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Exploring Complex Thinking in Latin American Universities: Comparative Analysis Between Programs and Alternative Credentials

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ABSTRACT

Training the high-order competency of complex thinking encompasses addressing its sub-competencies of critical, innovative, scientific and systemic thinking. In this framework, how do the practices of reasoning for complexity in Latin American institutions differ from other regions? This study focused on comparing training practices that promote complex thinking in national and international educational entities through analysis of their programs and alternative professional credentials to identify best educational practices. The comparative education method benchmarked the selected institutions and compared the best educational practices. The four categories of analysis were the philosophical, theoretical, and political components and the educational process. A significant-document analysis was applied to publications found on the websites of 19 educational institutions, and the data were triangulated. The findings accounted for (a) educational institutions seeking to educate individuals who can improve the quality of life in society and contribute to sustainable development, (b) educational practices aimed at developing complex thinking competencies and lifelong learning as essential for new educational models, (c) the collaboration of researchers, faculty, and other stakeholders, and appropriate tools for formative assessment, promoting the development of complex reasoning competencies in changing environments, and (d) educational processes focused on developing high skills, innovation, and digital transformation as essential for designing the future of education. This study is intended to be of value to managers, decision-makers, professors, researchers, and society interested in creating new programs to develop high-level capabilities, such as complex thinking.

KEYWORDS

Complex thinking; educational innovation; higher education; comparative analysis; alternative credentials word; another word

Introduction

In changing environments, complex thinking is a critical skill for problem-solving and decision-making. According to Ramírez-Montoya, Castillo-Martínez, et al. (2022) complex thinking is indeed a macro-competency made up of critical, innovative, scientific and systemic thinking, to be integrated in the training of higher education students to effectively face the challenges of today's society. Its scope entails transforming the worldview through a shift from the classical paradigm of education (Sigahi et al., 2023). The author to whom its notion is attributed, Morin (2010), points out that the

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traditional paradigm isolates things rather than connects them. Therefore, adopting a new paradigm that fosters critical reflection and generates new ways of thinking to address problems more effectively is necessary.

Complex thinking has received recent attention in various educational contexts in Latin America, as researchers explored its implications and intricacies in more detail. A study conducted in an undergraduate student population found no significant differences in perceived achievement of complex thinking across disciplines, challenging the notion that certain types of reasoning are specific to some professions (Vázquez-Parra et al., 2022). In another study focused on female university students, although no statistically significant differences were observed between men and women in the acquisition and development of complex thinking, a disparity was observed in the development of procedural knowledge among women, which had an impact on their perception of their ability to solve problems (Cruz-Sandoval et al., 2023). Further, an exploratory study by Sanabria-Z et al. (2023) showed that male students in selected Latin American countries had a higher perception of complex thinking, especially in tech-based disciplines. The findings of these studies underscore the importance of gaining a deeper understanding of the nuances of complex thinking in the Latin American context and lay the groundwork for further exploration of how universities foster this core competency.

Understanding how universities are imparting and stimulating the growth of complex thinking through different educational approaches is crucial. The most successful university institutions will equip their graduates with high-level critical and analytical thinking skills (Alkhatib, 2019). Consequently, models that foster essential life skills and workplace performance are gaining more support in higher education institutions and can be appropriately complemented with alternative certifications (Braxton, 2023). In the Latin American context, it is also crucial to develop high skills in the more than 30 million university students, as well as to increase opportunities for training programmes. Ramírez-Montoya, McGreal, et al. (2022) emphasize the need to rebuild people's learning spaces and expand possibilities, especially in university settings in emerging countries. Comparing universities' different programs and credentials for developing complex thinking allows for identifying their strengths and areas for opportunity.

This study is innovative in the academic field because it aims to compare formative practices that promote complex thinking in national and international educational institutions and other entities through an analysis of their programs and alternative professional credentials to identify best educational practices. This research seeks to be valuable for managers, decision-makers, teachers, researchers, and society interested in improving educational programs to train graduates in the high-level critical and analytical thinking skills that are highly valued in today's job market. The article may be particularly relevant for Latin America, where the complexity of problems in different areas of society requires uniquely creative solutions and innovative thinking.

Educational models to promote high abilities in universities

Universities are increasingly adopting educational models to prepare students with high-level skills, including complex thinking, to face life's challenges. These models focus on developing knowledge, skills, and attitudes applicable to real situations and promote creative and critical thinking (Kulik et al., 2020; Misbah et al., 2022). In these models, learning outcomes are measured by students' mastery in different areas (Salykova et al., 2022), aiming to train individuals with digital skills and competencies to make decisions under conditions of uncertainty (Leybert et al., 2022). Additionally, they are designed to be more flexible and adaptable, allowing universities to adjust to the demands of society and the job market.

The need to promote higher-order skills in universities arises because many lack technical and knowledge-based skills to thrive today. Thus, educational models have emerged that seek to guide skills development in complex environments (Ramírez-Montoya & Portuguez-Castro, 2024). The relevance of these models lies in their ability to convey knowledge effectively while emphasizing vital elements such as purpose, content, and structure (Escudero-Nahón & Ramírez-Montoya, 2021). In

Table 1. Components of educational models based on M. S. Ramírez-Montoya (2010).

Components of educational models	
Philosophical component	Shows the ideal and the path to understanding what education is and its purposes. It is related to the underlying paradigm: a set of beliefs, attitudes, values, and procedures.
Theoretical component	Considers the theories of learning, teaching, and socio-educational practices.
Political component	Defines the strategies through which philosophy and theory intervene in educational reality. It requires methods that help to learn throughout life and promote meaningful learning.
Educational process	Refers to the operation of the model in the institution. Different types of learning and performance profiles and plans that respond to those profiles are addressed.

this research, the components of the educational model declared by M. S. Ramírez-Montoya (2010) were used in the analysis. These components are related to the ultimate goals (philosophy), internal organization (theory), practical orientation (policy), and implementation (educational processes and practice) (see Table 1).

The distinctive characteristics of these new educational models reflect a shift toward a more dynamic and skills-oriented approach to education, which aims to equip students with the skills and knowledge necessary to succeed in today's world. One of these characteristics is the holistic approach, aimed at increasingly integrating the Sustainable Development Goals (SDGs) into educational strategies to address the planet's challenges (Sáez de Cámara et al., 2021). On the other hand, models must adapt to future societal needs. Changes caused by artificial intelligence and digitalization make developing higher-order skills, lifelong learning, and recognition of learning more relevant (Birtwistle et al., 2016). The most required skills are critical thinking, complex problem-solving, leadership, innovation, and creativity (Wagenaar, 2019). Finally, learning environments are expected to be more dynamic, where micro-credentials and lifelong learning occupy a relevant place in an environment of reflection and debate.

Framework of the study: towards an understanding of the components of the educational model

The study is guided by the components of the educational model (M. S. Ramírez-Montoya, 2010), which has been used in previous literature (M. S. Ramírez-Montoya, 2012; Sarango et al., 2021; Vicario et al., 2021), these experiences have influenced the interest to analyze the components to identify and understand its application in a complex thinking model.

The philosophical component in education focuses on the idea that educational aims and goals are fundamental to any educational approach. This component seeks to show the ideal or direction that education should take in order to truly understand what education is and what its goals are. In a macro context, such as a country, educational philosophy can be observed through aspects such as the Constitution which establishes the aims of education, such as human coexistence, the harmonious development of the individual, the harmonious development of society and national identity. These aims are not only objectives to be achieved, but also express a philosophy and a way of understanding society and history. At the micro level, as in the work of teachers, their educational philosophy is reflected in their actions and language, which demonstrates how educational philosophy is integrated into their work. In short, educational philosophy is key, as it expresses the goals and social frame of reference in which education takes place.

The theoretical component in education focuses on establishing a systematic and well-founded understanding of a part of the reality of educational processes. This theory acts as a guide to interpret that reality, orienting decisions and actions toward educational objectives. It is linked to the historical aspects of the educational process and the context in which it takes place, as well as to the future visions to be achieved. Educational theory represents the educational reality through various educational sciences, with the purpose of researching and intervening in the educational reality in formal, informal and non-formal settings, within a society. In this theoretical context,

concepts are developed that make up the proposed educational model, where the "what" of education is defined through relationships with the environment, with others and with oneself, and the "how" is represented through methods, values and languages. Methods and languages are seen as means of empowering people and guiding their relationships with the external world, while values define judgments and attitudes, being central to setting learning goals and procedures. In addition, the model addresses both the essential tools for learning and the very contents of basic learning, including theoretical and practical knowledge, as well as values and attitudes necessary for human development.

The policy component in the model is presented as a synthesis of the philosophical and theoretical components, as it encompasses all modernization processes and defines the strategies by which educational philosophy and theory intervene in educational reality. This involves involving teachers, managers, parents and students in the application of teaching-learning procedures, focusing on problem solving and the acquisition of skills for lifelong learning. The importance of developing an understanding of the world, practical skills, empathetic and critical attitudes, and a holistic development that includes body, mind, intelligence, sensitivity and spirituality. Education should also foster intercultural respect and understanding, promoting curiosity about other cultures and intercultural dialogue. In short, education must be of quality and committed to the integral formation of individuals, which implies a constant updating and improvement of teachers in various educational aspects.

