environment. At the same time, competency development provides students with the necessary skills to face real-world challenges through teamwork, leadership, creativity, communication, collaboration, digital skills, and complex thinking (Suárez-Morales et al., 2022).

Therefore, the capacity to generate educational innovation must be consolidated as a continuous activity to trigger the possibility of developing new teaching skills from the efficient and intentional use of digital technologies (Punie & Redecker, 2017). However, achieving this requires consolidating adequate training spaces oriented toward the design of innovative teaching environments such as the UNESCO Chairs (Patiño et al., 2023).

Complex Thinking as a Framework for Educational Innovation

Higher education must reinvent itself in an increasingly interconnected world to succeed in a constantly changing present. In this context, complex thinking emerges as a valuable approach to educational innovation as a reference framework to address the complexity of contemporary education (Sun et al., 2022). The overlapping of complex thinking, and educational innovation builds a pathway to more relevant and practical education (George-Reyes et al., 2023a).

Complex thinking understands the world as an interconnected system whose parts interact in unpredictable and non-linear ways. Unlike reductionist thinking, which tends to simplify and separate the elements, complex thinking seeks to capture the richness and interdependence of systems (Morin, 1994). It focuses on the relationships and connections between elements, recognizing that problems are not addressed in isolation. Educational innovation focuses on establishing how each educational actor perceives technology, interprets it, uses it, and considers it in the teaching-learning process (Parada et al., 2023).

Some research affirms that this paradigm is replacing the simplicity that fragments knowledge, overspecializes disciplines, and prevents knowledge from flowing to the different networks of knowledge that constitute the real world (Silva & Iturra, 2023). There has been no unified concept to define complex thinking because various lines of research have offered different perspectives to approach it from the development of competencies (Ramírez-Montoya, 2021; Tobon & Luna-Nemecio, 2021).

Recently, particularly since the year 2022, multiple studies have been developed that address complex thinking as a method to have a deeper understanding of various problems that arise in educational reality, such as implementing citizen science as an enabler to strengthen skills of complex thinking (Alfaro et al., 2023), to measure digital competence as a key to the financial inclusion of young people in complex scenarios (Buenestado et al., 2023), likewise, various instruments have been designed to evaluate complex thinking (Castillo-Martínez et al., 2023; Romero-Rodríguez et al., 2023).

These studies converge in understanding complex thinking as a macro competency (Sotelo et al., 2023) because four sub-competencies must be developed to activate it: critical thinking, systemic thinking, scientific thinking, and innovative thinking (Cruz-Sandoval et al., 2023). On the other hand, at the formative level, it does not require a specific pedagogical process because it can be developed in different scenarios, contexts, and situations (George-Reyes et al., 2023b), making complex thinking a pivotal macro-competency. Regardless of the discipline, it allows a professional in any discipline to solve problems (de Melo, 2022). **Figure 2** describes these sub-competencies.

However, the studies carried out to date have been the result of efforts focused on the research tendencies of the researchers who have conducted them, so it is necessary to implement complex thinking as a method that allows developing proposals in design and collaboration environments to achieve the elaboration of educational innovation proposals, in this sense, the UNESCO Chair of OERs represents an opportunity to interweave both topics.

The imbrication between complex thinking and educational innovation occurs through the referential framework of its sub-competencies, where through systemic thinking, problems are analyzed in an

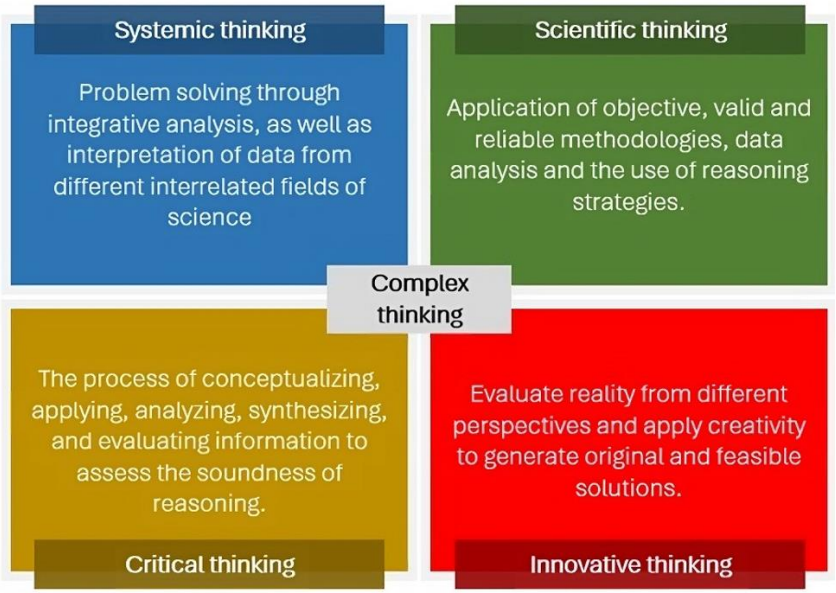

Figure 2. Complex thinking & sub-competencies (Source: Authors)

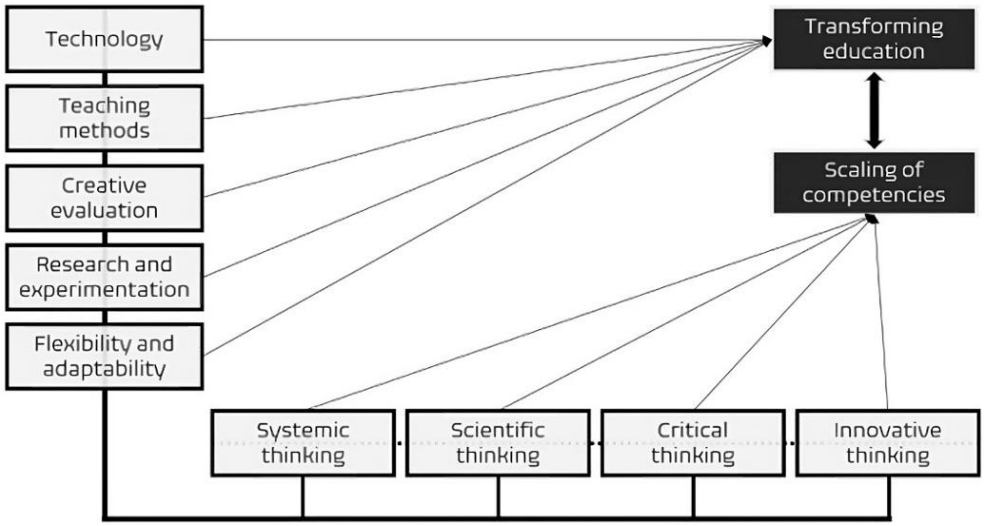

Figure 3. Imbrication of educational innovation & complex thinking (Source: Authors)

interconnected way, recognizing the elements that compose them and the dynamics among them (Vázquez-Parra et al., 2023). Critical thinking validates one's reasoning, allowing problems to be reconsidered beyond existing paradigms (Ibarra-Vazquez et al., 2023). Scientific thinking makes it easier for people to make decisions and solve problems by adopting objective and validated methodologies (Cruz-Sandoval et al., 2023), and with innovative thinking, reality can be evaluated from different perspectives to generate original and feasible solutions (George-Reyes et al., 2023b).

