Complex Thinking in Interdisciplinarity: An Exploratory Study in Latin American Population

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Abstract: In the context of Latin America, there are few studies that analyze complex thinking linked to disciplinary analysis. In this sense, locating the characteristics promoted by the different disciplines presents an opportunity to scale higher order competencies such as those of complex thinking. This article aims to show the results of a study that seeks to show the perception of complex thinking competence in young university students in the Latin American context. A multivariate descriptive statistical analysis has been carried out. Among the main findings we identified that there is a higher degree of perception of male students in Latin America on complex thinking competence and that this pattern is found in most of the countries in the sample.

1 INTRODUCTION

Assessment of low- and high-order thinking skills is frequently performed following the Cognitive Process dimension of Bloom's taxonomy of educational objectives, namely the progressive low-to-high ladder of remember, understand, apply, analyze, evaluate, and create. The taxonomy has undergone a revision that separates it into Knowledge dimension and Cognitive Process dimension (Anderson, 2005). This breadth has made it possible to accommodate in the Knowledge dimension characteristics of the experimental context (e.g., type of academic subject) on a concrete-to-abstract continuum of factual, conceptual, procedural and metacognitive knowledge (Poluakan et al., 2019). Therefore, in the case of assessment of thinking skills within a disciplinary area, it has opened the possibility to factor the characteristics of the area into the Knowledge dimension for their consideration, for instance, by labeling it as more or less technology oriented.

In the Latin American university context, disciplinary areas can be classified as either technology or non-technology based. In this area, the development of high-level competencies, such as reasoning for complexity (Lipman, 1997, Morin, 1990), can support training in higher education from multiple perspectives, considering the characterisation of students with their socio-demographic and disciplinary characteristics. The aim of this article is to analyse the perception of students from different disciplines, in terms of their level of mastery of the competency of reasoning for complexity, to locate possibilities to further enhance high capacities in future professionals.

1.1 Higher Order Thinking Skills in Education

High-order thinking skills assessment have been an area of interest throughout the evolution of philosophy and psychology. Historically, the path to defining thinking skills was already observing a

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certain maturity in the middle of the twentieth century, where Newman (1990) indicated the importance of including deep knowledge resources and thoughtfulness dispositions to solve problems, which must be evaluated in order to be able to develop them. Broadly defined, higher-order thinking skills refer to an advanced cognitive process that involves the manipulation of previous thinking schemes and new information to solve problems and challenges (Heong et al., 2011). The revised Bloom's taxonomy has been a widely accepted approach to identifying higher-order thinking skills in higher education, particularly aimeda at observing critical thinking and problem solving (Hadzhikoleva et al., 2019). The rebirth of Bloom’s taxonomy has also promote the creation of new instruments to measure thinking skills, and it continues to be a point of comparison and inspiration for other alternatives. Although there are numerous examples at different educational levels, the implementation of educational strategies that integrate the development of thinking at the higher educational level continues to maintain great interest.

Within the context of higher education, the consideration of higher order thinking skills in curricular activities has taken a vital role in the teaching-learning process. Appropriate incorporation of the concept of thinking skills from a systemic perspective should take into account the perceptions of both students and teachers (Shukla & Dungsungnoen, 2016), nevertheless, students are the natural focus for the development of thinking skills. To this end, a study conducted by Yuliati and Lestari (2018) on higher education students, have found that students poorly comprehend questions aimed at identifying higher-order thinking skills, which beyond comprehension, may also be an indicator of the need for better instruments to measure perception of thinking. Certainly, exploration for the development of thinking skills in educational contexts, in addition to instructional design, involves factors such as the type of environment and the type of tools used for learning.

Currently, in both formal and informal educational settings, the use of technologies for learning has become the mainstream. The framework of the fourth industrial revolution has brought with it Education 4.0, which embraces the use of technologies for the development of 21st century skills (Qureshi et al., 2021). Chinedu et al. (2015) discussed teaching practices for developing higher-order thinking skills in design and technology formal education contexts, featuring strategies that entail the importance of systematic planning and collaborative activities for creativity that enable students to develop insights and hence work out solutions. With respect to field implementations for non-formal education, Sanabria-Z et al. (2022) have found a window of opportunity to create native technologies that allow for greater citizen involvement leading to their development of complex thinking. With this assimilation of technologies in education for the development of competencies, it becomes significant to highlight the current perception in the development of thinking competencies.