The educational process encompasses the operation of the model in various contexts such as the educational community, informal education, out-of-school education and formal education, which includes school and where a wide range of learning takes place. In order to address these learnings, it is crucial to identify basic needs, translate them into performance profiles and develop plans that match these profiles by educational levels. These profiles must consider both the pedagogical aspect, which represents the contents, skills and attitudes to be developed, and the political aspect, which reflects the commitment of educational institutions and society toward students. In the selection of content, it is essential to determine its relevance by identifying its purpose. In short, education must adapt to the changing needs of society, while maintaining its fundamental aims and promoting research as a means to strengthen educational processes and generate new knowledge.

Alternative credentials in universities for lifelong learning

The accelerated technological evolution causes a faster depreciation of labor competencies compared to earlier times, creating gaps in employees' skills. Lifelong learning refers to employees' voluntary development of these skills (Kato et al., 2020), which is integral to ensuring the development of creativity (Antonova et al., 2020). This type of learning furthermore develops skills such as continuous improvement, self-regulation, and self-efficacy (Kozikoglu & Onur, 2019). By investing in lifelong learning, companies can retain and attract talented employees and stay competitive in an ever-changing marketplace.

Higher education has created alternative credentials to provide the skills required in a changing world. Such credentials can be categorized into certifications, badges, and micro-credentials (Kato et al., 2020), which can be offered formally and informally inside or outside curricula (Alsobhi et al., 2023). The foremost common are micro-credentials, short learning units in formats like MOOCs (Wheelahan & Moodie, 2021). These represent a flexible, fast, and efficient way to acquire new skills and stay current.

As Artificial Intelligence and automation develop, institutions and workers seek to develop new competencies to keep them relevant to their jobs. Upskilling and reskilling are two fundamental elements within lifelong learning that have become a priority for educational institutions due to the need to accommodate the changes brought about by Industry 4.0 (Broo et al., 2022; Pradhan & Saxena, 2023). In research on the essential competencies for 2025, the following emerge as the highest priority (Li, 2022): analytical thinking and innovation, active learning and learning strategies, complex problem solving, critical and analytical thinking, and finally, creativity and initiative. Accordingly,

lifelong learning is crucial for individuals and organizations to ensure competitiveness in the labor market and to meet the demands of a fast-changing economy.

Reasoning for complexity: strategies, methods, and assessment

The reasoning for complexity in higher education is posited globally as a topic of great value in enabling students' transition into the current labor market. For UNESCO (Leicht et al., 2018), developing skills to understand the complex environments we face is the means to deal with the uncertainties and trade-offs of global society to achieve sustainable development. Along the same lines, the OECD's vision emphasizes strengthening reasoning skills to prepare for immersion in digitalized societies and economies (Vincent-Lancrin et al., 2019). Meanwhile, the World Economic Forum (WEF) identifies reasoning for problem-solving as a fundamental job skill in the context of the 4th Industrial Revolution (World Economic Forum, 2020). Reasoning for complexity is vital in facilitating the pathway from higher education to the job market, combining strategies, methods, and assessment approaches across disciplines.

In higher education, it is relevant to develop and apply strategies and methods to develop thinking skills, as they provide a structured and intentional learning environment that promotes different types of thinking and skills helpful in solving complex problems in the real world. For instance, studies suggest that active learning strategies, including collaborative learning and guided inquiry, effectively enhance complex thinking sub-competencies in higher education students, particularly critical thinking (Kusumoto, 2018; Nisa et al., 2018). Likewise, several studies claim that project-based learning, where students apply knowledge to solve "real-life" problems, significantly improves the sub-competencies of innovative and critical thinking and collaboration (Puspita & Aloysius, 2019; Rini et al., 2020; Trisdiono et al., 2019). In addition, case-based and simulation-based learning approaches also show benefits in complex thinking sub-competencies, particularly critical thinking (Gatti et al., 2019; Mahdi et al., 2020). Even with the range of possibilities in educational strategies and methods, it is essential to provide means to assess their effectiveness in interpreting student outcomes in the competencies of interest.

Assessment in higher education often refers to judging student learning and is relevant to understanding their mastery of thinking sub-competencies. Of great recognition is the assessment of thinking skills based on cases, which involves identifying problems, collecting information, and proposing solutions to real situations (Qi et al., 2018). Multiple forms of measurement are known as a multimodal assessment, which can comprehensively and effectively capture different knowledge representations, for example, during work that involves digital mediation (Ross et al., 2020). While relying on real-world contexts, so-called authentic assessments are often used for their relevance to the scientific approach, holistically assessing students' readiness, process, and outcomes (Chusni & Suherman, 2021). Finally, among other existing types of feedback, we can mention reflection-based assessments that connect with the meta-cognitive process involved in learning experiences and situations intrinsic to complex thinking (Antonio, 2020). In general, a multifaceted approach to assessing complex thinking skills in higher education needs to consider the context, the skills being assessed, and the learning objectives, with various methods available to gain a more effective and comprehensive understanding.

Method

The methodology used in this research was comparative education, i.e., analyzing educational models in different regions and contexts (Hincapié Parejo et al., 2022). To conduct this qualitative study, we benchmarked best practices in different institutions developing the complex thinking competency and sub-competencies (Asif, 2015). According to Tamassia and Adams (2009), understanding education in a country can be more comprehensive by interpreting national results in a broader international

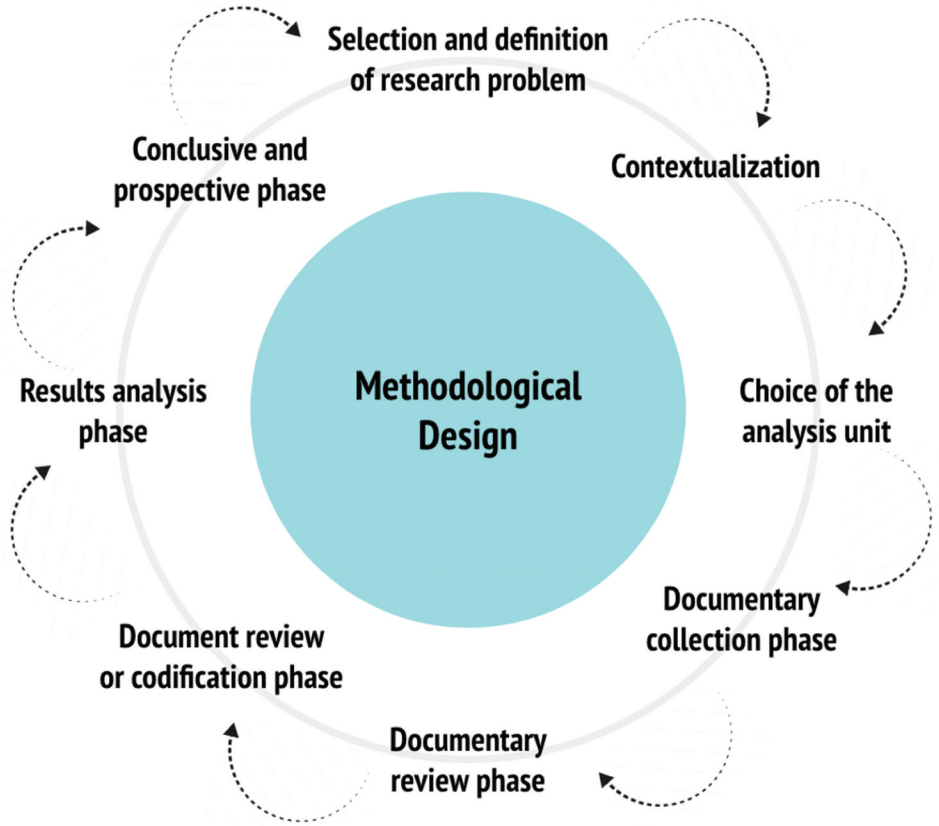

Figure 1. Methodological design based on Matarranz (2019).

context, allowing countries to identify their educational system's strengths and weaknesses. Therefore, this work's methodology aimed to identify best educational practices for developing complex thinking in higher education institutions.

Procedure

To carry out the research, we followed the procedure for comparative education studies proposed by Matarranz (2019), as shown in Figure 1.

First, the research problem was defined as how the practices of reasoning for complexity in Latin American institutions compare to other regions. To answer the research question, we intentionally selected eight Latin American institutions as units of analysis to identify and compare practices to achieve reasoning for complexity and its derived sub-competencies. Additionally, 11 institutions from other regions were chosen based on their previous academic publications on complex thinking development and integration into their educational models (Baena-Rojas et al., 2022; Pacheco-Velázquez et al., 2023). The list of analyzed institutions is shown in Table 2.

The intentional selection of the eight Latin American institutions was aimed at covering a wide range of educational practices and models that promote complex thinking, considering geographical diversity, institutional profile, and readiness for collaboration and data access. The intention behind this selection focused on capturing a representative spectrum of how complex thinking is addressed in different educational contexts in Latin America, comparing it with institutions from other regions to

Table 2. Institutions analyzed in benchmarking.