Educational innovation draws on these sub-competencies to design relevant and adaptable pedagogical approaches to diverse learning situations, transforming teaching and learning. Therefore, complex thinking has a broad and flexible nature that allows for addressing the changing reality of the world (Vázquez-Parra et al., 2022). **Figure 3** shows the possible interconnections and the unlimited imbrication of complex thinking and educational innovation.

METHOD

The bootcamp was developed using an ad hoc methodology for the event, **Figure 4** shows how it was implemented in the UNESCO Chair.

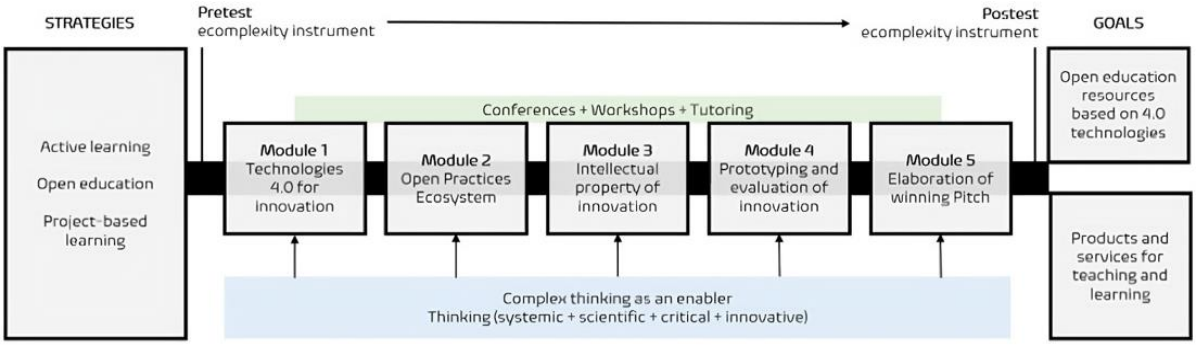

Figure 4. Methodology for implementation of bootcamp (Source: Authors)

Table 1. Statistical tests carried out

Analysis	Information you provide	Reference
Comparison with descriptive statistics	Comparison of representative values in the pre-test and post-test to know the variability or dispersion of the data.	Harremoës (2023)
t student & Tukey coefficient	Comparison of the means in the pre- & post-test to determine if there is statistical evidence of different means.	Barabesi et al. (2023)
Bonett & Levene tests.	Evaluate the equality of variances in the pre- & post-test.	Wang et al. (2023)
Normal distribution	Know the distribution of the data after applying the post-test.	Eidous (2022)

Good practices developed in previous chairs (Patiño et al., 2023) and proof-of-concept proposals in formative educational innovation experiences (Sanabria et al., 2023) helped configure it. The starting point was to choose strategies that allowed participants to assimilate knowledge and understanding. Active learning was selected to actively involve participants in the learning process, encouraging collaboration and decision-making in the formative process (Jesionkowska et al., 2020; Wetzel & Farrow, 2023). In addition to this, project-based learning, which develops skills for research and solving complex problems or questions through the planning, implementation, and presentation of a substantial project (Chen & Yang, 2021; Samaki et al., 2022); and as a contextual variable, Education 4.0 (Fidalgo-Blanco et al., 2022; Oliveira & de Souza, 2022), to integrate advanced digital technologies and innovative pedagogical approaches to the projects.

Questionnaire

To evaluate the scaling (improvement) of complex thinking of the participants, the *eComplexity* questionnaire was used. (Castillo-Martínez & Ramírez-Montoya, 2022), This questionnaire evaluates the sub-competences of critical, systemic, scientific, and innovative thinking. It is an instrument that has been validated by experts and has been shown to have very acceptable quality coefficients (Cruz-Sandoval et al., 2022). It has also been applied in numerous opportunities by researchers from various countries to identify the strengthening of creativity, citizen participation and entrepreneurship in university students (Farías-Gaytan et al., 2023; Patiño et al., 2023; Vázquez-Parra et al., 2023). The statistical tests applied to know the development of complex thinking achieved by the participants are described in **Table 1**.

Organization

10 work teams were formed. At the beginning of the activities, they were assigned a tutor, and each team member signed a project completion commitment letter. They were provided with an activity book and a template for developing an innovative project aligned with the bootcamp's schedule of activities. The activities were organized to offer conferences, presentations of successful cases, and workshops in the morning; in the afternoons, the participants carried out collaborative work.

The participants worked on five modules, each module was organized sequentially, so they worked systematically on developing an educational innovation proposal using an OER based on 4.0 technologies or a teaching and learning product or service. **Figure 4** shows that the systemic, critical, scientific, and innovative thinking sub-competencies were enablers in addressing problems and challenges, considering the interdependence of multiple elements in systems and situations (Ramírez-Montoya et al., 2022). The

eComplexity instrument was applied at the beginning (pre-test) and at the end of the bootcamp (post-test) to determine the scaling (improvement) of the participants' perceived complex thinking competency.

Participants

94 academicians from 12 countries participated, 53 women and 41 men. Mentoring of experts from Tecnológico de Monterrey, Open University, University of Leeds, and Siemens Stiftung supported the process, as well as 35 specialists from 10 organizations: Tecnológico de Monterrey, University of Salamanca, Open University, Leeds University, Siemens Stiftung, National Polytechnic Institute, National Autonomous University of Mexico, Autonomous University of Queretaro, University of Navarra, and Red LaTE-MX.

Ethics

Before, during and at the end of the Bootcamp, ethical aspects were taken care of, the participants were provided with a letter of informed consent in which the role of their participation and the reservation of their personal identity was specified, they were also notified that the data collected during The Bootcamp would be treated anonymously and are protected by laws applicable in Mexico aimed at protection of personal data.

Hypotheses

To evaluate the success of the bootcamp in the UNESCO Chair, we defined two hypotheses: The first related to the skills to develop educational innovation prototypes as a result of participating in the training experience, and the second related to the scaling of complex thinking competency.

H1. A bootcamp driven by active learning strategies, open education, and problem-based learning mediated by the development of complex thinking skills will allow the development of educational innovation prototypes supported by Education 4.0 technologies.

H2. Bootcamp participants will scale (improve) their complex thinking sub-competencies by developing skills to create educational innovation prototypes supported by Education 4.0 technologies.

RESULTS

The results are presented below in two sections. The first shows the prototyped projects and the main characteristics of the most outstanding ones; the second presents the results of comparing the pre- and post-test results of the *eComplexity* instrument.

Prototype Projects

Ten educational innovation projects, collaboratively designed by international teams, were prototyped; videos were produced to describe each particularity. In total, the 104 academicians presented various projects that promoted open education and the use of Education 4.0 technologies: digital platforms (n=4), web pages (n=3), artificial intelligence (n=3), pedagogical frameworks (n=1), and online collaborative networks (n=2). The documents detailing the prototypes are in open access at the Tecnologico de Monterrey Institutional Repository (Ramirez-Montoya, 2023). **Table 2** summarizes each project. As can be seen from **Table 2**, most projects aim to develop platforms or applications to design OERs, either for their creation or to host, before their curation, those already circulating on internet pages. Three projects intend to achieve gender equality and women's education access in STEAM (in EMM and STEAM GIRL).

