frontiers | Frontiers in Education

TYPE Original Research
PUBLISHED 27 May 2024
DOI 10.3389/feduc.2024.1336049

OPEN ACCESS

EDITED BY
Diana Hernández Montoya,
Universidad Estatal a Distancia, Costa Rica

REVIEWED BY
Mario Molina,
University of Los Andes, Colombia, Colombia
Mariana Buenestado Fernández,
University of Cantabria, Spain

*CORRESPONDENCE
Paloma Suarez-Brito
paloma.suarez@tec.mx

RECEIVED 09 November 2023
ACCEPTED 15 May 2024
PUBLISHED 27 May 2024

CITATION
Vázquez-Parra JC, Malagón-Castro LE, Suarez-Brito P and Valencia-González GC (2024) Complex thinking and profile of Colombian university teachers.
Front. Educ. 9:1336049.
doi: 10.3389/feduc.2024.1336049

Complex thinking and profile of Colombian university teachers

José Carlos Vázquez-Parra[1], Luz Elena Malagón-Castro[2], Paloma Suarez-Brito[3]* and Gloria Clemencia Valencia-González[4]

[1]Institute for the Future of Education, Tecnológico de Monterrey, Guadalajara, Mexico, [2]Faculty of Economic, Administrative and Accounting Sciences in the Business Administration Programme, Fundación Universitaria Los Libertadores, Bogotá, Colombia, [3]Institute for the Future of Education, Tecnológico de Monterrey, Mexico City, Mexico, [4]Faculty of Education - Doctorate in Education, Universidad Católica de Manizales, Manizales, Colombia

During the last decade, the development of competencies has become a cardinal point for universities, focusing not only on those skills directly associated with technical or disciplinary aspects but also on those necessary in training for life. In this sense, the so-called general (transversal) competencies become primary in the curricula as part of the training of students regardless of discipline. However, although much literature has reported on students' acquisition and development of these competencies, what is the reality for teachers facing this formative challenge? Methodologically, this study uses the validated EComplexity instrument to assess self-perceived competence in complex thinking among 51 university teachers (30 women and 21 men, mean age 39 years) from southern Colombia, covering five academic disciplines: Business, Health Sciences, Engineering, Social Sciences and Humanities. The aim was to measure their perceived preparedness to teach complex thinking as part of a teacher training course, with an emphasis on the participants' varied academic backgrounds. For data analysis this study employed a multivariate descriptive statistical analysis using SPSS software. The results determined that the teachers perceived themselves as competent in complex thinking and sub-competencies. In conclusion, the study found that differences in factors such as gender, age and academic discipline did not significantly influence teachers' self-perceived competence in complex thinking. This article contributes to the identification of essential teaching competences for the teacher education process within competence-based pedagogical models, ensuring the quality of academic work.

KEYWORDS

professional education, educational innovation, complex thinking, lifelong learning, teacher training, higher education

Introduction

In recent decades, the operational paradigm of universities worldwide, including those in Colombia, has significantly evolved. Historically focused on the dissemination of knowledge, universities are now recognized as crucibles for developing a broad spectrum of competencies, a transformation driven not only by the dynamic demands and complexities of the global labor market but also by a strategic commitment to equipping students with a versatile skill set essential for their lifelong personal and professional development (Riahi, 2022). This shift toward a more holistic educational model is evident in contemporary university curricula, which aim to cultivate not just specialized technical skills but also general competencies that cross disciplinary lines, such as communication abilities, social intelligence, and ethical and civic responsibility (Orhan, 2022).

In Colombia, the approach to teacher education mirrors this broader educational evolution, characterized by a comprehensive strategy that strives to meet the nuanced needs of a diversifying society. The framework for teacher education encompasses both undergraduate and graduate programs provided by accredited institutions, blending robust theoretical underpinnings with practical pedagogical applications (Soler et al., 2020). This model emphasizes not only expertise in specific subjects but also the development of pedagogical, critical, and reflective skills, enabling educators to adapt and grow in their teaching practices. Continuous professional development is pivotal, with educators encouraged to participate in workshops, seminars, and courses that promote innovative teaching methods and the use of technology in education. Supporting this endeavor, the National Ministry of Education in Colombia champions policies and initiatives aimed at improving educational quality and professionalizing teaching, thereby ensuring that educators and graduates alike are well-prepared to navigate and contribute to the multifaceted challenges of the modern world, aligning the Colombian educational system with international excellence standards (Lopez Rodriguez, 2020).

This reality poses a new challenge in training university teachers. Before, the academic credentials of a professor leading a class were primary. Is it possible to guarantee that the teachers have sufficient skills to develop student competencies? The present study analyzed university professors' perceived achievement of f complex thinking and its sub-competencies to assess whether they believe they have sufficient skills to teach their development to students. The choice of complex thinking resulted from the relevance of this competency in the training of any future professional. The study's methodology employed a multivariate descriptive statistical analysis using SPSS software to analyze means and standard deviations and perform significance tests.

Theoretical framework

The relevance of complex thinking in vocational training

Vocational education plays a pivotal role in cultivating skills and competencies necessary for navigating the intricacies of the contemporary world. Within this framework, the paradigm of complex thinking is identified as a crucial element that significantly enhances the caliber of professional education and equips individuals to adeptly tackle the multifaceted challenges prevalent in their specific domains (Cruz-Sandoval et al., 2023).

Morin (2006) articulates complex thinking as a methodology acknowledging the inherent complexity of the world, positing that phenomena cannot merely be deconstructed into isolated components but must be viewed as part of an interconnected whole. This approach emphasizes the non-linear nature of relationships and promotes a comprehensive understanding of systems, considering their various dimensions and variables. In the realm of education, complexity is a fundamental aspect, encompassing a myriad of interrelated factors from the educational content and learners to the socio-cultural backdrop. Adopting a holistic perspective enables educators to recognize that educational elements do not operate in isolation. Rather than approaching teaching through a segmented perspective, complex thinking encourages a deeper comprehension by examining the interrelations and mutual influences among all components, leading to teaching practices that are more contextualized, relevant, and impactful for students (Vázquez-Parra et al., 2023).

The attainment of such outcomes is facilitated through the conceptualization of complex thinking as an indispensable analytical tool, which examines competencies from a multidisciplinary and morphological standpoint (Calderón Urriola and Argota Pérez, 2023). In this context, the educational paradigm shifts toward fostering transdisciplinary training (García and Terlato, 2024), advocating for the synthesis of diverse knowledge domains and the strategic incorporation of information and communication technologies (García-Pinilla et al., 2023). This approach advocates for a comprehensive and multidisciplinary methodology in the competency analysis, emphasizing the integration of varied academic disciplines and technological fluency within the educational process.