Institution	Type of institution	Country	Foundation year	Website
Universidad de Barcelona	Public	Spain	1450	https://web.ub.edu/es/inicio
Universidad de Cantabria	Public	Spain	1972	https://web.unican.es/
Universidad de Granada	Public	Spain	1531	https://www.ugr.es/
Universidad de Panamá	Public	Panama	1935	https://www.up.ac.pa/
Universidad Técnica Particular de Loja (UTPL)	Private	Ecuador	1971	https://www.utpl.edu.ec
Tecnológico de Monterrey	Private	Mexico	1943	http://www.tec.mx/
Universidad Autónoma de México	Public	Mexico	1910	https://www.unam.mx/
Universidad Autónoma de Nuevo León	Public	Mexico	1933	https://www.uanl.mx/
Universidad Autónoma del Estado de Hidalgo	Public	Mexico	1869	https://www.uaeh.edu.mx/
Universidad Autónoma de San Luis Potosí (UASLP)	Public	Mexico	1923	https://www.uaslp.mx/
Servicio Andaluz de Salud/Biblioteca del Área de la Axarquía	Government	Spain	1984	http://www.bvsspa.es
Stanford University	Private	United States	1885	https://www.stanford.edu/about/
Vanderbilt University	Private	United States	1873	https://www.vanderbilt.edu/
University of California (UC)	Public	United States	1869	https://www.universityofcalifornia.edu/
Michigan State University	Public	United States	1885	https://msu.edu/
University of Cambridge	Private	United Kingdom	1209	https://www.cam.ac.uk/
University of Edinburgh	Public	United Kingdom	1583	https://www.ed.ac.uk/
Universidade Federal de Santa Catarina (UFSC)	Public	Brazil	1960	https://ufsc.br/
University of Auckland	Public	Australia	1883	https://www.auckland.ac.nz/en.html

identify the best educational practices and thus contribute to the improvement and design of future educational programs.

The selection process included institutions from various regions of Latin America, from North, Central, and South America, to seek a balanced representation that reflected the region's heterogeneity. Institutions with different profiles were also selected, including public and private universities, research institutes, and non-governmental organizations. This diversity allowed for the exploration of how different types of institutions address challenges and opportunities in their specific contexts. The willingness of institutions to collaborate and the feasibility of access to data and participants were important practical considerations in the selection process. Institutions willing to participate openly and transparently were sought, thus facilitating a deep and meaningful analysis.

Once the units of analysis were identified, the information was collected using the technique of significant document analysis, which consisted of searching the websites of the consulted institutions for information related to the categories of analysis. The gathered information was then organized into a matrix for subsequent analysis.

To identify relevant content on institutional websites, a systematic approach was used in which a database was developed in a table showing specific selection criteria to ensure the accuracy and relevance of data collection. The criteria framework includes components such as: 1) Type of institution (public or private); 2) Components of the educational model: philosophical (mission and vision), theoretical (competency-based educational model, lifelong learning, complexity), educational process (organization, types of programs, mode of delivery, use of alternative credentials and evaluation), policy (evaluation of complex thinking, incorporation into the curriculum, competencies associated with complex thinking), and 4) Use of information and communication technologies

(use of platforms for the development and evaluation of complex thinking, use of emerging technologies).

This criteria framework allowed not only to identify relevant keywords for searches on institutional websites but also to ensure that the selected institutions met specific requirements that guarantee their relevance to the study. For example, institutions that demonstrated a clear commitment to education and training in skills such as critical thinking and complex problem solving were especially valued, reflected in both their national scope and their educational offerings. The main keywords were associated with "complex thinking," "competency-based education," "innovative thinking," "critical thinking," "systemic thinking," "scientific thinking," "emergent technologies." The integration of these criteria into the search and selection process sought to ensure that data collection was not only exhaustive but also aligned with the specific objectives of the research on complex thinking in educational contexts.

Data analysis

A comparative analysis was carried out on the four elements of the educational models proposed by M. S. Ramírez-Montoya (2010), p. 1) philosophical component, 2) theoretical component, 3) political component, and 4) educational process, as shown in Figure 2.

The identification of themes was based on an analysis of the philosophical, theoretical, educational process, and political components of each institution. The conceptual framework served as an essential guide for this analysis, providing a structure upon which the varied information could be classified and understood. This framework highlighted the importance of considering how the philosophical, theoretical, process, and political aspects interact to form a cohesive educational model that promotes complex thinking. The detailed review of institutional documents according to these components allowed for a precise and contextualized identification of competencies and educational objectives, facilitating a deep understanding of underlying educational intentions and their alignment with complex thinking.

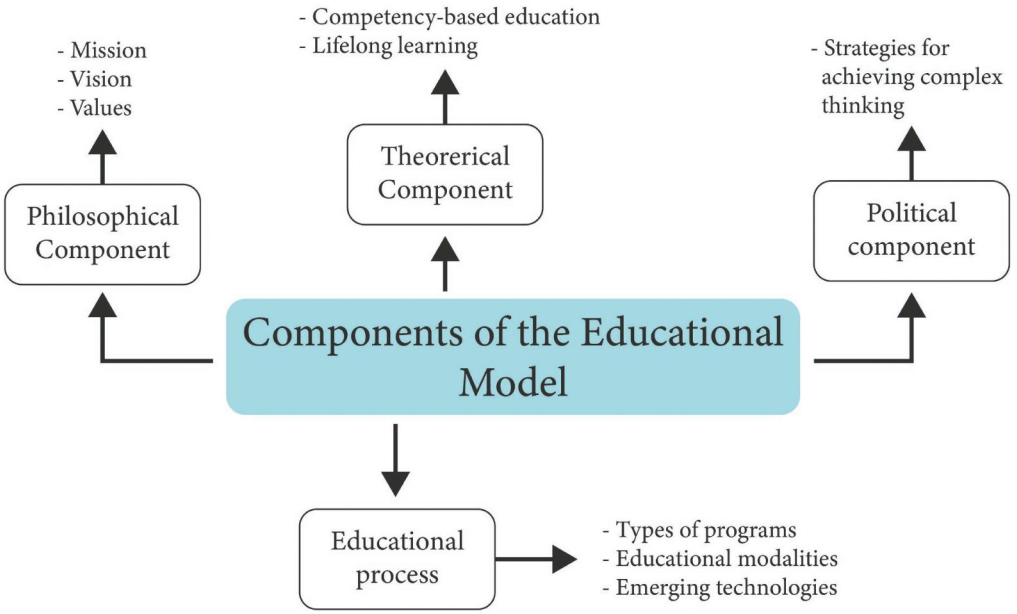

Figure 2. Components of the educational model analyzed for benchmarking, based on M. S. Ramírez-Montoya (2010).

For the philosophical component, the mission, vision, and values were reviewed to identify the institution's educational purpose and ideal competencies in their graduates. Examining these elements allowed us to understand how institutions position themselves regarding complex thinking and its sub-skills, as well as to identify the competencies toward which the current educational model is oriented for preparing students to face the challenges of an increasingly complex world. For the theoretical component was considered whether competency-based learning theories, especially those oriented toward complex thinking and lifelong learning, are applied in the institutions' educational practices. This evaluation aimed to determine if and how these theories are integrated into the curriculum and teaching methods, thereby promoting the development of essential skills for navigating and contributing to a complex, ever-changing world.

For the political component, we reviewed how institutions incorporate and evaluate reasoning for complexity and its sub-competencies. This involved analyzing the ways in which these educational entities formalize their commitment to fostering complex reasoning abilities, through curriculum development, teaching strategies, and evaluation methods. The focus was on identifying how institutions prioritize and operationalize the cultivation of complex thinking skills, ensuring that graduates are well-equipped to navigate and contribute to a multifaceted and interconnected world. Lastly, regarding the educational process, we reviewed the types of programs, teaching modalities, emergent technologies, and the relationship between graduates and employers. This analysis aimed to understand how these aspects collectively contribute to the development and enhancement of complex thinking skills among students, preparing them for the challenges and opportunities in the contemporary workforce.

Once the data were obtained, the findings were synthesized to present the main similarities and differences among the institutions. Through an inductive analysis, all the data obtained were analyzed, and codes were defined that allowed identifying more general themes associated with the characteristics of the institutions. Also, the results were presented using hierarchical tree diagrams (Creswell & Poth, 2018). This type of diagram is considered appropriate for presenting results in qualitative studies because it showcases varying levels of abstraction. The lower part of the tree represents less abstract concepts, while the upper part represents more abstract ones. Inductively, the most general information is depicted, which in this case includes the elements of each component. Gradually, two more general concepts are obtained, allowing for a review later to uncover additional relationships between their components (Asmussen & Creswell, 1995). The analysis was performed using the software MAXQDA 2022, finally proposing lines of action for improving educational models oriented toward developing competencies related to reasoning for complexity.

Results

By comparing the formative practices in the analyzed institutions oriented toward developing reasoning for complexity, we obtained the results showed in Table 3 according to the categories of analysis.

These elements can be considered by those who develop curricula to create programs more oriented toward the job market's needs and the technologies to provide solutions to social problems more proactively, critically, and analytically. Below, the findings for each of the analyzed components are explained in detail.

Philosophical component

Institutions from Latin America and other regions demonstrated an interest in training students to develop social commitment and critical thinking through education oriented toward solving current societal challenges. It was found that most institutions have an educational model based on competencies, as is the case with the University of Barcelona, Cantabria, Granada, Tecnológico de Monterrey, Stanford University, among others. This development of competencies is based on the acquisition of knowledge, skills, and attitudes that will enable future graduates to make positive changes in society.

Table 3. Components of the educational model for developing complex thinking competencies.