The selected digital tools focus on designing Internet sites, where learning materials can be accessed (LatinREA; HAATI Hub; and LEAL-REA), as well as the construction of platforms to host directories of best teaching practices carried out by Latin American professors (RED LATINTED). On the other hand, some projects intend to use free applications to host short videos to promote integral well-being and job training (EMM Women-Mother Empowerment). Three of the projects stand out for their intention to use disruptive technologies, such as artificial intelligence (AI LEARN), to develop Educational Innovation Laboratories through a hybrid platform to host digital content and the management of learning experiences under an open access Information System for the Management of Social and Educational Innovation Laboratories (SIGLISE), as well as to redesign language model tools for the organization of open resources (GPT Curator).

Table 2. Projects prototyped in the UNESCO Chair

Project	Description	Link to project
LatinREA	Access to open educational resources through creation of an electronic site for consultation, creation, & initial digital content training.	https://hdl.handle.net/11285/650053
Latin American network of innovation, educational technology, & good open practices in university teaching (RED LATINTED)	Seeks to ensure that Latin American professors can find open educational resources & good educational innovation practices in teaching various university disciplines by building a professional network.	https://hdl.handle.net/11285/650044
EMM women-mother empowerment	Promote empowerment of women & mothers through creation of *reels* (short videos) in open access with content on comprehensive well-being & promotion of schooling & trade training.	https://hdl.handle.net/11285/650066
GPT curator	Develop critical, scientific, systemic, & creative thinking skills through search skills, curation, & dissemination of open educational resources on an artificial intelligence platform.	https://hdl.handle.net/11285/650067
Social & educational innovation laboratories on vulnerability with a gender approach-SIGLISE open source	Development of educational innovation laboratories on vulnerability with a focus on gender from perspective of complex thinking through generation & implementation of open educational resources through SIGLISE open-source.	https://hdl.handle.net/11285/650057
Teacher reskilling	Achievement of teacher reskilling through training that improves teaching skills through PBL.	https://hdl.handle.net/11285/650061
HAATI open hub for learning in immersive technologies	Build an open hub offering teaching community educational resources that guide didactic employment of immersive technologies at different levels of complexity on accessibility & connectivity.	https://hdl.handle.net/11285/650048
Open educational resources platform for teacher training and accreditation in artificial intelligence (AI LEARN)	Build an open platform so that people linked to training processes can develop innovative & significant teaching & learning practices through AI tools.	https://hdl.handle.net/11285/650050
LEAL-REA: Laboratory for evaluation of open educational resources for Latin America	Platform for evaluation of OER in higher education.	https://hdl.handle.net/11285/650062
STEAM GIRL: Empowering young women in education & employability in STEAM	Design a STEAM reference framework for complexity empowerment to achieve quality education & greater employability of women.	https://hdl.handle.net/11285/650045

One of the developed projects is the HAATI Open Hub for Learning in Immersive Technologies, which aims to build an open site (hub) that offers educational resources to the teaching community. This project aims to create a repository in which linked educational resources can guide teachers in the didactic use of technologies at different levels of complexity. On the other hand, STEAM GIRL (empowering young women in STEAM labor fields) proposed closing the gender gap in women's employment in science, technology, engineering, and mathematics through OERs and mentoring for equitable and fair education.

One project that stands out that, due to its characteristics, could significantly impact the academic community: is the Social and Educational Innovation Laboratory. It comprises the experiences of educational entrepreneurship and the design of OERs to scale to a massive level the construction of a proprietary software web environment that maintains a historical memory of OERs and Webinars taught by international experts (Contreras et al., 2023).

The tutors assigned to each work team guided, reviewed, and favorably validated these projects; therefore, it is feasible to accept hypothesis **H1.** A bootcamp driven by active learning strategies, open education, and problem-based learning mediated by the development of complex thinking skills will allow the development of educational innovation prototypes supported by Education 4.0 technologies.

Scaling of Complex Thinking Skills

The researchers examined the 94 participants' responses to carry out this analysis. Note that the pre-test and the post-test were mandatory activities in the bootcamp, and the tutors verified that all the participants completed the questionnaires.

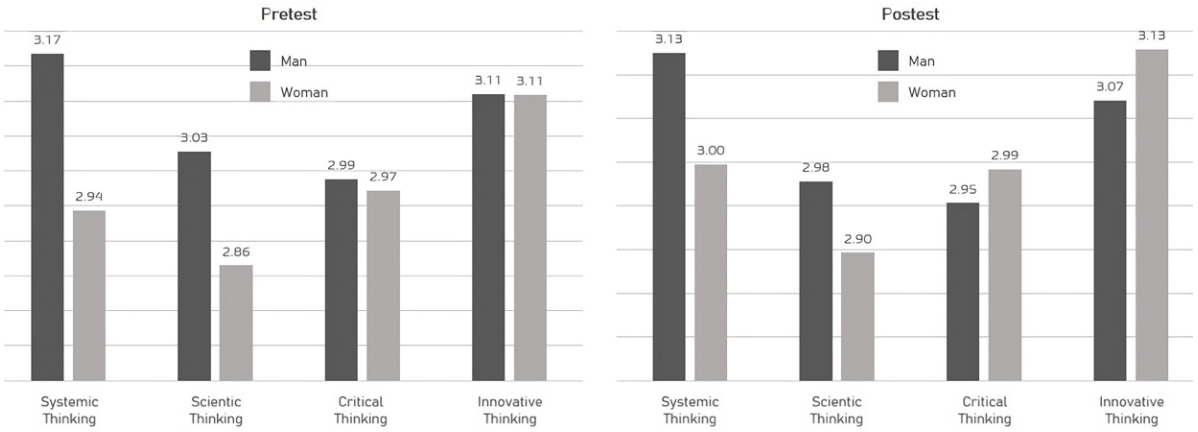

Figure 5. Comparison between pre- & post-test-1 (Source: Authors)

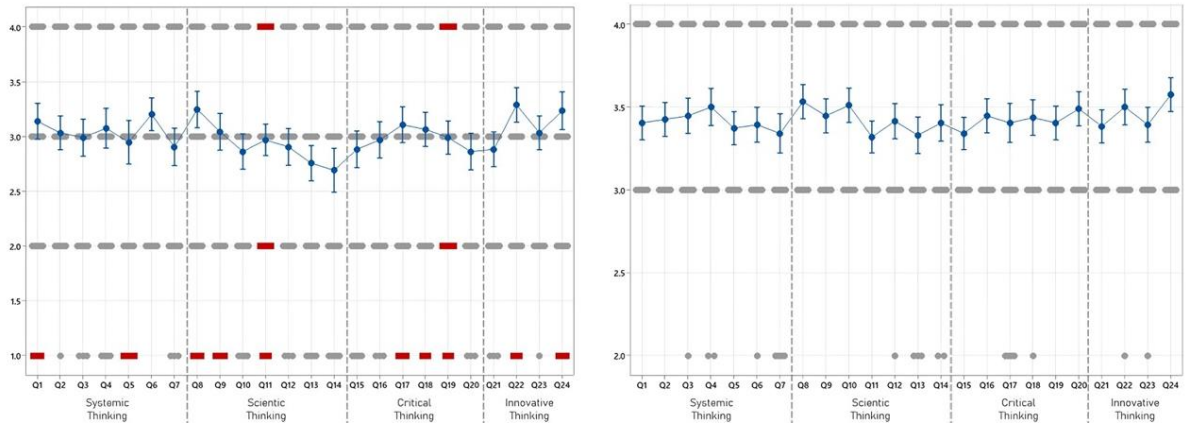

Figure 6. Comparison between pre- & post-test-2 (Source: Authors)

The first descriptive analysis (see **Figure 5**) shows that although the perception of men in the pre-test indicated a higher level of perceived complex thinking sub-competencies, the women reduced the differences in the post-test. The women outperformed men in critical and innovative thinking.