The incorporation of complex thinking into the realm of professional education presents a significant avenue for enhancing the efficacy and depth of educational experiences. Drawing upon Morin (2008) insights into complexity, a conceptual framework emerges that has the potential to revolutionize pedagogical strategies and learning outcomes. This paradigm underscores the influence of complex thinking on pedagogical practices, inviting educators to engage in a continual process of reflection both in the midst of action and upon its conclusion, as highlighted by Schön (1987). Effective teaching transcends static methodologies, embracing instead a fluid and responsive approach that necessitates ongoing self-evaluation, informed decision-making, and experiential learning. Such reflective practices are crucial for navigating the complexities inherent in the educational landscape, enabling educators to swiftly adapt to changing classroom dynamics. Furthermore, this reflective approach empowers teachers to tailor their instructional strategies to better address the diverse needs of students, thereby cultivating an enriched and adaptive learning environment (Parveen et al., 2021).

Interdisciplinarity stands as a pivotal element within the framework of complex thinking, underscoring the imperative of synthesizing concepts and methodologies across various academic domains to cultivate a comprehensive understanding of knowledge's multifaceted nature (Palmer, 2007; Gil-Sucerquia, 2019). This approach enables educators to bridge disparate disciplines, thereby facilitating students' grasp of the inherent interconnectedness that characterizes the real-world application of knowledge. Such an educational strategy not only deepens students' comprehension but also accentuates the relevance and practical utility of their academic pursuits. Moving beyond the traditional compartmentalization of academic fields, an interdisciplinary perspective illuminates the synergistic contributions of different disciplines toward a cohesive body of knowledge, highlighting the intricate web of connections that define our understanding of the world.

The integration of complex thinking into the educational journey is paramount in navigating the evolving challenges of contemporary education. Embracing a holistic perspective, fostering reflective practices, advocating for interdisciplinary approaches, and employing metaphors and narratives as pedagogical tools, educators are equipped to craft a dynamic and stimulating learning atmosphere. This enriched educational environment not only facilitates the acquisition of knowledge but also nurtures the development of critical thinking, problem-solving skills, and the ability to apply learning in diverse contexts. By doing so, teachers play a crucial role in preparing students to effectively engage with and contribute to a complex and ever-changing global landscape (Alkhatib, 2019).

Constant changes in technology, economy, and society characterize the 21st century. Professional training based on complex thinking enables professionals to adapt to changing situations by identifying emerging patterns and making informed decisions; understanding the complexity inherent in their fields of work allows them to anticipate and adapt to transformations. Most contemporary problems cannot be addressed from a single discipline, requiring a deeper understanding of scientific knowledge and human problems (Urrea Corrales et al., 2021).

Complex thinking enables individuals to approach problems from multiple perspectives (Noguera de Echeverri and Villota Martínez, 2020), stressing the importance of not limiting the understanding of these terms and of seeking new ways of approaching them that are not conditioned by traditional notions. In this context, the teacher's profile should include the ability to foster critical thinking and reflection in students to actively develop new perspectives that align with realities and needs; they must collaborate effectively in interdisciplinary teams. This is fundamental for professional training, as it allows professionals to face challenges that span multiple areas of knowledge. Innovation is also essential in today's world of work. Professionals must be able to generate creative ideas and practical solutions. Complex thinking fosters creativity by encouraging professionals to consider multiple variables and approaches; this translates into the ability to find innovative solutions to complex problems (Cruz-Sandoval et al., 2023).

Retana Alvarado and Vázquez Bernal (2019) articulate that, within the paradigm of complex thinking, the role of the educator is paramount in fostering pedagogical methodologies that are both intricate and geared toward inquiry within the classroom setting. Their research underscores the imperative for ongoing pedagogical support and professional development for educators, to aid their transition toward employing more sophisticated teaching and learning strategies. The process of reflection and the cultivation of a well-defined educator profile are identified as critical components in advancing pedagogical practices that encourage deep inquiry and the enhancement of critical thinking skills among students.

The significance of integrating complex thinking into the realm of professional education cannot be overstated. By embedding complex thinking within professional training programs, it equips practitioners with the necessary tools to navigate and address the multifaceted challenges characteristic of our modern era. This approach enables professionals to devise solutions that are not only practical but also ethically sound, reflecting a deep understanding of the complexities and dynamism of the contemporary world (Vázquez-Parra et al., 2023). The adoption of complex thinking strategies in professional education thus plays a crucial role in preparing individuals to confront and manage the intricate and ever-evolving challenges they will encounter in their professional landscapes.

Complex thinking and the teaching profession

Teaching holds a pivotal position within society, given its profound impact on shaping the minds and futures of subsequent generations. In the modern era, educators are confronted with the daunting task of navigating a landscape marked by intricate complexities and perpetual transformation. Against this backdrop, complex thinking emerges as an essential pedagogical paradigm, serving to inform and enhance educational practices. This discourse delves into the symbiotic relationship between complex thinking and teaching, underscoring its criticality in the realms of teacher education, pedagogical strategies, decision-making processes, and the facilitation of deep, meaningful learning experiences.

Furthermore, complex thinking embodies the capacity to dissect and comprehend situations and challenges through a multifaceted, interdisciplinary lens. This involves a comprehensive consideration of the myriad factors that shape specific circumstances. Within the educational sphere, an educator's inclination toward complex thinking necessitates a dynamic adaptation to the evolving needs of students, coupled with a nuanced understanding of the myriad connections amongst various pedagogical components (Calderón Urriola and Argota Pérez, 2023). Educators who integrate complex thinking into their pedagogical identity are better positioned to foster enriching learning environments and equip students with the competencies required to tackle the multifarious challenges of the real world. Such an approach empowers students to grasp the nuances of emerging scenarios, characterized by the intricate interplay of diverse variables, thereby cultivating more integrative and efficacious problem-solving strategies (González-Martínez, 2021).

The integration of complex thinking into teacher education is imperative, serving as a cornerstone in the preparatory journey of future educators (Nicolescu et al., 1996). This integration necessitates fostering critical reflection and a nuanced comprehension of the intricate interconnections that permeate the educational landscape. It is essential for teacher education programs to equip aspiring educators with the tools to navigate the multifaceted challenges intrinsic to the teaching profession. According to Albadan Varga (2020), the infusion of complex thinking into the fabric of teacher education significantly enriches teachers' professional identities. Through grappling with the complexities of their roles, educators gain the capacity for introspection concerning the ethical dimensions of their practice, thereby enhancing their ability to navigate difficult situations with moral integrity.