Components of the Education Model	Purpose	Competencies	Contribution to Complex Thinking	Universities where Competences were found
Philosophical component	Improvement of quality of life Sustainable development	Social commitment Critical thinking Leadership Research Creativity	Establishes an educational paradigm that promotes deep understanding, critical analysis, and social responsibility, key elements of complex thinking.	University of Barcelona, University of Cantabria, University of Granada, Tecnológico de Monterrey, Stanford University, University of Panamá, UNAM, UANL, Autonomous University of Hidalgo, University of Edinburgh, UFSC, University of Auckland, Michigan State University, University of Cambridge, UTPL
Theoretical component	Competency-based education Lifelong learning	Interdisciplinary Complex reasoning Collaboration Microcredentials	Provides a foundational educational approach that fosters complex thinking by integrating educational theories for critical competencies in addressing complex problems continuously.	UFSC, Tecnólogico de Monterrey, UNAM, Stanford University, Vanderbilt University's School of Medicine, University of California, University of Edinburgh, University of Auckland, University of Granada and the Andalusian Health Service, University of Cambridge.
Political component	Strategies Evaluation	Center or research groups Teacher training Collaborative spaces Formative assessment tools	Support collaboration, effective formative assessment, and educational approaches that focus on developing advanced skills, innovation, and adaptability to digital transformation.	UASLP, Tecnólogico de Monterrey, UNAM, University of Cambridge, University of Panama, UTPL, UFSC in Latin America, University of Edinburgh, Auckland University, Vanderbilt University, University of California, Michigan State University.
Educational process	Graduate profile Needs for careers and personal lives	Types of programs Educational modalities Emerging technologies	Addresses and fosters understanding of complexity in education and society, promoting critical thinking, adaptation and connection to the real world, impacting industry by meeting their needs.	Tecnológico de Monterrey, UTPL, UASLP, Cambridge, Stanford, University of Barcelona, Cantabria, Granada, and the Andalusian Health Service, Cambridge, UC, and Edinburgh, UNAM, UASLP, and Michigan State University, University of Auckland.

There is also an interest in contributing to sustainable development and prioritizing the role of the student as a central agent in their learning process, as stated by the University of Panama. Likewise, it is expected that these citizens contribute to society in a responsible manner with a global perspective, as established by UNAM, UANL, and the Autonomous University of Hidalgo. In this sense, the models' characteristics included integrating the 2030 Agenda and the SDGs and holistic approaches.

The competencies sought to be fostered in students are diverse. For instance, the mission of UASLP is to comprehensively train individuals with critical thinking and social commitment to be capable of creating and applying scientific knowledge for sustainable development and improving society's quality of life. Similarly, Stanford University aims to develop students who contribute their leadership to provide impactful solutions for a complex world. For Michigan State University, it is important to nurture future leaders to create positive change, and the University of Cambridge emphasizes creative problem-solving, critical analysis, and effective communication as skills to be developed in their students.

Another notable element in this component is the pedagogical and philosophical foundations of educational models, in which the universities' actions are sought to be grounded, like UTPL and the

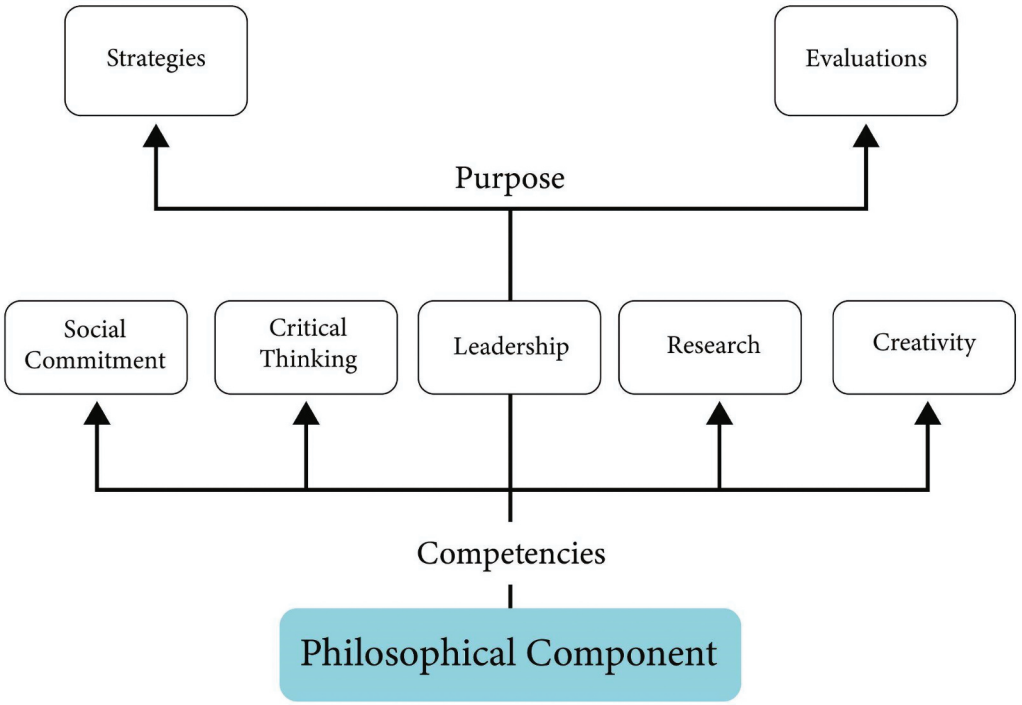

Figure 3. Philosophical component in developing complex thinking competencies.

Universidad Autónoma de Hidalgo. Within their actions, research development for problem-solving, creativity, and leadership have been promoted, such is the case for the University of Edinburgh, UFSC, and the University of Auckland, which aim for global transformation through research and collaboration.

For the promotion of complex thinking competency these universities emphasize the importance of holistic development, viewing education not merely as a means to acquire qualifications, but as a transformative process aimed at nurturing individuals with a strong sense of social responsibility and the ability to think critically. The emphasis lies on fostering a deep understanding of societal issues and encouraging students to engage in meaningful contributions that address these challenges. The philosophical foundation underscores the belief that education should instill a profound commitment to improving society and empower graduates to drive positive change through their acquired competencies. Figure 3 shows the ideal of competencies and the purposes sought to be achieved by the institutions.

Educational institutions can consider these elements when designing competency-based educational models aimed at their graduates' contributions toward improving the quality of life and sustainable development as ideals of education.

Theoretical component

Universities in LATAM and other regions declare having competency-based educational models, including them in their study programs and promoting lifelong learning. However, not all institutions declare developing complex thinking as a competency. For example, universities such as the University of Panama, the University of Nuevo Leon, and Cantabria University do not mention training in complex thinking.

Regarding LATAM, it is noteworthy that UFSC promotes interdisciplinarity in its study programs and includes complexity in problem-solving in its research groups. Tecnológico de Monterrey includes reasoning for complexity within its competencies seeking to develop skills and knowledge that enable students to face the challenges of the modern world, while UNAM develops the four sub-competencies of complex thinking in its curriculum, where each study program contains the competencies required for the graduate profile and those that will be developed throughout the course. In other regions, Stanford University offers resources for developing and evaluating competencies related to complex thinking, which include performance assessments aimed at more complex tasks, seeking to develop critical thinking, inquiry, and communication. Examples of scientific thinking can also be found at Vanderbilt University's School of Medicine where interdisciplinary research and collaboration are promoted, and critical thinking at the University of California (UC). This university utilizes a flipped model of instruction, where lectures and other traditional classroom content are provided online, and classroom time is dedicated to group discussions, problem-solving activities, and other experiential exercises.

The contribution between disciplines is a prominent element, especially in universities from other regions. For example, Stanford emphasizes interdisciplinary learning and critical thinking as part of its educational model, while Vanderbilt promotes interdisciplinary research and collaboration. The University of Edinburgh promotes working with communities, governments, and businesses to solve complex problems from different disciplines. Similarly, the University of Auckland integrates problem-solving into its programs, and UC holds debate groups and problem-solving activities involving the community.

Micro credentialing supports lifelong learning and continuing education courses, such as those offered by the University of Granada and the Andalusian Health Service. Regarding the offering of micro-credentials in Latin American universities, it was found that Tecnologico de Monterrey offers micro masters, massive online courses (MOOCs) with the possibility of accrediting materials in some programs of the institution, and high specialization certificates. No such offering was found at UTPL, Universidad Autónoma del Estado de Hidalgo, or Universidad de Panamá.

In other regions, the University of Barcelona and Vanderbilt University offer MOOCs on Coursera. Vanderbilt University also offers courses on its own platforms and educational resources for developing competencies such as scientific reasoning in medicine. Stanford offers alternative credentials for different subjects and has open educational resources, free and paid, from professional and executive certification programs to postgraduate courses. Additionally, Stanford offers courses on Linkedin and Coursera, EDX Het Smarter, G, among others, and offers professional development programs related to competencies required by employers, delivering them to companies through Cardinal at work. On the other hand, UC has alternative credentials and courses on Coursera and Edx, among others, focusing on critical thinking as one of the competencies to be developed in students, aligning with the offering of Edinburgh and Auckland. This course offering is to develop skills and knowledge for people in the workforce and the community. Additionally, free and open educational courses (OER) are offered to the community, as with the University of Auckland. The University of Cambridge offers MOOC platforms like Coursera, Udemy, and its proprietary platform for delivering distance and asynchronous courses.

These universities use a range of approaches, including interdisciplinary collaboration, problem-solving integration, specialized competencies, and educational resources, to promote and develop complex thinking competency among their students. Microcredentials, such as micro-masters, specialized certificates, and short courses, offer targeted and focused learning opportunities that often concentrate on specific skills and competencies, including complex thinking. Figure 4 shows educational practices related to competency-based learning.

Educational institutions can consider these elements when designing practices for students to develop high competencies such as complex thinking and lifelong learning strategies.