Pre- & Post-Test

Figure 6 is a comparative analysis of the results of the *eComplexity* instrument before and after the teachers' participation in the Bootcamp. It shows a greater presence of outliers in the pre-test; that is, there was a greater dispersion of opinions regarding the improvement of their complex thinking sub-competencies. In the pre-test, the items with outliers were Q1 and Q5 (systemic thinking), Q8, Q9, and Q11 (scientific thinking), Q17, Q18, and Q19 (critical thinking), and Q22 and Q24 (innovative thinking). Note that items Q11 (I can distinguish the structure required for writing the chapters of a research project) and Q19 (I critically evaluate the probable solutions of a research problem) had the most dispersion of participants' opinions, suggesting that emphasis should be placed on improving the development of scientific and critical thinking skills. After participation in the bootcamp, a marked reduction in the presence of outliers in the results was observed. In general terms, the concentration of responses reflected a notable improvement in the perception of competence in complex thinking. The measurements yielded a minimum mean of 3.3191, with a standard deviation of 0.4686, and a maximum of 3.5745, with a standard deviation of 0.468, evidencing coherence and stability in the responses obtained.

From a theoretical perspective of complex thinking, the results adhere to the notion that the development of critical, systemic, scientific, and innovative thinking skills involves greater coherence and less variability in responses (George-Reyes et al., 2023a). Complex thinking is characterized by the ability to address difficult situations effectively and, therefore, a lower presence of outliers can be interpreted as an improvement in adaptation and understanding of complexity (Ramírez-Montoya, 2023).

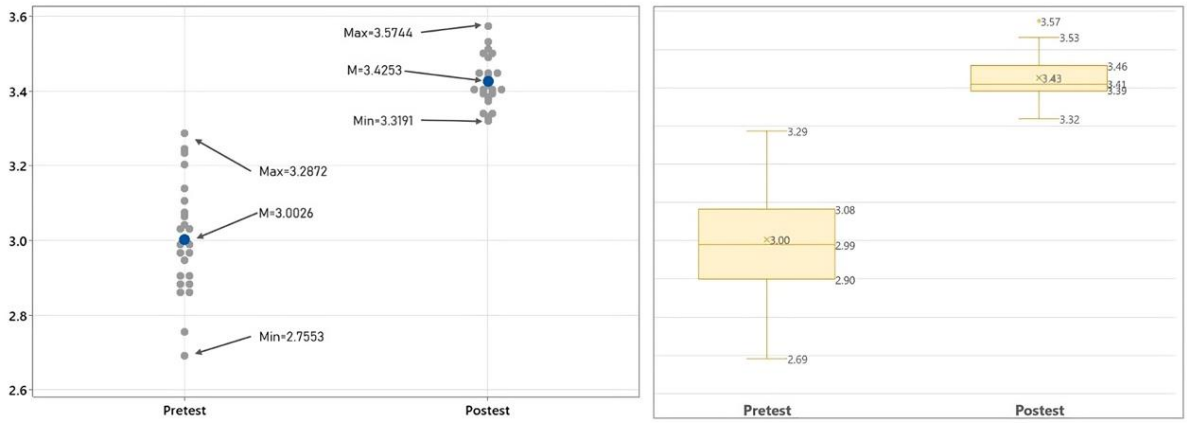

Figure 7. Comparison of differences in minimum, maximum, & mean values (Source: Authors)

Table 3. Analysis of student's t-test by dimension

Dimensions	t-test	Pre-test mean	Post-test mean	Mean difference	Método de Tukey (0.17)
Systemic thinking	0.0000	3.04103	3.4119	0.37082	Significant difference
Critical thinking	0.0001	2.92401	3.4225	0.49848	Significant difference
Scientific thinking	0.0002	2.97872	3.4202	0.44149	Significant difference
Innovative thinking	0.0044	3.10904	3.4628	0.35372	Significant difference

Examining **Figure 7** clearly reveals that there is no equivalence between the pre-test and post-test results. The pre-test mean was 3.0026, with a standard deviation of 0.1512, while the post-test mean was 3.4255, with a standard deviation of 0.0662. This significant difference of 0.4229 in the interval between three and four suggests a substantial increase in perceived competence in complex thinking after participation in the bootcamp. These results theoretically support the idea that educational interventions can contribute to the improvement of complex thinking by reducing variability and increasing consistency in participants' responses (Cruz-Sandoval et al., 2022).

The evaluation carried out using the Student t test, detailed in **Table 3**, not only offers a quantitative but also a substantial vision of the impact of the UNESCO Chair Bootcamp on the complex thinking of the participants. By confirming that the general average in the post-test (mean [M]=3.4255) significantly exceeds that of the pre-test (M=3.026), a convincing narrative of improvement in the perception of each sub-competence related to complex thinking emerges.

Pearson's correlation test (0.5025) reveals a positive linear correlation. This finding underlines the coherence and positive direction of the changes observed in the scores between the pre-test and the post-test, further consolidating the validity of the increase in the perception of complex thinking skills and confirming the results of similar studies (Romero-Rodríguez et al., 2022; Sanabria et al., 2023; Suárez-Brito et al., 2022), by using the Tukey method (T=0.17) to identify significant differences, the robustness of the analysis is increased by highlighting statistically significant changes in all dimensions of the instrument. This result transcends mere general improvement, specifically showing in which aspects the participants' perceptions experienced notable transformations.

The Student t test, supported by Pearson correlation and Tukey's method, not only quantifies the overall improvement in perception, but also contextualizes and specifies the specific areas, where changes have occurred (Barabesi et al., 2023). This analysis demonstrates the importance of the t-test in providing a complete and detailed understanding of the impact of the Bootcamp on the development of complex thinking competencies among UNESCO Chair participants.

Subsequently, the paired t-test compared the pre-test and post-test means. Because the two data sets are uniquely paired, this test was helpful to evaluate if there was a significant difference between the means and determine if the participants' complex thinking competency developed positively. **Figure 8** confirms that the mean of the paired differences is less than zero, which indicates that one can be 95% sure that the actual pre-test and post-test difference is less than 0.3770.