Flores (2019) advocates for the inclusion of complex thinking within contemporary pedagogical paradigms, arguing that educational models aligned with this approach, such as problem-based learning, are instrumental in facilitating exploration, reflection, and collaborative engagement. These methodologies underpin deeper, more meaningful learning experiences. Furthermore, Flores highlights the pivotal role of complex thinking in the evaluation of learning outcomes, suggesting that assessment techniques like authentic assessment are crucial for gauging students' comprehensive learning and their proficiency in tackling real-world challenges (Vega Flores et al., 2021). Such pedagogical and assessment strategies, grounded in complex thinking, not only elevate the quality of education but also prepare students more effectively for the complexities of the contemporary world.

The discussion thus far underscores the imperative for adopting a socio-constructivist didactic framework (Lima Sarmiento et al., 2021), which places a premium on the cultivation of both logical and intellectual faculties alongside professional competencies. From the vantage point of complex thinking, this necessitates a significant evolution in the teaching paradigm to adeptly foster theoretical-systemic, critical, and creative thinking among students. Concurrently, it emphasizes the inculcation of core values and a robust work ethic. Within such a pedagogical landscape, educators are envisaged as facilitators who steer a student-centric learning process.

This approach is geared toward equipping future professionals with the requisite acumen to address multifaceted problems in a holistic (Tovar Riveros, 2023) and morally responsible manner within their prospective professional endeavors. It accentuates the criticality of nurturing adaptive and inventive capabilities in students, a goal that mandates a paradigm shift in both instructional methodologies and the educator's role. This transformation underscores the transition toward a more dynamic, interactive, and flexible educational environment, where teachers not only impart knowledge but also inspire innovation, ethical reasoning, and a deep-seated understanding of complex systems, thus preparing students to navigate and thrive in an ever-evolving global landscape.

Methods

Design and participants

This research employs an exploratory methodological approach, designed to quantitatively analyze university professors' perceptions of their proficiency and achievement in complex thinking and its related sub-competencies. The focus on the exploratory aspect aims to derive insights into educators' self-evaluation of their ability to nurture and implement complex thinking skills within an educational context.

Within the context of a teacher training program in southern Colombia, this study aimed to evaluate the participants' self-perceived competencies in complex thinking and its various components. The participant pool consisted of 51 individuals (30 females and 21 males) with an average age of 39, representing a broad spectrum of academic fields including Business, Health Sciences, Engineering, Social Sciences, and Humanities.

Given that this assessment was being conducted for the first time at the institution, the research was designated as exploratory. Consequently, the institutional ethics committee set a cap on the sample size at no more than 60 teachers, with the possibility of sample expansion in future studies based on initial findings.

Instrument and data analysis

The study employed the E-Complexity instrument, previously validated by Castillo-Martínez et al. (2024), to assess participants' self-perceived proficiency in complex thinking and its sub-competencies. This tool underwent a comprehensive validation process, including theoretical foundations, expert evaluations, and statistical analyses, establishing its clarity, coherence, and reliability for gauging perceived competencies in complex thinking. The E-Complexity instrument features 25 items categorized into four distinct sub-competencies: Systems Thinking, Scientific Thinking, Critical Thinking, and Innovative Thinking, with responses recorded on a Likert scale ranging from "Strongly disagree" to "Strongly agree."

Highlighting the importance of measuring perceived competency beyond mere developmental attainment underscores a critical insight: possessing competency is insufficient without the corresponding self-perception of competency, particularly in educational settings. This principle emphasizes the necessity for teachers to view themselves as adept in these areas to effectively foster such skills among their students.

Data analysis and processing were facilitated through multivariate descriptive statistical techniques using SPSS software, supporting the comprehensive evaluation of the collected data.

Results

First, Table 1 shows the means and standard deviations of the scores obtained in the eComplexity instrument. It separates these results by the teachers' gender and their professional disciplines.

The results show that the means for men and women were close, and the men's was higher. Among the disciplines, social sciences had the highest mean, followed by the humanities and education. In contrast, the lowest scores occurred in business discipline and engineering and science.

The mega-competency of complex thinking comprises four sub-competencies: critical, systemic, scientific, and innovative thinking. Table 2 shows the results of each by men and women, and Table 3 analyzes the different disciplines via the competencies. The results show that men had the highest means in critical thinking; the lowest means were attained by women in scientific thinking.

In Table 3, the sub-competency with the highest mean was systems thinking in the business group (4.33), and the lowest mean was in scientific thinking (3.69), also in business. In addition to the high values in systems thinking, there were generally high means in critical thinking and low means in scientific thinking in most disciplines.

Figure 1 shows the overall means obtained in the eComplexity instrument by men and women; the difference was minimal, slightly higher for men (4.14) than women (4.03).

In the same vein, to graphically show the results of the study participants in each sub-competency measured with the E-complexity instrument, Figure 2 shows the mean values of critical, systemic, scientific, and innovative thinking differentiated by teachers' gender.

TABLE 1 eComplexity scores obtained by teachers, grouped by gender and discipline.

	Mean	Std. deviation	*N*	%
Gender				
Female	38.93	10.478	30	59%
Male	39.38	10.661	21	41%
Discipline				
Business	35.88	11.090	8	16%
Social sciences	44.89	12.614	9	18%
Engineering and sciences	35.40	10.458	10	20%
Health sciences	39.33	7.971	18	35%
Humanities and education	40.33	12.078	6	11%
Total	39.12	10.449	51	100%

TABLE 2 Means and standard deviations by gender.

Gender		Total	Systemic	Scientific	Critical	Innovative
Female	Mean	4.0327	4.1447	3.8950	4.0807	4.0277
	Std. deviation	0.50722	0.48582	0.79558	0.55572	0.47353
	N	30	30	30	30	30
Male	Mean	4.1419	4.1114	4.0200	4.3471	4.0795
	Std. deviation	0.66138	0.63142	0.85398	0.58273	0.87520
	N	21	21	21	21	21
Total	Mean	4.0776	4.1310	3.9465	4.1904	4.0490
	Std. deviation	0.57196	0.54465	0.81405	0.57662	0.66114
	N	51	51	51	51	51

TABLE 3 Mean and standard deviation by discipline.