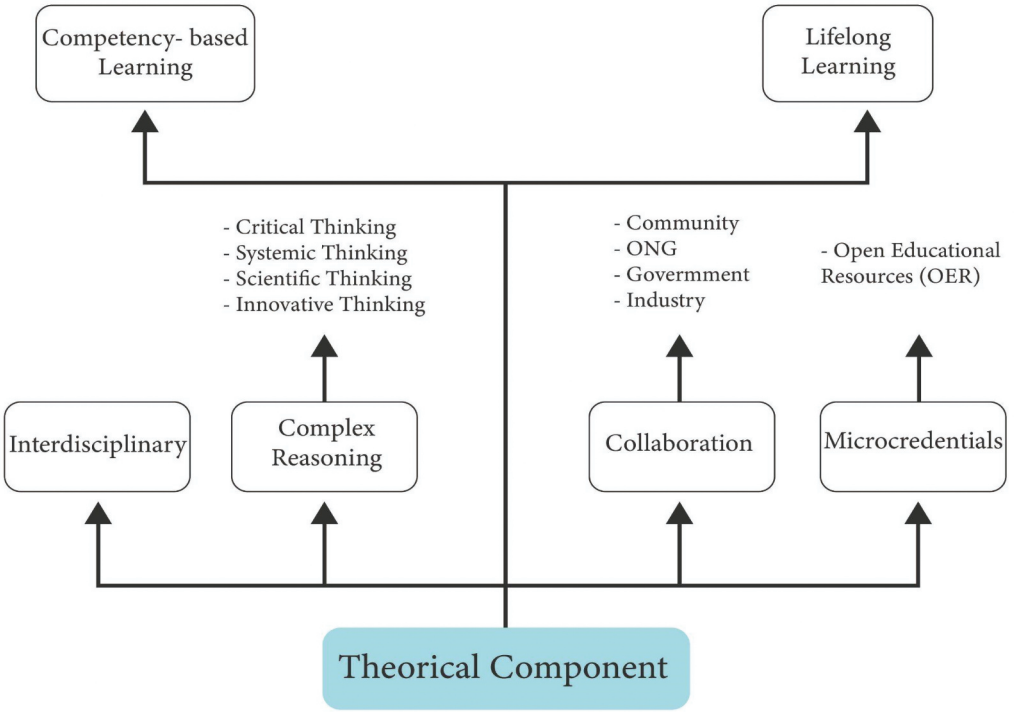

Figure 4. Theoretical component in developing complex thinking competencies.

Political component

Most institutions consider the development of reasoning for complexity as transversal in their curricula. Also, it was found that the Latin American universities UASLP, Tecnologico de Monterrey, and UNAM claim to develop all four sub-competencies, while Stanford does so in other regions. Critical thinking is the sub-competency most emphasized at the University of Panama, UTPL, and UFSC in Latin America, and Edinburgh, Auckland, Vanderbilt, and U.C. in the other regions analyzed. Michigan State University was found to declare the development of critical thinking, while UANL does not declare the development of any of the sub-competencies.

An example of how complex thinking has been integrated into Latin American institutions is found at Tecnologico de Monterrey, where as part of the Tec 21 Educational Model, it is included as a transversal competency for students to develop. Additionally, the university established the R4C-IRG Interdisciplinary Research Group: Scaling Complex Thinking, which researches how to link the competency and its sub-competencies with various training elements. For its part, UASLP has teacher training programs to promote critical and reflective thinking, research centers, and interdisciplinary and inclusion programs for vulnerable groups. UNAM has the Center for Complexity Sciences (C3), oriented toward interdisciplinary research into emerging and vanguard scientific problems.

In other regions' institutions, Stanford incorporates systemic thinking and develops it through problem mapping and experimentation to achieve solutions, they encourage professionals to visualize the system they are working within, map out causes and effects, and focus on points where they can intervene effectively, experimenting with potential solutions. Vanderbilt University promotes critical thinking through research, with a distinctive emphasis on interdisciplinarity. Students have the opportunity to engage in diverse disciplines during their studies by combining courses from different branches. UC promotes collaboration between faculty and researchers in activities to develop these competencies. Student learning at UC involves classes, seminars, and lab sections enhanced by

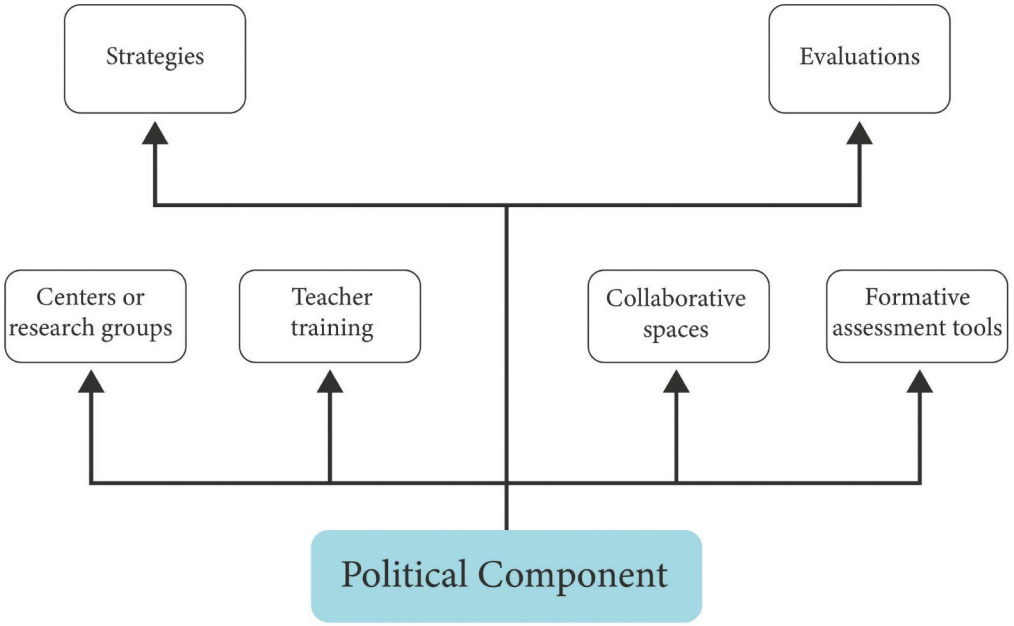

Figure 5. Political component in developing complex thinking competencies.

collaboration with faculty and researchers. Through these activities, faculty and students engage in a learning process that helps develop critical thinking, communication, and problem-solving skills, as well as discipline-specific knowledge. This collaboration is further extended at the University of Edinburgh through discussion forums, clubs, and workshops open to other educational stakeholders. This inclusive approach incorporates critical and innovative thinking through research. Moreover, it is interdisciplinary, addressing the challenges presented by the SDGs. Open facilities are utilized to encourage collaborative work among researchers, students, the public sector, and businesses.

Regarding assessment, some Latin American universities declare evaluating complex thinking, such as Tecnologico de Monterrey and UNAM, which use various instruments and tools like exams, projects, team assignments, challenges, among others, as well as rubrics to evaluate sub-competencies. On the other hand, UASLP uses standardized tests, portfolios, and project observations utilizing competency-based assessments, formative evaluations, integrative assessments, and feedback evaluations. Some universities do not assess this competency development, such as the University of Panama, the Universidad Autónoma del Estado de Hidalgo, and UANL.

The University of Auckland promotes formative evaluation, self-evaluation, and peer evaluation so students provide feedback to improve courses. On the other hand, Stanford University has a bank of validated and free assessment tools that measure complex thinking focused on more meaningful learning. At Vanderbilt University, performance assessments and research papers are proposed. On the other hand, in the Andalusian Health Service, competency assessment is carried out through various instruments and tools such as exams, projects, teamwork, challenges, among others.

These universities showcase a diverse array of strategies and approaches within their political component to promote and evaluate complex thinking competency. From incorporating it as a transversal competency to establishing research groups and fostering interdisciplinary collaboration, these efforts demonstrate a dedication to nurturing complex thinking skills and competencies in students. Additionally, assessment methods, whether through exams, projects, or performance assessments, play a crucial role in measuring and reinforcing the development of complex thinking abilities. Figure 5 shows strategies and evaluations to develop complex thinking competencies.

These elements can be considered by researchers, teachers, and administrators to strengthen collaborative spaces both inside and outside the institution and improve programs for assessing these competencies.

Educational process

Regarding the types of programs, it was found that institutions offer academic degrees from secondary education to postgraduate studies. Some institutions, such as Tecnologico de Monterrey, UTPL, USLP, Cambridge, and Stanford, offer continuing education courses. The teaching modality is mainly face-to-face, as in the case of the University of Barcelona, Cantabria, Granada, and the Andalusian Health Service. The offerings from Cambridge, UC, and Edinburgh are a hybrid of face-to-face and online learning, while UNAM, UASLP, and Michigan State University offer face-to-face, online, and hybrid formats. The careers offered are diverse for all universities and include programs such as humanities, sciences, health sciences, and social sciences.

Educational institutions are carrying out projects using emerging technologies such as artificial intelligence, virtual and augmented reality, blockchain, the Internet of Things, machine learning, and big data. In Latin America, Tecnologico de Monterrey has initiatives promoting the development of educational innovations that generate disruptive solutions for the future of education and lifelong learning. One example is the Novus projects by the Institute for the Future of Education, which encourage teachers to carry out projects using new technologies such as augmented reality, drones, and telepresence. UNAM is involved in a research project on blockchain and its use in teaching and designing mathematics and engineering applications.