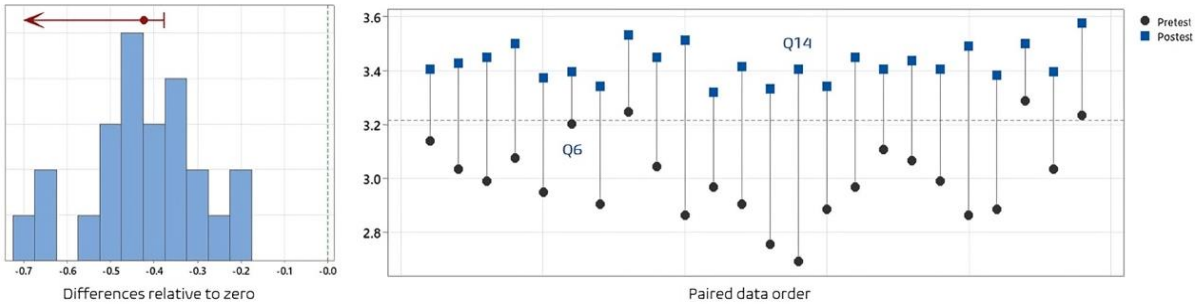

Figure 8. Paired t-test graphs (Source: Authors)

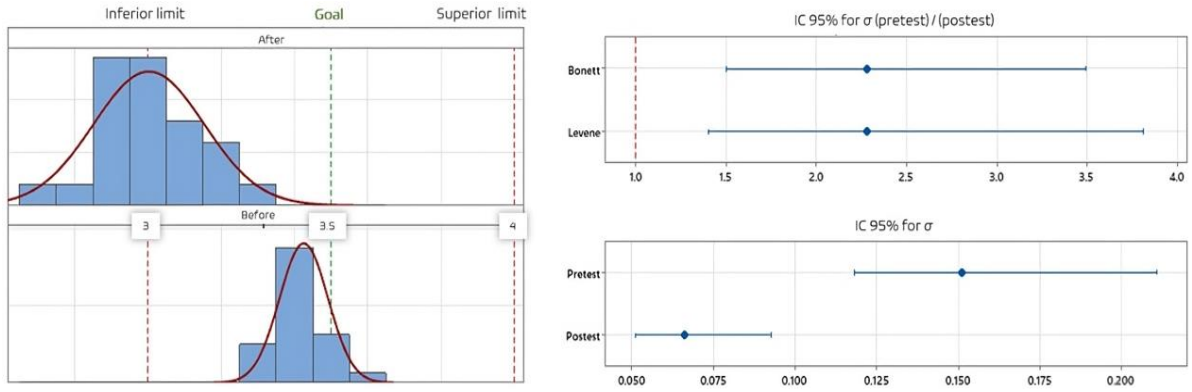

Figure 9. Standard deviation plots: Bonett and Levene tests (Source: Authors)

In the analysis of paired data, discernible differences are observed between the scores obtained, and this contrast offers a valuable perspective on the development of competencies associated with complex thinking. Particularly, when breaking down the results, it stands out that the smallest improvement scale was recorded in item Q6 (I can solve research problems by interpreting different types of data). This finding suggests a specific area, where participants may benefit from an additional or tailored approach to strengthen their skills in interpreting data in the research context.

The most pronounced improvement was observed in item Q14 (I develop and test hypotheses to investigate problems related to research projects). This result indicates significant progress in the ability to formulate and evaluate hypotheses in the context of research projects, pointing to substantial progress in critical skills associated with complex thinking.

These findings highlight the multidimensionality and adaptability of complex thinking sub-competencies. While recognizing specific areas for greater focus, the diversity in improvements suggests that participants are not only strengthening specific skills but are also holistically integrating complex thinking into various facets of their investigative capabilities.

Thus, according to the above results, **H2** should be accepted: Bootcamp participants will scale (improve) their complex thinking sub-competencies by developing skills to create educational innovation prototypes supported by Education 4.0 technologies. The results presented in **Figure 9** offer a revealing insight, highlighting how the standard deviation (-0.0849) and the mean experienced a positive change as they approached the critical value of 3.5. This trend suggests a convergence towards a more uniform and consistent perception among participants, reflecting a possible alignment with the principles of complex thinking, which imply an ability to approach and understand diverse situations in a balanced way (Ramirez-Montoya et al., 2022).

In further analysis, the Bonnett (p=0.001) and Levene (p=0.003) tests provide substantial evidence of statistically significant differences in the variances between the pre-test (var=0.023) and the post-test (var=0.004). This discovery reinforces the importance of considering the homogeneity of variances when interpreting results (Wang et al., 2023), highlighting that perceptions of research competencies experienced significant and non-uniform changes between participants before and after the Chair bootcamp. UNESCO.

Table 4. Checking normality of distribution

Dimensions	Mean	Standard deviation	Asymmetry	Kurtosis
Systemic thinking	3.4119	0.5196	0.0638	-1.3306
Critical thinking	3.4225	0.5125	0.1098	-1.5020
Scientific thinking	3.4202	0.5117	0.1240	-1.5084
Innovative thinking	3.4628	0.5098	0.0285	-1.7049

The variability in responses before the Bootcamp could reflect a diversity of approaches and perspectives among participants. However, the significant reduction in post-Bootcamp variances indicates greater consistency in perceptions, which could be interpreted as a movement towards a more shared and homogeneous understanding in the area of research competencies. This analysis not only contributes to a more nuanced interpretation of the results, but also suggests that the Bootcamp not only influenced the average scores, but also triggered a convergence in participants' perception, aligning with the principles of complex thinking.

In the final phase of the analysis, a verification was carried out in the post-test to ensure that the sampling distribution conformed to the normality criteria. This process included the calculation of skewness and kurtosis indicators for the questionnaire results. The results obtained revealed that no extreme values were identified for skewness (greater than |2.00|) or kurtosis (in the range of 8.00 to 20.00) according to the criteria established by Bandalos and Finney (2001), which is detailed in the **Table 4**.

This finding conclusively supports the inference that the sample follows a normal distribution in the post-test. The absence of exceptional skewness or kurtosis suggests that the data are distributed symmetrically and more concentrated around the mean, strengthening the validity of the results obtained (Eidous, 2022). The validation of normality provides a solid basis for the application of additional statistical methods and reinforces the reliability of the inferences derived from the analysis of the questionnaire used.

DISCUSSION

The learning experience mediated by the UNESCO Chair Bootcamp is an efficient strategy to strengthen the skills needed to develop educational innovation projects by strengthening the participants' complex thinking sub-competencies. From the teachers' perspective, they perceived significant improvement in critical, scientific, systemic, and innovative thinking. An unexpected finding was that women improved their complex thinking skills better than men. **Figure 5** shows that they prevailed in developing critical and innovative thinking.

On the other hand, as shown in **Figure 6** and **Figure 7**, the dispersion of the participants' perceptions reduced between tests, and it was possible to exceed the average of these. All this suggests that good practices in applying strategies to implement technological resources in the scientific research process thrive (González-Pérez et al., 2022). Thus, we can infer that there are significant contributions to forming skills to identify ideas for educational innovation.

Reviewing the findings shown in **Figure 8** and **Figure 9** affirms this inference, indicating significant differences in improving complex thinking competency. All suggest that the conferences, workshops, and tutorials catalyzed the ability to elaborate, for example, open innovation ecosystems and attain knowledge about the intellectual property of innovation and how to design prototypes.

The improvement in complex thinking skills after the Bootcamp can be explained by having facilitated the development of multidimensional connections in the participants' thinking (Sotelo et al., 2023). Exposure to diverse topics, practices and activities could have promoted the integration of knowledge and the ability to approach problems from multiple perspectives, an essential characteristic of complex thinking (Silva & Iturra, 2023), likewise, the observed improvement could reflect the increased capacity of participants to adapt and respond effectively to complex situations (Farías-Gaytan et al., 2023).

Therefore, this research suggests that collaborative learning experiences, where diverse professional profiles and cultures from different countries come together, are beneficial for developing educational innovation projects. However, it is necessary to consider other alternatives to develop technological skills to make new proposals (George-Reyes & Glasserman, 2021).