Discipline		Total	Systemic	Scientific	Critical	Innovative
Business	Mean	4.0713	4.3338	3.6975	4.1425	4.1663
	Std. deviation	0.64337	0.57736	1.00748	0.67776	0.44526
	N	8	8	8	8	8
Social sciences	Mean	4.0078	3.9444	4.0300	4.2067	3.8144
	Std. deviation	0.54990	0.68425	0.73434	0.40985	0.77093
	N	9	9	9	9	9
Engineering and sciences	Mean	4.0340	4.1500	3.8710	4.1010	4.0340
	Std. deviation	0.50178	0.46263	0.64426	0.64207	0.44398
	N	10	10	10	10	10
Health sciences	Mean	4.1744	4.1856	4.0322	4.2611	4.2317
	Std. deviation	0.62889	0.53598	0.93454	0.62490	0.64644
	N	18	18	18	18	18
Humanities and education	Mean	3.9733	3.9450	4.0217	4.1667	3.7217
	Std. deviation	0.59220	0.45527	0.68561	0.55178	0.99841
	N	6	6	6	6	6
Total	Mean	4.0776	4.1310	3.9465	4.1904	4.0490
	Std. deviation	0.57196	0.54465	0.81405	0.57662	0.66114
	N	51	51	51	51	51

At a glance, it shows that in almost all cases, men obtained slightly higher scores than women in each sub-competency. Also notable is the scientific thinking means, which were lowest for both genders. In contrast, the values for the scientific thinking sub-competency were slightly higher and similar to those obtained in systems thinking.

Figure 3 shows each discipline's total scores obtained in the eComplexity instrument. This figure shows that the social sciences and the engineering and science disciplines had the least variability in their results, with the highest scores in social sciences. However, two points are outliers in these disciplines and do not affect the group results. Health sciences and business had the largest data dispersions. Likewise, the areas of humanities and education, and business stand out with the lowest instrument scores.

Figure 4 shows the data for each sub-competency differentiated by men and women in the five disciplines analyzed. At first glance, there is not much variability by gender; however, when the differences between disciplines are observed, it is notable that the scores for scientific thinking and, above all, for innovative thinking have lower values in the social sciences and the humanities and education disciplines.

The following section determines whether the differences observed in the eComplexity scores were statistically significant through a student t-test on the gender variable. Table 4 shows the data from this analysis, where there were no statistically significant differences between men and women for the total test score nor the critical, systemic, and scientific thinking scores. The only statistically significant difference occurred for the sub-competency of innovative thinking ($p < 0.05$), with men having a slightly higher value.

Similarly, we performed a one-factor ANOVA test on discipline as the dependent variable and the results of the instrument as independent variables. This test's results showed no statistically significant differences based on the professional discipline to which

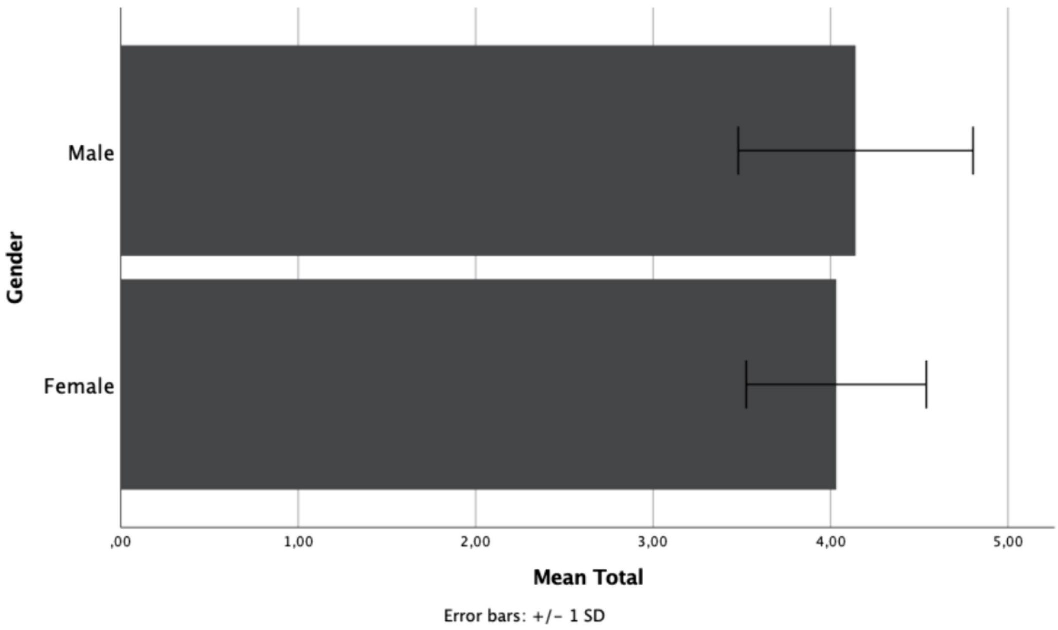

FIGURE 1
Total score (mean) by males and females in the e-Complexity results.

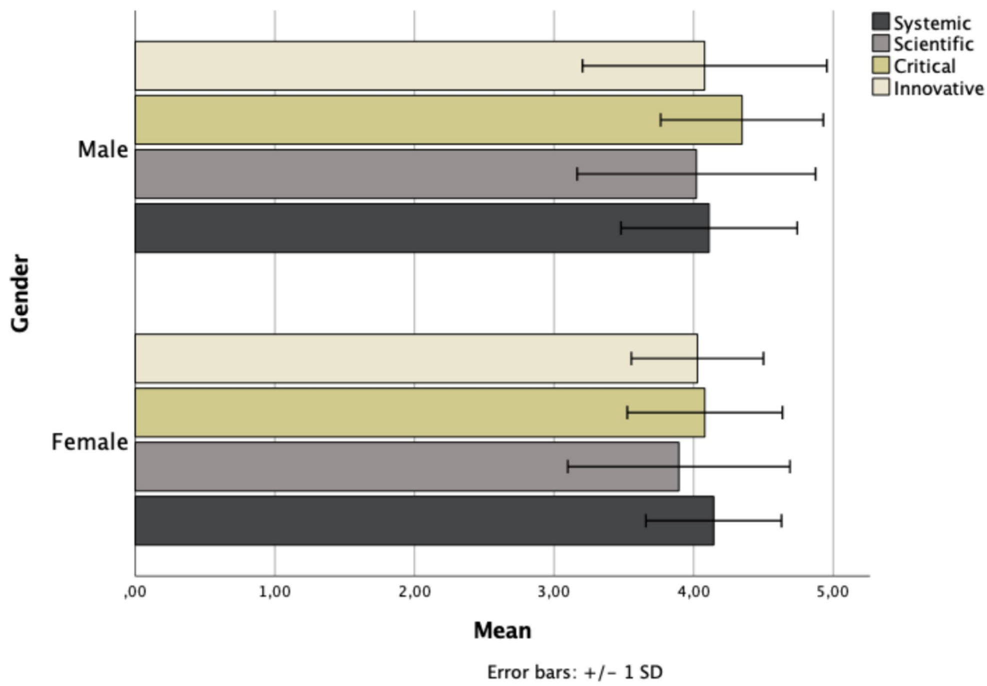

FIGURE 2
Graphical illustration of e-Complexity means by males and females in each sub-competency.

the participants belong (Table 5). These results imply that the teachers perceived themselves as having equivalent performance in each sub-competency regardless of the discipline to which they belong.