The University of Stanford has the Virtual Human Interaction Lab that researches the effects of virtual and augmented reality on human behavior and emotions. It also offers the Center for Blockchain Research to explore the applications of blockchain technology in different industries. On the other hand, the University of Barcelona is carrying out projects to predict diseases using machine learning and remote sensors, such as the Microb-Predict project. Another example is the University of Auckland, which conducts research with autonomous vehicles to achieve vehicle tracking through simulations; it also researches blockchain and cryptography and is recognized as the best university in Australia.

Finally, graduates' performance in the workplace is monitored in some institutions through surveys to learn about their employment situations and communications with employers to understand their needs and expectations to adapt programs to those needs, for example, UASLP and Tecnologico de Monterrey in Latin America. In addition, UNAM follows up with graduates to place them in the workforce and develop their competencies. No information was found on UANL. In other regions, universities such as Stanford and UC have resources and volunteer programs for alums. Vanderbilt offers coaching services and platforms for lifelong learning courses. In Michigan, there was no specific information about monitoring graduates, and no information was found from the University of Granada.

The educational process involves a dynamic interplay of diverse programs, flexible teaching modalities, cutting-edge technologies, and proactive measures to enhance graduates' employability and readiness for the complex challenges of today's society. Fostering strong connections between academic programs and industry needs is intrinsically linked to the development of complex thinking among graduates. Complex thinking involves the ability to analyze, synthesize, and evaluate information from various sources, adapt to change, and solve intricate problems efficiently. When educational institutions align their programs with industry requirements, they implicitly encourage the development of these critical thinking skills. Figure 6 shows the elements of the educational process necessary for developing the profiles required in society.

In this educational model, each component focuses on the development of complex thinking skills. The fundamental goal is to train highly competent professionals capable of generating significant contributions to society, preparing them to face real challenges in their respective disciplines. This

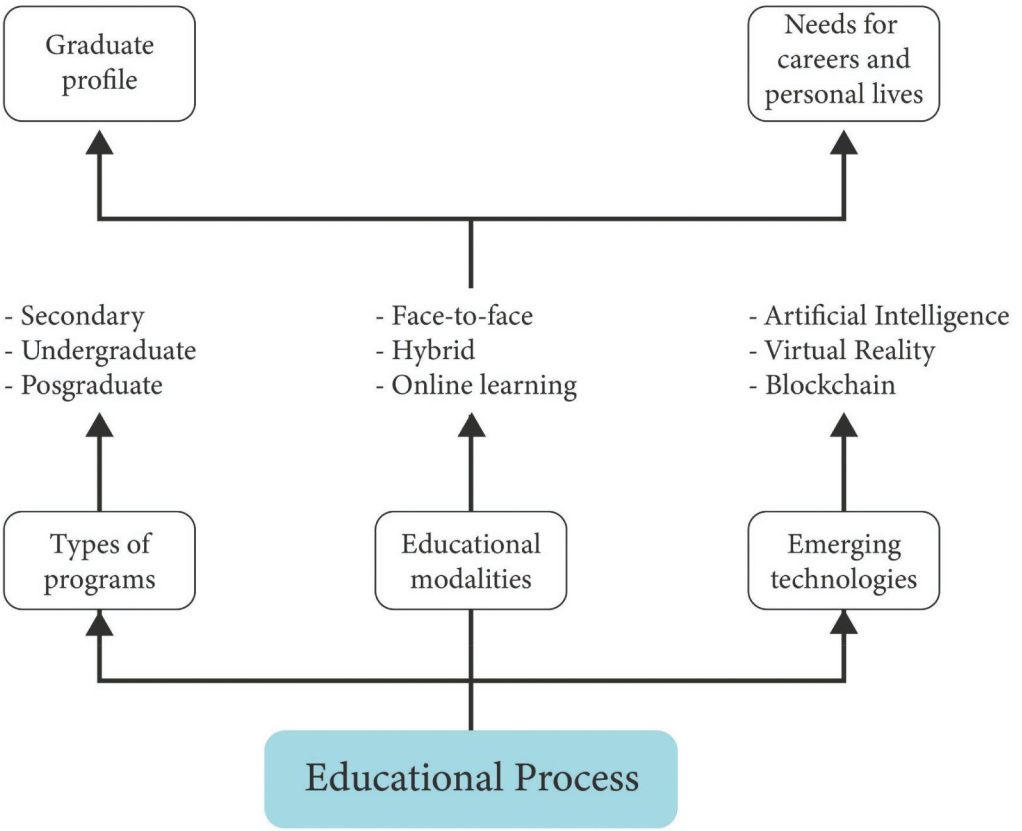

Figure 6. Educational process for developing complex thinking competencies.

educational approach is based on research that highlights the importance of critical thinking and problem-solving skills in an ever-changing world.

Triangulation

The triangulation process was carried out after the website analysis. In this process, the publications generated by the universities, both scientific and outreach, were reviewed in order to validate the treatment of these concerns. After analyzing the characteristics of educational models in the consulted institutions, we could identify that institutions require a curriculum that includes teaching methods for developing complex thinking competencies. They also need to encourage research and exploration to facilitate the development of complex thinking. Additionally, institutions need to provide resources such as technology, educational materials, and opportunities for collaboration to support the development of complex thinking among students and faculty. Finally, universities need to promote a culture of lifelong learning and continuous improvement to ensure the sustained development of complex thinking skills.

The fundamental tools to develop complex thinking are research and interdisciplinarity. This can be seen at UNAM. According to Calixto Flores (2014), several curricular proposals consider complexity theory as an essential component in the design of their programs, where research is a vital tool to generate curricular changes. On the other hand, lifelong learning emphasizes the importance of continuously developing oneself to keep up with new technologies and social changes. Therefore, its integration into educational models is central to ensuring that graduates

have the necessary skills to succeed professionally. For example, Stanford University offers educational resources for populations of all ages, continuing education, and professional development (Stanford, 2023).

Regarding educational processes focused on developing high skills, innovation and digital transformation are essential for future education designs. Institutions like Tecnologico de Monterrey are committed to improving the teaching and learning process through experimentation and educational innovation projects using digital education, AI, extended realities, telepresence, robotics, and the Internet of Things, among others (Lara-Prieto et al., 2019; Luévano et al., 2015; Molina Gutiérrez et al., 2018; Portuguez-Castro et al., 2022). Similarly, at the University of Barcelona, projects related to disease prediction through machine learning have advanced personalized medicine by identifying patient risk characteristics (Castelli et al., 2022).

Discussion

The ideal of the educational model is to train individuals with the necessary competencies to improve society's quality of life and work to achieve a sustainable development agenda. According to the findings in Figure 3, the analyzed institutions seek developing competencies in critical thinking, social commitment, research, leadership, and creativity. In Li's research (Li, 2022), the mentioned competencies were considered a critical element and predictor of job success for professionals in Industry 4.0. Furthermore, it aligns with Sáez de Cámara's et al. (2021) statement that among the characteristics found in modern models of higher education is the integration of the 2030 agenda and SDGs and the development of increasingly holistic models. These competencies and purposes can be considered by educational institutions when designing competency-based educational models to help their graduates contribute to society.

Educational models based on competency-based learning and lifelong learning promote the development of complex thinking, provided that their educational practices are oriented toward achieving these competencies. According to Figure 4, interdisciplinarity, fostering collaboration with stakeholders outside of academia, and offering micro-credentials and OER are fundamental practices that should be in educational models. Supported by educational platforms, this new way of acquiring skills and remaining knowledgeable gives learners a significant advantage (Wheelahan & Moodie, 2021). Including these practices can allow research to evaluate their effectiveness and measure their impact on student learning outcomes.

The complex thinking competency is considered cross-curricular in institutions. Research, collaboration strategies, and formative assessment tools favor its development. Figure 5 shows that this competency can be enhanced by developing research centers or spaces for collaborative groups where various actors can participate; institutions can offer various tools to support teacher training and formative assessment. Therefore, integrated spaces for debate, life-long learning, and micro-credentialing are components of the new educational models (Birtwistle et al., 2016). Additionally, multimodal assessment allows educational institutions to better prepare students for the demands of the modern workplace and a more comprehensive assessment of their skills and knowledge (Ross et al., 2020). Researchers, educators, and administrators can consider these factors to enhance collaborative environments inside and outside the institution and enhance the quality of competency assessment programs.

Innovative and digitally transformed education is crucial for developing high skills and preparing critically and proactively thinking graduates to meet job market needs and contribute to society. Figure 6 shows that the curricula of educational institutions should strive to create a graduate profile having the competencies demanded by the job market, supported by emerging technologies. While studies indicate that initiatives promoting digital transformation and technology are necessary for universities, in the case of Latin America, there are more challenges to achieving this transformation, such as connectivity, infrastructure, innovation, and research (Portuguez-Castro et al., 2022).

Therefore, curriculum developers must consider these components to design programs that better meet job market demands and use technology to address social issues.

Conclusion

This study aimed to compare training practices that promote complex thinking in national and international educational institutions through a comparative analysis using four categories: philosophical, theoretical, and political components and educational process. The findings revealed that: a) educational institutions seek to educate individuals who can improve the quality of life in society and contribute to sustainable development; b) educational practices aimed at developing complex thinking and lifelong learning competences are essential for new educational models; c) collaboration of researchers, faculty and other stakeholders and appropriate formative assessment tools promote the development of complex reasoning competences in changing environments; and d) educational processes focused on high competence development, innovation and digital transformation are essential for designing the future of education.