The present study yields two results: first, as confirmed in **Table 1**, the participants used Education 4.0 digital tools, such as artificial intelligence and interactive platforms, to build innovative prototypes, all of them incipient but with a solid foundation to build new projects of social benefit. Second, the study showed that active and problem-based learning strategies help improve critical, systemic, scientific, and innovative thinking skills. They also allow for the generation of skills to identify and build innovative prototypes to address problems. These findings shed light on the hypothesis that motivates this study, which proposes significant differences between students' perceived improvement of skills before and after participating in the UNESCO Chair.

CONCLUSIONS

This article examined how the activities implemented by the UNESCO Chairs contribute to generating educational innovation projects. During the Chair in Mexico, the preparation of the pre-prototyping of 10 initiatives aimed at contributing to complex thinking, constructing knowledge spaces for the design and development of platforms to host OERs, and developing social collaboration environments, where experts in different disciplines can interact to promote the value of inclusion issues such as gender equality.

The Chair not only contributed to the generation of projects but also focused on training new entrepreneurs in educational innovation and social entrepreneurship through the transfer of knowledge by international experts who gave conferences and workshops on topics such as Open Practice Ecosystems, Resource Center Open Education, Equity in Knowledge, Functional Prototypes, Intellectual Property in Educational Solutions, Design of Open Practices, Megatrends for the Ideation and Identification of New Solutions for Open Education, among others.

Also, during the development of the chair, an analysis examined how the activities favored the development of critical, systemic, scientific, and innovative thinking sub-competencies, which managed to improve. The preceding indicates that the collective effort of organizers, speakers, and collaborators made it possible to achieve two purposes: first, the pre-prototyping of innovative projects, and second, training human resources in complex thinking skills.

During the development of the Chair, a significant area of opportunity was identified related to the direction taken by the projects presented. It was observed that most of these projects focused mainly on addressing social problems with stratified solutions, moving away from issues of global importance, such as environmental care and personal well-being. In addition, a distancing was observed from emerging trends in Education 4.0, such as machine learning, blockchain and data analysis.

It is essential to recognize that this project orientation can limit the breadth and diversity of proposed solutions. Concentration on specific social problems could restrict the Chair's overall impact in crucial areas, such as environmental sustainability and technological progress. Likewise, the lack of exploration of relevant Education 4.0 trends could limit participants' preparation for future challenges.

To guarantee the sustainability and relevance of the proposals in future editions of the Chair, it is suggested to delve into strategies to link the projects with the business and economic sector. This approach could strengthen the viability and practical applicability of the proposed solutions, ensuring that they are aligned with the needs of the business world and economic reality.

The UNESCO Chair of the Open Educational Movement for Latin America plays a crucial role in promoting open education in the region, serving as a catalyst for educational progress and collaboration between Latin American countries. Its value contribution is manifested significantly by promoting collaboration and the exchange of knowledge, fostering an environment conducive to educational innovation.

This initiative not only aims to improve educational quality, but also works to promote equity and inclusion. By focusing on these fundamental aspects, the Chair directly contributes to the construction of a more accessible educational landscape for Latin Americans, guaranteeing that educational opportunities are available to everyone, regardless of their geographic location or socioeconomic conditions.

The distinctive value of the UNESCO Chair lies in its capacity to be an agent of change and transformation in the educational field. By promoting open education practices, you are not only improving the quality of

teaching, but you are also laying the foundation for a more inclusive, participatory, and dynamic educational system in Latin America.

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Data availability: Data generated or analyzed during this study are available from the authors on request.

REFERENCES

Alfaro, B., Patiño, A., & Sanabria-Z, J. (2023). Components of computational thinking in citizen science games and its contribution to reasoning for complexity through digital game based learning: A framework proposal. *Cogent Education, 10*(1), 2191751. https://doi.org/10.1080/2331186X.2023.2191751

Barabesi, L., Cerioli, A., & García-Escudero, L. A. (2023). Consistency factor for the MCD estimator at the Student-t distribution. *Statistics and Computing, 33*, 132. https://doi.org/10.1007/s11222-023-10296-2

Buenestado, M., Ramírez-Montoya, M. S., Ibarra, G., & Patiño, A. (2023). Digital competency as a key to the financial inclusion of young people in complex scenarios: A focus groups study. *Citizenship, Social and Economics Education, 22*(1), 48-62. https://doi.org/10.1177/14788047231170083

Castillo-Martínez, I. M., & Ramírez-Montoya, M. S. (2022). *Instrumento eComplexity: Medición de la percepción de estudiantes de educación superior acerca de su competencia de razonamiento para la complejidad* [*eComplexity instrument: Measuring the perception of higher education students about their reasoning competence for complexity*]. https://hdl.handle.net/11285/643622

Castillo-Martínez, I. M., Ramírez-Montoya, M. S., Glasserman-Morales, L, D., & Millán-Arellano, A. (2023). eComplex: Validity and reliability of rubric for assessing reasoning for complexity competence. *Quality & Quantity*. https://doi.org/10.1007/s11135-023-01697-6

Chen, H., & Yang, J. (2021). Application of IT-integrated project-based learning in the teaching reform of undergraduate education. *International Journal of Emerging Technologies in Learning, 16*(05), 248-260. https://doi.org/10.3991/ijet.v16i05.21085

Contreras, Y., George-Reyes, C., Polo, R, Fernández, K., & Jerónimo, J. (2023*). Laboratorios de innovación social y educativa sobre vulnerabilidad con enfoque de género a través de SIGLISE-open source* [*Social and educational innovation laboratories on vulnerability with a gender focus through SIGLISE-open source*]. https://hdl.handle.net/11285/650058

Cruz-Sandoval, M., Vázquez-Parra, J. C., & Alonso-Galicia, P. (2022). Student perception of competencies and skills for social entrepreneurship in complex environments: An approach with Mexican university students. *Social Sciences, 11*(7), 314. https://doi.org/10.3390/socsci11070314

Cruz-Sandoval, M., Vázquez-Parra, J. C., Carlos-Arroyo, M., & Amézquita-Zamora, J. (2023) Student perception of the level of development of complex thinking: An approach involving university women in Mexico, *Journal of Latinos and Education*. https://10.1080/15348431.2023.2180370

de Melo, A. (2022). Conceptualizing and designing (co)augmented intelligence(s) enacting complex thinking: Morphological constraints, challenges, and implications. *Proceedings, 81*(1), 85. https://doi.org/10.3390/proceedings2022081085

Eidous, O. (2022). New tightness lower and upper bounds for the standard normal distribution function and related functions. *Authorea, 14*, 15011-15019. https://doi.org/10.22541/au.165777665.50705634/v1

Farías-Gaytan, S., Aguaded, I., & Ramírez-Montoya, M. S. (2023). Digital transformation and digital literacy in the context of complexity within higher education institutions: A systematic literature review. *Humanities & Social Sciences Communications, 10*, 386. https://doi.org/10.1057/s41599-023-01875-9

Fidalgo-Blanco, Á., Sein-Echaluce, M. L., & García-Peñalvo, F. J. (2022). Método basado en Educación 4.0 para mejorar el aprendizaje: Lecciones aprendidas de la COVID-19 [Method based on Education 4.0 to improve learning: Lessons learned from COVID-19]. *Revista Iberoamericana de Educación a Distancia* [*Ibero-American Journal of Distance Education*]*, 25*(2), 49-72. https://doi.org/10.5944/ried.25.2.32320

Francom, G. M. (2020). Barriers to technology integration: A time-series survey study. *Journal of Research on Technology in Education, 52*(1), 1-16. https://doi.org/10.1080/15391523.2019.1679055

Gallardo-Córdova, K. E., Lozano Rodríguez, A., & Elizondo García, J. (2019). Innovación educativa en estudios de psicología educativa: Un mapeo sistemático [Educational innovation in educational psychology studies: A systematic mapping]. In M. S. Ramírez-Montoya, & J. R. Valenzuela González (Eds.), *Innovación educativa: Tendencias globales de investigación e implicaciones practices* [*Educational innovation: Global research trends and practical implications*]. Octaedro.