Finally, a mean comparison test took age as the independent variable at its average cut-off point to determine if there are differences in the perception of achievement of complex thinking and its sub-competencies among the sample's higher education teachers of different ages. In this study, the average cut-off point was 39 years, and no difference was observed between the groups derived from the independent samples' *t*-student tests. The latter implies that, at least as observed here, age was not a variable that directly influences the

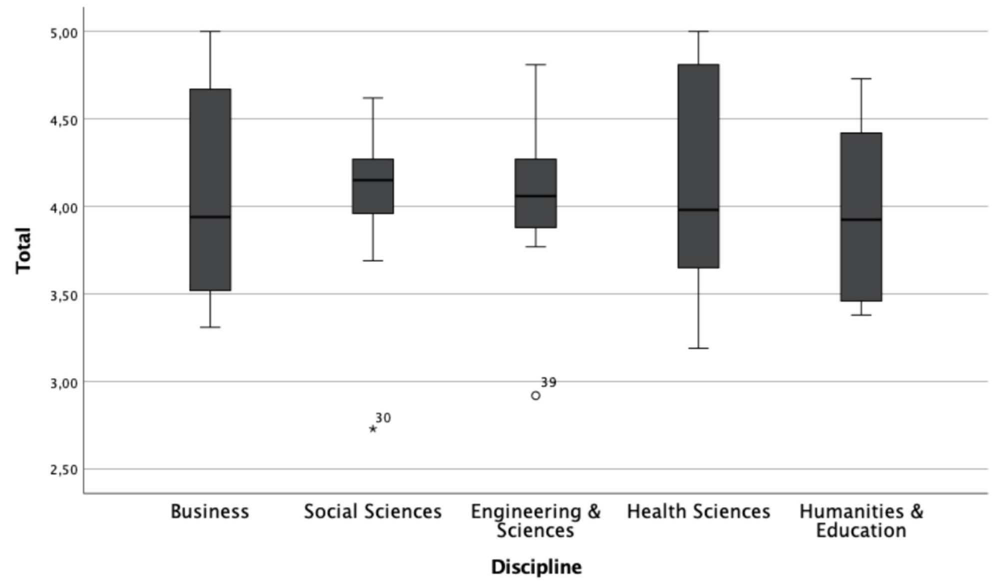

FIGURE 3
eComplexity total scores by discipline.

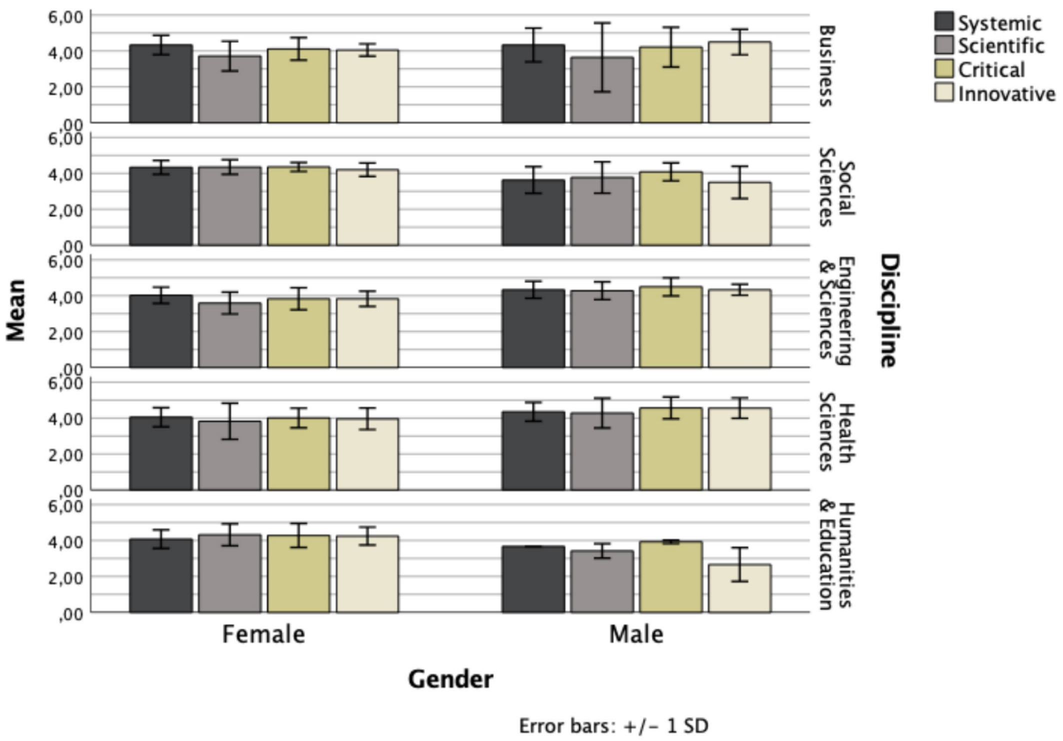

FIGURE 4
eComplexity scores in each sub-competency, differentiated by gender and discipline.

teachers' perceived achievement of complex thinking in different disciplines. Table 6 shows the characteristics of both age groups, and the statistical test results are in Table 7.

In this sense, no statistically significant difference was observed between both age groups ($p < 0.05$), which implies that the university teachers did not make a distinction regarding their perceived achievement of the complex thinking competency or its sub-competencies.

Based on these results, the findings are:

a. Men's perceived achievement of complex thinking competency was slightly better than women's, although this difference was

TABLE 4 Comparison of means between men and women in the total scores and by sub-competencies of the eComplexity measurement in each discipline.