While this study represents a substantial advance in the field of higher education by stressing the critical role of developing key competences aligned with the demands of Industry 4.0 and Sustainable Development Goals, our findings broaden the existing literature by providing a pragmatic framework for integrating these competencies into educational models, focusing on the importance of competency-based learning, lifelong learning and digital transformation. Along with our research, we have identified practices essential to modern educational models, such as interdisciplinarity, collaboration and the use of open educational resources (OER), which are essential for cultivating complex thinking and preparing higher education students for the labor market. Moreover, there is a need for collaborative and integrated learning environments, supported by digital technologies, to improve educational outcomes and address societal challenges. The elements found in these results can be used by educational institutions to design educational practices to achieve high competencies such as complex thinking. In addition, researchers and teachers can increase their collaboration within and outside the institution to apply the knowledge generated within the academy, strengthening the curriculum and the use of technologies that allow the development of professionals increasingly committed to developing their competencies and solving the problems facing society today.

As a study limitation, most universities do not expressly state complex thinking in their programs, evaluations, or credentialing, although they are found in their curricula under similar names. In addition, when searching for information, websites present information in very different configurations, which not only involves several iterations of the search but also makes it difficult to have all the required information.

Based on the study some specific recommendations are issued to stakeholders who play a key role in influencing complex thinking: The first recommendation is from the personal, to conceive themselves as an important part of nature and their relationship with it, therefore, the interaction that each subject has must be valuing that their actions are committed to sustainability. The second recommendation is from the perspective, where reality must be broad and must be observed from many realities, stop observing the disciplines as a watertight compartment, so that disciplinary barriers are eliminated and we begin to think and act in a transdisciplinary way, that is, establish relationships with people of different thoughts and ideologies that allow a greater openness to perceive reality from different perspectives. The third recommendation is from the collective, understanding that complex thinking invites us to take educational institutions as a bridge that connects various sectors of society, this will also increase the possibility of diversifying views and begin to understand the complexity of the world and the importance of conceiving collaboration as a fundamental instance of the search for alternatives to the problems of today's society.

Some steps that teachers and researchers can take to collaborate with each other include the creation of challenge-based research networks, using the opportunities offered by the Sustainable Development Goals as an action point to search for transdisciplinary solutions to complex problems.

Also, decision-makers, civil society organizations and policy makers can postulate opportunities for collaboration across problem boundaries, linking talents from different regions with local and global problems. The study finds opportunities to establish evidence in this regard, which opens the door to contribute, with vision and action, to the mobilization of complex thinking, with implications for practice and research. For future studies, we suggest investigating in more detail the characteristics of best practices, analyzed from the perspectives of managers, administrators, teachers, students, companies, and government organizations to provide a model for institutions to strengthen the development of these competencies.

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Data availability statement

The data that support the findings of this study are publicly available for evaluators at: https://figshare.com/articles/dataset/Data_base_OEM4C_project_2023_xlsx/22492894.

References

Alkhatib, O. J. (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)*, Dubai, United Arab Emirates. https://doi.org/10.1109/icaset.2019.8714232

Alsobhi, H. A., Alakhtar, R. A., Ubaid, A., Hussain, O. K., & Hussain, F. K. (2023). Blockchain-based micro-credentialing system in higher education institutions: Systematic literature review. *Knowledge-Based Systems*, *265*, 110238. https://doi.org/10.1016/j.knosys.2022.110238

Antonio, R. P. (2020). Developing students' reflective thinking skills in a metacognitive and argument-driven learning environment. *International Journal of Research in Education and Science (IJRES)*, *6*(3), 467–483. https://doi.org/10.46328/ijres.v6i3.1096

Antonova, N. V., Shmeleva, Z. N., & Kozulina, N. S. (2020). Lifelong learning as the way of modern personality development in Russia on the example of higher educational institutions of technical and natural-scientific profile. IOP publishing. *Journal of Physics: Conference Series*, *1691*(1), 012146–8. https://doi.org/10.1088/1742-6596/1691/1/012146

Asif, M. (2015). Determining improvement needs in higher education benchmarking. *Benchmarking: An International Journal*, *22*(1), 56–74. https://doi.org/10.1108/BIJ-02-2013-0025

Asmussen, K. J., & Creswell, J. W. (1995). Campus response to a student gunman. The Journal of Higher Education, *66* (5), 575–591. https://doi.org/10.1080/00221546.1995.11774799

Baena-Rojas, J. J., Ramírez-Montoya, M. S., Mazo-Cuervo, D. M., & López-Caudana, E. O. (2022). Traits of complex thinking: A bibliometric review of a disruptive construct in education. *Journal of Intelligence*, *10*(3), 1–17. https://doi.org/10.3390/jintelligence10030037

Birtwistle, T., Brown, C., & Wagenaar, R. (2016). A long way to go . . . a study on the implementation of the learning-outcomes based approach in the EU. *Tuning Journal for Higher Education*, *3*(2), 429–463. https://doi.org/10.18543/tjhe-3(2)-2016pp429-463

Braxton, S. N. (2023). Competency frameworks, alternative credentials and the evolving relationship of higher education and employers in recognizing skills and achievements. *The International Journal of Information and Learning Technology*, *40*(5), 373–387. https://doi.org/10.1108/IJILT-10-2022-0206

Broo, D. G., Kaynak, O., & Sait, S. M. (2022). Rethinking engineering education at the age of industry 5.0. *Journal of Industrial Information Integration*, *25*(8), 100311. https://doi.org/10.1016/j.jii.2021.100311

Calixto Flores, R. (2014). La construcción del currículum de las instituciones de educación superior desde el pensamiento complejo. *Trayectorias: Revista de Ciencias Sociales de La Universidad Nacional de Nuevo León*, *38*, 67–87. https://dialnet.unirioja.es/servlet/articulo?codigo=7367414

Castelli, R. G., Moguet, C., Fuentes, C., Marrugo-Ramírez J, Lefebvre T, Volland H, Merkoçi A, Simon S, Fenaille F, Junot C. (2022). Metabolomics for personalized medicine: The input of analytical chemistry from biomarker discovery to point-of-care tests. *Analytical & Bioanalytical Chemistry*, *414*(2), 759–789. https://doi.org/10.1007/s00216-021-03586-z

Chusni, M. M., & Suherman, S. (2021). Developing authentic assessment instrument based on multiple representations to measure students' critical thinking skills. *Momentum: Physics Education Journal*, *5*(2), 194–208. https://doi.org/10.21067/mpej.v5i2.5790

Creswell, J., & Poth, C. (2018). *Qualitative inquiry & research design*. Sage Publications.

Cruz-Sandoval, M., Vázquez-Parra, J. C., Carlos-Arroyo, M., & Amézquita-Zamora, J. A. (2023). Student perception of the level of development of complex thinking. An approach in university women in Mexico. *Journal of Latinos and Education*, *23*(2), 1–13. https://doi.org/10.1080/15348431.2023.2180370

Escudero-Nahón, A., & Ramírez-Montoya, M. S. (2021). El modelo y sus marcos. In C. M. Vicario, R. Huerta-Cuervo, A. Escudero-Nahón, M. S. Ramírez-Montoya, Y. Espinosa-Díaz, M. A. Solórzano-Murillo, & G. E. Trejo-Parada (Eds.), *Modelo de continuidad de servicios educativos ante un contexto de emergencia y sus etapas de crisis* (pp. 19–29). CUDI- ANUIES. https://hdl.handle.net/11285/637144

Gatti, L., Ulrich, M., & Seele, P. (2019). Education for sustainable development through business simulation games: An exploratory study of sustainability gamification and its effects on students' learning outcomes. *Journal of Cleaner Production*, *207*, 667–678. https://doi.org/10.1016/j.jclepro.2018.09.130

Hincapié Parejo, N. F., Orozco Carvajal, C. A., & Guzmán Rodríguez, J. S. (2022). La educación comparada en el contexto educativo de América Latina. *Revista Dialogus*, *6*(4), 84–96. https://doi.org/10.37594/dialogus.v1i6.400

Kato, S., Galán-Muros, V., & Weko, T. (2020). The emergence of alternative credentials. *OECD Education Working Papers 216*. https://doi.org/10.1787/b741f39e-en

Kozikoglu, I., & Onur, Z. (2019). Predictors of lifelong learning: Information literacy and academic self-efficacy. *Cypriot Journal of Educational Science*, *14*(4), 492–506. https://doi.org/10.18844/cjes.v11i4.3460

Kulik, A. A., Lazareva, P. V., Ippolitova, N. V., Egorova, A. E., & Nedorezova, O. Y. (2020). Competency-based approach and competencies in higher education: A theoretical review. *Propósitos y Representaciones*, *8*(2), 1–10. https://doi.org/10.20511/pyr2020.v8nSPE2.645

Kusumoto, Y. (2018). Enhancing critical thinking through active learning. *Language Learning in Higher Education*, *8*(1), 45–63. https://doi.org/10.1515/cercles-2018-0003

Lara-Prieto, V., de la Cruz-Hinojosa, J., Arrambide Leal, E. J., Palomera-Palacios, F., Ruiz-Cantisani, M. I., & Campos-Sandoval, J. M. (2019). First-year engineering students' engagement by hands-on experience with star wars robotics. In *Proceedings of the 2019 IEEE Global Engineering Education*, Dubai, United Arab Emirates. https://doi.org/10.1109/EDUCON.2019.8725168.