Gautam, D. K., & Basnet, D. (2020). Organizational culture for training transfer: The mediating role of motivation. *International Journal of Organizational Analysis, 29*(3), 769-787. https://doi.org/10.1108/IJOA-04-2020-2147

George-Reyes, C. E., & Glasserman, L. (2021). Research competencies mediated by technologies: A systematic mapping of the literature. *Education in the Knowledge Society, 22*, e23897. https://doi.org/10.14201/eks.23897

George-Reyes, C. E., & Glasserman, L. (2022). Elaboración y análisis de confiabilidad de un cuestionario para medir desde la perspectiva del estudiante las competencias digitales del docente en entornos no presenciales de enseñanza [Development and reliability analysis of a questionnaire to measure, from the student's perspective, the teacher's digital competencies in non-face-to-face teaching environments]. *Revista Complutense de Educación* [*Complutense Education Magazine*]*, 3*(33). https://doi.org/10.5209/rced.74467

George-Reyes, C. E., López-Caudana, E. O., & Ramírez-Montoya, M. S. (2023a). Research competencies in university students: Intertwining complex thinking and Education 4.0. *Contemporary Educational Technology, 15*(4), ep478. https://doi.org/10.30935/cedtech/13767

George-Reyes, C. E., Ramírez-Montoya, M. S., & López-Caudana, E. O. (2023b). Imbricación del Metaverso en la complejidad de la educación 4.0: Aproximación desde un análisis de la literatura [Interweaving of the Metaverse in the complexity of education 4.0: Approach from an analysis of the literature]. *Pixel-Bit. Revista de Medios y Educación* [*Media and Education Magazine*]*, 66*, 199-237. https://doi.org/10.12795/pixelbit.97337

Gilbert, A., Tait-McCutcheon, S., & Knewstubb, B. (2021) Innovative teaching in higher education: Teachers' perceptions of support and constraint. *Innovations in Education and Teaching International, 58*(2), 123-134. https://doi.org/10.1080/14703297.2020.1715816

González, C., Ponce, D., & Fernandez, V. (2023). Teachers' experiences of teaching online during COVID-19: Implications for post-pandemic professional development. *Educational Technology Research and Development, 71*, 55-78. https://doi.org/10.1007/s11423-023-10200-9

González-Pérez, L., Ramírez-Montoya, M. S., & García-Peñalvo, F. J. (2022). Habilitadores tecnológicos 4.0 para impulsar la educación abierta: Aportaciones para las recomendaciones de la UNESCO [4.0 technological enablers to promote open education: Contributions to UNESCO recommendations]. *Revista Iberoamericana de Educación a Distancia* [*Ibero-American Journal of Distance Education*]*, 25*(2). https://doi.org/10.5944/ried.25.2.33088

Harremoës, P. (2023). Rate distortion theory for descriptive statistics. *Entropy, 25*(3), 456. https://doi.org/10.3390/e25030456

Howard, S., Schrum, L., Voogt, J., & Sligte, H. (2021). Designing research to inform sustainability and scalability of digital technology innovations. *Educational Technology Research and Development, 69*(4), 2309-2329. https://doi.org/10.1007/s11423-020-09913-y

Ibarra-Vazquez, G., Ramírez-Montoya, M. S., & Terashima, H. (2023). Gender prediction based on university students' complex thinking competency: An analysis from machine learning approaches. *Education and Information Technologies*. https://doi.org/10.1007/s10639-023-11831-4

IEEE Standards Association. (2020). IEEE standard for digital intelligence (DQ)–Framework for digital literacy, skills, and readiness. *IEEE SA*. https://standards.ieee.org/ieee/3527.1/7589/

Jesionkowska, J., Wild, F., & Deval, Y. (2020). Active learning augmented reality for STEAM education–A case study. *Education Sciences, 10*(8), 198. https://doi.org/10.3390/educsci10080198

Jevsikova, T., Stupurienė, G., Stumbrienė, G., Juškevičienė, A., & Dagienė, V. (2021). Acceptance of distance learning technologies by teachers: Determining factors and emergency state influence. *Informatica, 32*(3), 517-542. https://doi.org/10.15388/21-INFOR459

Lavidas, K., Apostolou, Z., & Papadakis, S. (2022). Challenges and opportunities of mathematics in digital times: Preschool teachers' views. *Education Sciences, 12*(7), 459. https://doi.org/10.3390/educsci12070459

Leoste, J., Heidmets, M., Ley, T., & Stepanova, J. (2021). Classroom innovation becoming sustainable: A study of technological innovation adoption by Estonian primary school teachers. *Interaction Design and Architecture(S), 47*, 144-166. https://doi.org/10.55612/s-5002-047-007

Letseka, M. (2020). Stimulating ODL research at UNISA: Exploring the role and potential impact of the UNESCO Chair. Open Learning: *The Journal of Open Distance and e-Learning, 36*(2), 133-148. https://doi.org/10.1080/02680513.2020.1724780

López-Larios, C., Estévez-Nénninger, E.-H., & González-Bello, E.-O. (2022). Cambio e innovación educativa en la teoría y la práctica de la formación inicial docente [Educational change and innovation in the theory and practice of initial teacher training]. *Revista Iberoamericana de Educación Superior* [*Ibero-American Journal of Higher Education*]*, 13*(37), 155-174. https://doi.org/10.22201/iisue.20072872e.2022.37.1309

Marujo, H., & Casais, M. (2021). Educating for public happiness & global peace: Contributions from a Portuguese UNESCO Chair towards the sustainable development goals. *Sustainability, 13*, 9418. https://doi.org/10.3390/su13169418

Michelsen, G., & Wells, P. J. (2017). A decade of progress on education for sustainable development: Reflections from the UNESCO Chairs program. *UNESCO*. https://unesdoc.unesco.org/ark:/48223/pf0000252319

Morin, E. (1994). *Introducción al pensamiento complejo* [*Introduction to complex thinking*]. GEDISA.