		Levene's test for equality of variances		*t*-test for equality of means							
		F	Sig.	*t*	df	Significance		Mean difference	Std. error difference	95% confidence interval of the difference	
						One-Sided *p*	Two-Sided *p*			Lower	Upper
Total	Equal variances assumed	2.660	0.109	−0.668	49	0.254	0.508	−0.10924	0.16364	−0.43809	0.21962
	Equal variances not assumed			−0.637	35.687	0.264	0.528	−0.10924	0.17148	−0.45712	0.23865
Systemic	Equal variances assumed	2.981	0.091	0.212	49	0.416	0.833	0.03324	0.15647	−0.28119	0.34767
	Equal variances not assumed			0.203	35.773	0.420	0.840	0.03324	0.16387	−0.29917	0.36565
Scientific	Equal variances assumed	0.989	0.325	−0.536	49	0.297	0.595	−0.12500	0.23328	−0.59380	0.34380
	Equal variances not assumed			−0.529	41.197	0.300	0.600	−0.12500	0.23628	−0.60210	0.35210
Critical	Equal variances assumed	0.793	0.378	−1.652	49	0.052	0.105	−0.26648	0.16130	−0.59061	0.05766
	Equal variances not assumed			−1.638	41.868	0.054	0.109	−0.26648	0.16268	−0.59481	0.06185
Innovative	Equal variances assumed	4.389	0.041	−0.273	49	0.393	0.786	−0.05186	0.18987	−0.43342	0.32971
	Equal variances not assumed			−0.247	28.219	0.403	0.806	−0.05186	0.20964	−0.48114	0.37742

not statistically significant. At the sub-competency level, men's better perception was in critical thinking, while women's in systems thinking. In both cases, the worst perception was in scientific thinking. Despite these contrasts, a statistically significant difference was only in innovative thinking, where men perceived themselves better.

b. Considering the disciplines, the Social Sciences teachers had the best perceived achievement of the complex thinking competency, unlike the Engineering and Science teachers, who showed the lowest perception. As for the sub-competencies, the business discipline showed the most marked positive and negative trends, with the best in systems thinking and the worst in scientific thinking. Despite these differentiated data, no statistically significant difference was found in the general competency or sub-competencies, meaning that the entire sample, regardless of their discipline, perceived themselves with an equivalent level of performance.
c. In general, health sciences teachers had the highest means in all sub-competencies, although they also had the largest dispersion of responses. In contrast, social sciences and engineering and science teachers had the lowest standard deviations, meaning perceptions were more balanced.
d. The participants' ages did not generate statistically significant differences in their perceptions of the general competency or its sub-competencies.

Discussion

The exploration of complex thinking within higher education underscores a multifaceted dialog interwoven with cultural, pedagogical, and technological threads. This discussion, enriched by the contributions of various scholars, presents a comprehensive view of the elements essential for nurturing complex thinking among university professors and their students. The research by Vázquez-Parra et al. (2023), alongside Rodríguez-Abitia (2022) findings, anchors the discourse in the profound impact of cultural knowledge and national culture on complex thinking. These studies collectively argue that a deep engagement with and understanding of cultural contexts significantly enhance complex thinking capabilities, suggesting that the cultivation of such skills cannot be divorced from the cultural milieu in which learners and educators operate. This highlights the need for educational strategies that are culturally responsive and attuned to the diverse backgrounds of students.

TABLE 5 Results of the one-factor ANOVA test considering "discipline" as the dependent variable and eComplexity scores as the independent variable.

		Sum of squares	df	Mean square	*F*	Sig.
Total	Between groups	0.297	4	0.074	0.213	0.930
	Within groups	16.060	46	0.349		
	Total	16.357	50			
Systemic	Between groups	0.907	4	0.227	0.749	0.564
	Within groups	13.925	46	0.303		
	Total	14.832	50			
Scientific	Between groups	0.782	4	0.195	0.278	0.891
	Within groups	32.352	46	0.703		
	Total	33.134	50			
Critical	Between groups	0.194	4	0.049	0.136	0.968
	Within groups	16.431	46	0.357		
	Total	16.625	50			
Innovative	Between groups	1.851	4	0.463	1.064	0.385
	Within groups	20.005	46	0.435		
	Total	21.855	50			

TABLE 6 eComplexity scores by age group.

	Age	*N*	Mean	Std. deviation	Std. error mean
Total	≥39	24	4.1579	0.57227	0.11681
	<39	27	4.0063	0.57286	0.11025
Systemic	≥39	24	4.1113	0.57922	0.11823
	<39	27	4.1485	0.52249	0.10055
Scientific	≥39	24	4.1192	0.69072	0.14099
	<39	27	3.7930	0.89462	0.17217
Critical	≥39	24	4.3092	0.56606	0.11555
	<39	27	4.0848	0.57564	0.11078
Innovative	≥39	24	4.0758	0.68630	0.14009
	<39	27	4.0252	0.65014	0.12512

The emphasis on pedagogical training by Kovshikova et al. (2019) shifts the focus toward the capabilities of university educators. Their call for comprehensive pedagogical development for professors lacking in this area points to a critical gap in current educational practices. Effective teaching of complex thinking, as they argue, is predicated on a robust pedagogical foundation, underscoring the symbiotic relationship between educators' teaching skills and students' cognitive development.

Further complicating the landscape are the insights from Cruz-Sandoval et al. (2023), which reveal gender disparities in the development of complex thinking skills, particularly in procedural knowledge. This gender gap not only reflects underlying systemic issues but also stresses the importance of gender-sensitive educational policies and practices that ensure equitable development of complex thinking skills across genders. Beckett and Hager (2018), and de Lima Ferreira et al. (2013), expand the discussion by exploring the role of experiential learning and technological integration in developing complex thinking. The advocacy for "learning thinking by doing thinking" and the adoption of a new complexity paradigm in pedagogy, particularly through technological resources, presents a forward-thinking approach to education. These perspectives underscore the potential of technology and experiential learning to revolutionize teaching methods, facilitating deeper engagement with complex thinking tasks.

Collectively, these studies form a rich tapestry of insights that underscore the necessity of a holistic approach to fostering complex thinking. This approach must be culturally informed, pedagogically sound, gender-sensitive, and technologically enabled, pointing toward a comprehensive framework for enhancing complex thinking in higher education. The integration of these diverse elements promises not only to enrich the educational experience but also to prepare students more effectively for the complexities of the modern world. This dialog, therefore, not only advances our understanding of complex thinking in higher education but also charts a path forward for educators, policymakers, and researchers dedicated to cultivating these critical skills in the next generation of learners.