Leicht, A., Heiss, J., & Byun, W. J. (2018). *Issues and trends in education for sustainable development*. United Nations Educational, Scientific and Cultural Organization. https://unesdoc.unesco.org/ark:/48223/pf0000261954

Leybert, T. B., Khalikova, E. A., & Valinurova, L. S. (2022). Innovative transformations of higher education in the age of the digital economy. In E. G. Popkova (Ed.), *Business 4.0 as a subject of the digital economy. Advances in science*. Technology & Innovation. Springer, Cham. https://org.ezproxy.sibdi.ucr.ac.cr/10.1007/978-3-030-90324-4_11

Li, L. (2022). Reskilling and upskilling the future-ready workforce for industry 4.0 and beyond. *Information Systems Frontiers*, 1–16. https://doi.org/10.1007/s10796-022-10308-y

Luévano, E., de Lara, E. L., & Castro, J. E. (2015). Use of telepresence and holographic projection mobile devices for college degree level. *Procedia Computer Science*, *75*, 339–347. https://doi.org/10.1016/j.procs.2015.12.256

Mahdi, O. R., Nassar, I. A., & Almuslamani, H. A. (2020). The role of using case studies method in improving students' critical thinking skills in higher education. *The International Journal of Higher Education*, *9*(2), 297–308. https://doi.org/10.5430/ijhe.v9n2p297

Matarranz, M. (2019). Propuesta metodológica para estudiar la política educativa supranacional: alumbrando el marco axiológico de la Unión Europea. *Revista Española de Educación Comparada*, *34*(34), 73–96. https://doi.org/10.5944/reec.34.2019.23079

Misbah, Z., Gulikers, J., Widhiarso, W., & Mulder, M. (2022). Exploring connections between teacher interpersonal behaviour, student motivation, and competency level in competency-based learning environments. *Learning Environments Research*, *25*(3), 641–661. https://doi.org/10.1007/s10984-021-09395-6

Molina Gutiérrez, A., Miranda, J., Chavarría, D., Noguez, J., Ramírez, M., MacíMacíAs, M. E., López, E., Bustamante, M., Molina, M., & Ponce, P. Noguez J, Pérez-Rodríguez R, Wright, PK, Molina A. Open innovation laboratory for rapid realization of sensing, smart and sustainable products: Motives, concepts, and uses in higher education. In *Proceedings of the Working Conference on Virtual Enterprises*, Cardiff, UK, September 17–19, 2018.

Morin, E. (2010). *Science Avec Conscience* (14th ed.). Rio de Janeiro.

Nisa, E. K., Koestiari, T., Habibbulloh, M., & Jatmiko, B. (2018). Effectiveness of guided inquiry learning model to improve students' critical thinking skills at senior high school. *Journal of Physics*, *997*, 012049. https://doi.org/10.1088/1742-6596/997/1/012049

Pacheco-Velázquez, E. A., Vázquez-Parra, J. C., Cruz-Sandoval, M., Salinas-Navarro, D. E., & Carlos-Arroyo, M. (2023). Business decision-making and complex thinking: A bibliometric study. *Administrative Sciences*, *13*(3), 1–17. https://doi.org/10.3390/admsci13030080

Portuguez-Castro, M., Hernández-Méndez, R. V., & Peña-Ortega, L. O. (2022). Novus projects: Innovative ideas to build new opportunities upon technology-based avenues in higher education. *Education Sciences*, *12*(10), 1–17. https://doi.org/10.3390/educsci12100695

Pradhan, I. P., & Saxena, P. (2023). Reskilling workforce for the artificial intelligence age: Challenges and the way forward. In P. Tyagi, N. Chilamkurti, S. Grima, K. Sood, & B. Balusamy (Eds.), *The adoption and effect of artificial intelligence on human resources management, part B (emerald studies in finance, insurance, and risk management)* (pp. 181–197). Emerald Publishing Limited. https://doi.org/10.1108/978-1-80455-662-720230011

Puspita, A. S., & Aloysius, S. (2019). Developing student's critical thinking skills through implementation of problem-based learning approach. *Journal of Physics*, *1241*, 012020. https://doi.org/10.1088/1742-6596/1241/1/012020

Qi, M., Yi, Q., Mo, M., Huang, H., & Yang, Y. (2018). Application of case-based learning in instructing clinical skills on nursing undergraduates. *Biomedical Research-Tokyo*, *29*(2), 300–304. https://doi.org/10.4066/biomedicalresearch.29-17-2377

Ramírez-Montoya, M. S. (2010). *Modelos de enseñanza y método de casos*. Trillas.

Ramírez-Montoya, M. S. (2012). *Modelos y estrategias de enseñanza para ambientes innovadores*. Editorial digital Tecnológico de Monterrey. http://repositorioslatinoamericanos.uchile.cl/handle/2250/1223486

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*(1), 4–15. https://doi.org/10.3390/joitmc8010004

Ramírez-Montoya, M. S., McGreal, R., & Obiageli Agbu, J. F. (2022). Complex digital horizons in the future of education 4.0: Insights from UNESCO recommendations. *RIED-Revista Iberoamericana de Educación a Distancia*, *25*(2), 1–21. https://doi.org/10.5944/ried.25.2.33843

Ramírez-Montoya, M.S., & Portuguez-Castro, M. (2024). Expanding horizons for the future with an open educational model for complex thinking: External and internal validation. *On the Horizon*. Ahead of Print. in press. https://doi.org/10.1108/OTH-12-2023-0042

Rini, D. S., Adisyahputra, A., & Sigit, D. V. (2020). Boosting student critical thinking ability through project-based learning, motivation, and visual, auditory, kinesthetic learning style: A study on ecosystem topic. *Universal Journal of Educational Research*, *8*(4), 37–44. https://doi.org/10.13189/ujer.2020.081806

Ross, J., Curwood, J. S., & Bell, A. (2020). A multimodal assessment framework for higher education. *E-Learning & Digital Media*, *17*(4), 290–306. https://doi.org/10.1177/2042753020927201

Sáez de Cámara, E., Fernández, I., & Castillo-Eguskitza, N. (2021). A holistic approach to integrate and evaluate sustainable development in higher education. The case study of the university of the Basque Country. *Sustainability*, *13*(1), 1–19. https://doi.org/10.3390/su13010392

Salykova, L., Ibadildin, N., & Lebedev, D. (2022). Competency model development at Astana it University. In *2022 International Conference on Smart Information Systems and Technologies (SIST)* (pp. 1–6). Nur-Sultan, Kazakhstan. https://doi.org/10.1109/SIST54437.2022.9945819.

Sanabria-Z, J., Ramírez-Montoya, M. S., García-Peñalvo, F. J., & Cruz-Sandoval, M. (2023). Complex thinking in Interdisciplinarity: An exploratory study in Latin American Population. In *Proceedings of the 15th International Conference on Computer Supported Education*. Prague - Czech Republic. 2, 288–295.

Sarango, P., Mena, J. J., & Ramírez-Montoya, M. S. (2021). Evidence-based educational innovation model in the framework of education 4.0: Promoting digital information competencies for teachers. *Sustainability*, *13*(18), 10034. https://doi.org/10.3390/su131810034

Sigahi, T. F., Rampasso, I. S., Anholon, R., & Sznelwar, L. I. (2023). Classical paradigms versus complexity thinking in engineering education: An essential discussion in the education for sustainable development. *International Journal of Sustainability in Higher Education*, *24*(1), 179–192. https://doi.org/10.1108/IJSHE-11-2021-0472

Stanford. (2023). Lifelong learning. https://lifelonglearning.Stanford.edu/

Tamassia, C., & Adams, R. (2009). *International assessments and indicators: How will assessments and performance indicators improve educational policies and practices in a globalized society?*. SAGE Publications, Inc. https://doi.org/10.4135/9781452226606

Trisdiono, H., Siswandari, S., Suryani, N., & Joyoatmojo, S. (2019). Multidisciplinary integrated project-based learning to improve critical thinking skills and collaboration. *International Journal of Learning, Teaching and Educational Research*, *18*(1), 16–30. https://doi.org/10.26803/ijlter.18.1.2

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*(5), 1–12. https://doi.org/10.3390/educsci12050289

Vicario, C. M., Huerta-Cuervo, R., Escudero-Nahón, A., Ramírez-Montoya, M. S., Espinosa-Díaz, Y., Solórzano-Murillo, M. A., & Trejo-Parada, G. E. (2021). *Modelo de continuidad de servicios educativos ante un contexto de emergencia y sus etapas de crisis*. CUDI-ANUIES. https://hdl.handle.net/11285/637146

Vincent-Lancrin, S., González-Sancho, C., Bouckaert, M., de Luca, F., Fernández-Barrerra, M., Jacotin, G., Urgel, J., & Vidal, Q. (2019). *Fostering students' creativity and critical thinking: What it means in school, educational research and innovation*. OECD Publishing. https://doi.org/10.1787/62212c37-en

Wagenaar, R. (2019). Reform! Tuning the Modernisation Process of Higher Education in Europe. a Blueprint for Student-Centred *Learning* (Doctoral dissertation). University of Groningen. University of Groningen. https://pure.rug.nl/ws/portalfiles/portal/75936039/Complete_thesis.pdf

Wheelahan, L., & Moodie, G. (2021). Analysing micro-credentials in higher education: A Bernsteinian analysis. *Journal of Curriculum Studies*, *53*(2), 212–228. https://doi.org/10.1080/00220272.2021.1887358

World Economic Forum. (2020). *The future of jobs report 2020*. https://www.weforum.org/reports/the-future-of-jobs-report-2020