Noor, M., & Crossley, M. (2013). Educational innovation and the knowledge society: Development and issues of the clusters of excellence initiative in Malaysia. *Asia Pacific Journal of Education, 33*(2), 156-169. https://doi.org/10.1080/02188791.2013.780675

Oliveira, K., & de Souza, R. (2022). Digital transformation towards Education 4.0. *Informatics in Education, 21*(2), 283-309. https://doi.org/10.15388/infedu.2022.13

Parada, J., Aguillón, M. A., & Zambrano, S. M. (2023). Emprendimiento y educación: Un enfoque desde el pensamiento complejo. Un enfoque de género [Entrepreneurship and education: An approach from complex thinking. A gender approach]. *Revista Venezolana de Gerencia* [*Venezuelan Management Magazine*]*, 28*(9), 757-776. https://doi.org/10.52080/rvgluz.28.e9.47

Parejo, J., Revuelta-Domínguez, F., Guerra-Antequera, J., & Ocaña-Fernández, A. (2022). An analysis of educational innovation culture by a Delphi expert panel. *Frontiers in Education, 7*, 991263. https://doi.org/10.3389/feduc.2022.991263

Patiño, A., Ramírez-Montoya, M. S., & Buenestado-Fernández, M. (2023). Active learning and education 4.0 for complex thinking training: Analysis of two case studies in open education. *Smart Learning Environments, 10*(8). https://doi.org/10.1186/s40561-023-00229-x

Portuguez, M., & Gómez-Zermeño, M. (2021). Educational innovation supported by ICT to identify entrepreneurial skills in students in higher education. In *Proceedings of the 8th International Conference on Technological Ecosystems for Enhancing Multiculturality* (pp. 977-984). ACM. https://doi.org/10.1145/3434780.3436556

Punie, Y., & Redecker, C. (2017). *European framework for the digital competency of educators: DigCompEdu*. Publications Office of the European Union. https://doi.org/10.2760/159770

Ramírez-Montoya, M. S. (2019). *Informe técnico de los proyectos de la estancia internacional UNESCO 2019* [*Technical report of the UNESCO international stay projects 2019*]. https://repositorio.tec.mx/handle/11285/636119

Ramírez-Montoya, M. S. (2020). Challenges for open education with educational innovation: A systematic literature review. *Sustainability, 12*(17), 7053. https://doi.org/10.3390/su12177053

Ramírez-Montoya, M. S. (2021). *Informe técnico de los proyectos de la estancia internacional UNESCO 2021* [*Technical report of the projects of the UNESCO 2021 international stay*]. https://repositorio.tec.mx/handle/11285/643359

Ramírez-Montoya, M. S. (2023). *Estancia internacional 2023 Cátedra UNESCO/ICDE movimiento educativo abierto para América Latina* [*International stay 2023 UNESCO/ICDE Chair open educational movement for Latin America*]. https://repositorio.tec.mx/handle/11285/650073

Ramírez-Montoya, M. S., Castillo-Martínez, I.M., Sanabria-Zepeda, J.C., & Miranda, J. (2022). Complex thinking in the framework of Education 4.0 and open innovation–A systematic literature review. *Journal of Open Innovation: Technology, Market, and Complexity, 8*(4). https://doi.org/10.3390/joitmc8010004

Romero-Rodríguez, J. M., Ramírez-Montoya, M. S., Buenestado-Fernández, M., & Lara, F. (2023). Use of ChatGPT at university as a tool for complex thinking: Students' perceived usefulness. *Journal of New Approaches in Educational Research, 12*(2), 323-339. https://doi.org/10.7821/naer.2023.7.1458

Romero-Rodríguez, J. M., Ramirez-Montoya, M. S., Glasserman-Morales, L., & Ramos Navas-Parejo, M. (2022). Collaborative online international learning between Spain and Mexico: A microlearning experience to enhance creativity in complexity. *Education + Training, 7*. https://doi.org/10.1108/ET-07-2022-0259

Sanabria, J. C., Castillo-Martínez, I. M., González-Pérez, L. I., & Ramírez-Montoya, M. S. (2023). Complex thinking through a transition design-guided Ideathon: Testing an AI platform on the topic of sharing economy. *Frontiers in Education, 8*, 1186731. https://doi.org/110.3389/feduc.2023.1186731

Scherer, R., Howard, K. S., Tondeur, J., & Siddiq, F. (2021). Profiling teachers' readiness for online teaching and learning in higher education: Who's ready? *Computers in Human Behavior, 118*. https://doi.org/10.1016/j.chb.2020.106675

Silva, C., & Iturra, C. (2023). Development and validation of the complex thinking assessment instrument (CTAI). *Thinking Skills and Creativity, 48*, 101305. https://doi.org/10.1016/j.tsc.2023.101305

Sotelo, D., Vázquez-Parra, J. C., Cruz-Sandoval, M., & Sotelo, C. (2023). Lab-Tec@Home: Technological innovation in control engineering education with impact on complex thinking competency. *Sustainability, 15*(9), 7598. https://doi.org/10.3390/su15097598

Stumbrienė, D., Jevsikova, T., & Kontvainė, V. (2023). Key factors influencing teachers' motivation to transfer technology-enabled educational innovation. *Education and Information Technologies, 29*, 1697-1731. https://doi.org/10.1007/s10639-023-11891-6

Suárez-Brito, P., López-Caudana, E. O., Baena-Rojas, J. J., & Ramírez-Montoya, M. S. (2022). Eliciting complex thinking through open educational resource projects. *Journal of Social Studies Education Research, 13*(4), 56-77.

Suárez-Morales, L. X., Rojas-Torres, D., Paredes-Parada, W., & Rodríguez, M. (2022). Innovation competencies in higher education institutions (HEIs) students: A systematic literature review. In M. Zambrano Vizuete, M. Botto-Tobar, A. Diaz Cadena, & B. Durakovic, B. (Eds.), *Innovation and research–A driving force for socio-econo-technological development*. Springer. https://doi.org/10.1007/978-3-031-11438-0_14

Sun, H., Xie, Y., & Lavonen, J. (2022). Exploring the structure of students scientific higher-order thinking in science education. *Thinking Skills and Creativity, 43*. https://doi.org/10.1016/j.tsc.2022.100999

Tecnológico de Monterrey. (2022). *Cátedra UNESCO-ICDE movimiento educativo abierto para América Latina* [*UNESCO-ICDE Chair open educational movement for Latin America*]. https://oerunesco.tec.mx

Trust, T., & Whalen, J. (2021). Emergency remote teaching with technology during the COVID-19 pandemic: Using the whole teacher lens to examine educator's experiences and insights. *Educational Media International, 58*(2), 145-160. https://doi.org/10.1080/09523987.2021.1930479

UNESCO (2017). UNITWIN/UNESCO Chairs program: Guidelines and procedures. *UNESCO*. https://unesdoc.unesco.org/ark:/48223/pf0000380998

United Nations. (2015). United Nations sustainable development goals document. *Sustainable Development Goals*. https://www.un.org/sustainabledevelopment/sustainable-development-goals/

UNITWIN/UNESCO. (2017). Chairs program: Brilliant minds for sustainable solutions, 25th anniversary. *UNESCO*. https://unesdoc.unesco.org/ark:/48223/pf0000259967

Vázquez-Parra, J. C., Carlos-Arroyo, M., & Cruz-Sandoval, M. (2023). Social entrepreneurship and complex thinking. Validation of methodology for the scaling of the perception of competency achievement. *Education Sciences, 13*(2), 186. https://doi.org/10.3390/educsci13020186

Vázquez-Parra, J. C., Castillo-Martínez, I. M., Ramírez-Montoya, M. S., & Millán, A. (2022). Development of the perception of achievement of complex thinking: A disciplinary approach in a Latin American student population. *Education Sciences, 12*, 289. https://doi.org/10.3390/educsci12050289

Wang, Y., Tang, M., Wang, P. Liu, B., & Tian, R. (2022). The Levene test based-leakage assessment. *Integration, 87*, 182-193. https://doi.org/10.1016/j.vlsi.2022.06.013

Wetzel, E., & Farrow, B. (2023). Active learning in construction management education: Faculty perceptions of engagement and learning. *International Journal of Construction Management, 23*(8), 1417-1425. https://doi.org/10.1080/15623599.2021.1974684