Conclusion

This article presented the results of a study that analyzed university professors' perceived achievement of complex thinking competency and its sub-competencies to assess whether they considered they had sufficient skills for their training. The results argue that, on average, the participants perceive themselves as competent, and that although some factors could influence their level of perception (age, gender, and discipline), the differences are not statistically significant.

Thus, it can be concluded that the teachers participating in this study perceived themselves as having sufficient skills to train their students in complex thinking and its sub-competencies, which provides their educational institution with the certainty that, at least in terms of this competency, their teachers are capable of facing the challenges of a competency-based educational model. In this sense, although exploratory, this study provides relevant findings for educational theory and teaching practice for educational institutions interested in this type of training model.

Implications

The results of this study are equally valuable for understanding how competencies are acquired and developed and for identifying possible elements that impact the perception of achievement (gender, age, and discipline), which, in turn, may influence how the competencies are taught. Although complex thinking is usually

TABLE 7 Results of the *t*-Student test among age groups.

Independent samples test											
		Levene's test for equality of variances		*t*-test for equality of means							
						Significance				95% Confidence Interval of the difference	
		F	Sig.	*t*	df	One-Sided *p*	Two-Sided *p*	Mean difference	Std. error difference	Lower	Upper
Total	Equal variances assumed	0.062	0.804	0.944	49	0.175	0.350	0.15162	0.16063	−0.17119	0.47443
	Equal variances not assumed			0.944	48.313	0.175	0.350	0.15162	0.16062	−0.17128	0.47452
Systemic	Equal variances assumed	0.003	0.954	−0.242	49	0.405	0.810	−0.03727	0.15426	−0.34726	0.27272
	Equal variances not assumed			−0.240	46.694	0.406	0.811	−0.03727	0.15521	−0.34956	0.27503
Scientific	Equal variances assumed	0.770	0.384	1.444	49	0.078	0.155	0.32620	0.22594	−0.12784	0.78025
	Equal variances not assumed			1.466	48.108	0.075	0.149	0.32620	0.22253	−0.12120	0.77361
Critical	Equal variances assumed	0.013	0.911	1.400	49	0.084	0.168	0.22435	0.16023	−0.09765	0.54636
	Equal variances not assumed			1.402	48.481	0.084	0.167	0.22435	0.16007	−0.09742	0.54612
Innovative	Equal variances assumed	0.227	0.636	0.271	49	0.394	0.788	0.05065	0.18722	−0.32559	0.42688
	Equal variances not assumed			0.270	47.559	0.394	0.789	0.05065	0.18783	−0.32710	0.42840

associated with the ability to face challenges, make decisions, and comprehensively perceive the environment, it has additional meaning when the individual is a teacher since their perception is associated with their work as an educator. In this sense, these results directly affect the teaching-learning process because the presumption is that the better the teacher's perception, the more confident he or she should be when developing competencies in students.

This study also has implications for academic training and development because its results shed light on differences that, although not statistically significant, are perceptible per gender and discipline. In this sense, it is relevant that educational institutions, besides recognizing the academic credentials of their teachers, should assess their levels of performance and perceived achievement of both the disciplinary and transversal competencies they train. In the long term, this study seeks to provide practical tools to educational institutions to improve the quality of their teachers and, consequently, their work in the classroom.

Limitations

Although the results presented here respond to the initial objective of the study, they may be limited and, therefore, neither conclusive nor generalizable. The first limitation identified is the limited sample, which means the number of participants and that they were from a single educational institution. In this study, the limited sample was because it was an exploratory study; however, we are confident that based on these results, the ethics committee that regulates the research will allow us to increase the number of participants and the areas of application. It is hoped that with the above, it will also be possible to access more information about the sample, since being an exploratory study, the ethics committee restricted the number of participants per discipline and the specific ages of each participant, which limited the possibility of further analysis.

As a possible future line of work, it would be valuable to cross-check this information with the perception and achievement level of the students of each teacher involved to validate whether the teachers' perception truly influences how they train in these skills. Despite these limitations, the results are valuable because they are from a first study that invites delving deeper into these topics.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Institute for the Future of Education, Tecnológico de Monterrey. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required from the participants or the participants' legal guardians/next of kin because no personal data, such as names, addresses, or any other identifying information, was collected from the participants. As a result, written informed consent was not deemed necessary for this research, as there was no risk of compromising the confidentiality or privacy of the individuals involved.

Author contributions

JV-P: Conceptualization, Methodology, Project administration, Writing – original draft, Writing – review & editing. LM-C: Investigation, Writing – review & editing. PS-B: Formal analysis, Visualization, Writing – review & editing. GV-G: Investigation, Writing – review & editing.

Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. The authors would like to thank the financial support from Tecnológico de Monterrey through the "Challenge-Based Research Funding Program 2022." Project ID # I001 - IFE001 - C1-T1 - E.

Acknowledgments

The authors acknowledge the technical and financial support of Writing Lab, Institute for the Future of Education, Tecnológico de Monterrey, Mexico, in the production of this work.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

Albadan Varga, J. P. (2020). Professional teaching identity as a link between complex thinking and the educational field. *Sophia Philos. Educ. Collect.* 29, 127–156. doi: 10.17163/soph.n29.2020.04

Alkhatib, O. (2019). A framework for implementing higher-order thinking skills (problem-solving, critical thinking, creative thinking, and decision-making) in engineering & humanities. 2019 Advances in Science and Engineering Technology International Conferences (ASET).

Beckett, D., and Hager, P. (2018). "A complexity thinking take on thinking in the university" in *The thinking university: A philosophical examination of thought and higher education*. Eds. S. S. E. Bengtsen and R. Barnett. Springer. 137–153.

Castillo-Martínez, I. M., Velarde-Camaqui, D., Ramírez-Montoya, M. S., and Sanabria-Z, J. (2024). Psychometric properties of eComplexity scale. *J. Soc. Stud. Educ. Res.*

Calderón Urriola, N. F., and Argota Pérez, G. (2023). Competitividad desde el pensamiento complejo y rizomático mediante ingeniería en ciencias de datos no computacional. *Rev. Camp.* 28, 35–44. doi: 10.24265/campus.2023.v28n35.03

Cruz-Sandoval, M., Vázquez-Parra, J., Carlos-Arroyo, M., and Amézquita-Zamora, J. (2023). Student perception of the level of development of complex thinking. An approach in university women in Mexico. *J. Latin. Educ.* 23, 768–780. doi: 10.1080/15348431.2023.2180370

Cruz-Sandoval, M., Vázquez-Parra, J. C., Carlos-Arroyo, M., and Del Angel-González, M. (2023). Complex thinking and its relevance in professional training: an approach to engineering students in a Mexican university. *Int. J. Eng. Pedagogy* 13, 100–119. doi: 10.3991/ijep.v13i3.36885

de Lima Ferreira, J., Carpim, L., and Behrens, M. A. (2013). The university professor who builds up innovative knowledge for a complex, collaborative and dialogical practice. *Diál. Educ.* 13:69. doi: 10.7213/DIALOGO.EDUC.7627

Flores, M. (2019). Four ways of understanding education: pedagogical models, conceptualization, organization, and theoretical construction. *Educ. Human.* 21, 137–159. doi: 10.17081/eduhum.21.36.3147

García, E. C. B., and Terlato, A. N. (2024). Systemic factors relevant to strategic risk analysis. A case study of Colombian private universities. *Cienc. Adm.* 11:128. doi: 10.24215/23143738e128

García-Pinilla, J. I., Rodríguez-Jiménez, O. R., and Olarte-Dussan, F. A. (2023). Complex teacher appropriation of ICT in educational institutions equipped with technological tools. A qualitative analysis from the technology appropriation model (MAT). *Perfiles Educ.* 45, 37–54. doi: 10.22201/iisue.24486167e.2023.179.59798

Gil-Sucerquia, J. A. (2019). Development of integrative physiological systems thinking as a learning tool at the undergraduate level for health science programs, a pedagogical reflection on the teaching of human physiology. *CES Med.* 33, 257–306. doi: 10.21615/cesmedicina.33.4.1

González-Martínez, C. (2021). Epigenetics and health: an analysis from complex thinking. *Rev. Salud Bosque* 9, 31–38. doi: 10.18270/rsb.v9i2.2796

Kovshikova, E., Shindryaeva, I., Gulyaeva, E., and Ogarkov, A. (2019). Pedagogical components of professional activity of university professors: complex analysis. ARPHA Proceedings, 1.

Lima Sarmiento, L., Rivera Michelena, N. M., de Jesús Pérez Esquivel, G., López Aguilera, Á. F., and Díaz Molleda, M. (2021). Socio-constructivist approach and teaching process of the 2019-2020 course during COVID-19. *Rev. Cub. Educ. Méd. Superior* 35, 1–16. Available at: https://ems.sld.cu/index.php/ems/article/view/2903

Lopez Rodriguez, R. R. (2020). Reflections on teacher training needs in Colombia in the times of liquid society. *Rev. Educ.* 45, 534–546. doi: 10.15517/REVEDU.V45I1.42233

Morin, E. (2006). *El método VI. La ética*. Madrid: Ediciones Cátedra.

Morin, E. (2008). *El método: La naturaleza de la naturaleza*. Madrid: Cátedra.

Nicolescu, B., Gaston, P., Humberto, M., Michel, R., and Paul, T. (1996). *Educação e Transdisciplinaridade*. Brasília: UNESCO, 2002.

Noguera de Echeverri, A. P., and Villota Martínez, D. A. (2020). Sustainability as an alternative path to development in Latin America. Strengths and Weaknesses. Understanding from the Aesthetic-Complex Environmental Thinking. *Gestión Ambiente* 23, 138–149. doi: 10.15446/ga.v23n1.77632

Orhan, A. (2022). Critical thinking dispositions and decision making as predictors of high school students' perceived problem-solving skills. *J. Educ. Res.* 115, 235–245. doi: 10.1080/00220671.2022.2113498

Palmer, P. J. (2007). *La comunidad del aprendizaje*. Madrid: Morata.

Parveen, F., Nazir, N., and Zamir, S. (2021). Analyzing teacher competency: knowledge, skills, and aptitude of secondary school teachers. *UMT Educ. Rev.* 4, 58–79. doi: 10.32350/uer.41.04

Retana Alvarado, D. A., and Vázquez Bernal, B. (2019). Inquiry-based science education: analysis of didactic conceptions of practicing teachers in Costa Rica based on a complexity model. *Rev. Educ.* 43:31. doi: 10.15517/revedu.v43i2.32427

Riahi, S. (2022). Strengthening the teaching of soft skills in the pedagogical architecture of Moroccan universities. *Int. J. Eng. Pedagogy* 12, 47–62. doi: 10.3991/ijep.v12i4.22329

Rodríguez-Abitia, G. (2022). Cultural differences in complexity reasoning in higher education. Proceedings TEEM 2022: Tenth International Conference on Technological Ecosystems for Enhancing Multiculturality

Schön, D. A. (1987). *Educating the reflective practitioner*. New Jersey: Jossey-Bass.

Soler, C., Palermo, Y. C., and Chiappe, S. M. D. (2020). Teacher education for early childhood in the National Pedagogical University of Colombia: an approach from the themes and objects of research production. *Estud. Infan. Educ. Formación* 20, 279–294. doi: 10.17533/UDEA.UNIPLURI.20.2.017

Tovar Riveros, B. E. (2023). Teaching experience in the teaching of nursing ethics. *Enfermagem Brasil* 22, 229–246. doi: 10.33233/eb.v22i2.5198

Urrea Corrales, M., Villadiego Rincón, D. A., and Torres Díaz, G. A. (2021). Complexity theory and its contribution to the debate on the academic competencies of the university engineer-teacher. *Rev. Filosofía*. 97, 279–294. doi: 10.5281/zenodo.4877157

Vázquez-Parra, J. C., Alfaro-Ponce, B., Guerrero-Escamilla, J., and Morales-Maure, L. (2023). Cultural imaginaries and complex thinking: impact of cultural education on the development of perceived achievement of complex thinking in undergraduates. *Soc. Sci.* 12:272. doi: 10.3390/socsci12050272

Vázquez-Parra, J., Alonso-Galicia, P., Cruz-Sandoval, M., Suarez-Brito, P., and Carlos-Arroyo, M. (2023). Social entrepreneurship, complex thinking, and entrepreneurial self-efficacy: correlational study in a sample of Mexican students. *Adm. Sci.* 13:104. doi: 10.3390/admsci13040104

Vega Flores, R. I., Díaz Araya, M. H., Sánchez Rodríguez, J. R., and Muñoz González, L. A. (2021). Characteristics of the teaching-learning process linked to critical thinking from the point of view of nursing teachers and students. *Rev. Cubana Enferm.* 37, 1–12. Available at: https://www.medigraphic.com/cgi-bin/new/resumenI.cgi?IDARTICULO=114060.