1.2 Complex Thinking from Disciplinary Analysis

The development of complex thinking promotes analysis in an integrated rather than fragmented way, as an interrelated system and not as disconnected parts. Morin (2022) calls for "complex thinking", especially with the experience of the multidimensional planetary crisis resulting from the COVID pandemic. Teixeira et al. (2021) associate complexity in the combination of computational and qualitative methods to extract definitions and analyse their use. Decision-making through complex thinking is also associated in its conceptualisation (Mohammadi-Shahboulaghi et al., 2021). As a high-level competence, reasoning for complexity involves scientific, systemic, critical and innovative thinking (Ramírez-Montoya et a., 2022). Developing complexity reasoning competences involves the interrelationship of analysing the parts in the whole and the whole in its interconnected parts.

Complex thinking has a substantial challenge in training across disciplines because of the crossover that is required towards interdisciplinarity. Domínguez (2022) puts forward ideas on interdisciplinarity and its presence at the educational level in links with the humanities, as an engine that increases its quality in combination with other disciplines. In the same sense, Baena-Rojas et al. (2022) through a bibliometric analysis of the concept of complexity locate incidence in various fields and the breadth towards multidisciplinarity. And in a practical analysis with students from various disciplines, Vázquez-Parra et al. (2021) found a greater preponderance of systemic thinking with students from the disciplines of Engineering, Business and Humanities, while the highest means for critical thinking were found in architecture students. Interdisciplinary and multidisciplinary has a field of action in the development of complex thinking.

Particularly in the context of Latin America, there are few studies that analyse complex thinking linked to disciplinary analyses. Among them, Maturo (2009) finds that, in Latin America, the philosophical discussion that stimulates complex thinking necessarily requires culturally diverse poetic experiences that are part of the meanings of historical reality. In the area of health, De Bortoli et al. (2017) emphasise that nursing education in Latin America and the Caribbean promotes nursing curricula that include the principles and values of Universal Health and promote the development of critical and complex thinking. For its part, a Mexican study found the relationship between complex thinking and social entrepreneurship in higher education students (Cruz-Sandoval, et al., 2022), as well as research in the area of education that proposes an international learning experience between Mexican and Spanish students (Romero-Rodríguez et al., 2022). In this sense, locating the characteristics promoted by the different disciplines presents an opportunity to scale higher-order competences such as those of complex thinking.

2 METHODOLOGY

To carry out the present study, a population sample of 150 undergraduate students from different Latin American countries was taken for convenience (see Table 1). The sample consists of 75 men and 75 women from different disciplinary areas. The study was carried out during the period August - December 2022. A questionnaire was administered via Google Forms in which the students responded voluntarily. Taking into account that the study involves human subjects, and being a pilot test, the implementation has been regulated and approved by the interdisciplinary research group R4C with the technical support of Writing Lab. Both entities belong to the Institute for the Future of Education (IFE) of the Tecnológico de Monterrey.

Regarding the instrument to evaluate the level of perception in the development of the complex thinking competency, the validated eComplexity instrument has been carried out. The purpose of this instrument is to measure the participants' perception of the development of the complex thinking competency and its sub-competencies. The instrument comprises 25 items (i.e., questions) linked to each of the sub-competencies of complex thinking: scientific thinking; critical thinking; innovative thinking; and systemic thinking. In this sense, the participant responds to each of the items according to their perception of achievement on a 5-level Likert scale. The items of this instrument can be reviewed in Cruz-Sandoval, Vázquez-Parra, and Carlos-Arroyo (2023).

Table 1: Participant data and gender. Source: Created by the authors.

Country	Men	Women	Total
Argentina	2	2	4
Chile	18	30	48
Colombia	3	3	6
Dominican Republic	3	3	6
Ecuador	35	23	58
Guatemala	2	2	4
Mexico	12	12	24
Total	75	75	100

Subsequently, a descriptive statistical analysis of the data was carried out using the computation software R (R Core Team, 2017) and RStudio (RStudio Team , 2022). The analysis consisted mainly of measures of central tendency (i.e., arithmetic mean, standard deviation), complemented with boxplot analysis and violin plot analysis. An ANOVA analysis was also performed to observe the significance of the difference in mean values by gender in Latin American university students. It is worth mentioning that, as far as possible, a comparison was made between countries and a comparison by gender according to the country to which the students belong.

3 RESULTS

Figure 1 shows the first approach to the results obtained. It shows the percentage of students per country in Latin American context with respect to the mean values obtained in perception of the complex thinking competency. The results are shown in a 10 X 10 grid in which each square represents 10%. Likewise, each square is color-coded according to the range in mean values obtained in the perception of the development of the competency.. In this sense, the figure illustrates that Chile (10%) and Ecuador (2%) present the highest percentage of population with perception levels between 2 and 3. It is important to mention that the results are relative to each country and not to the population in general.

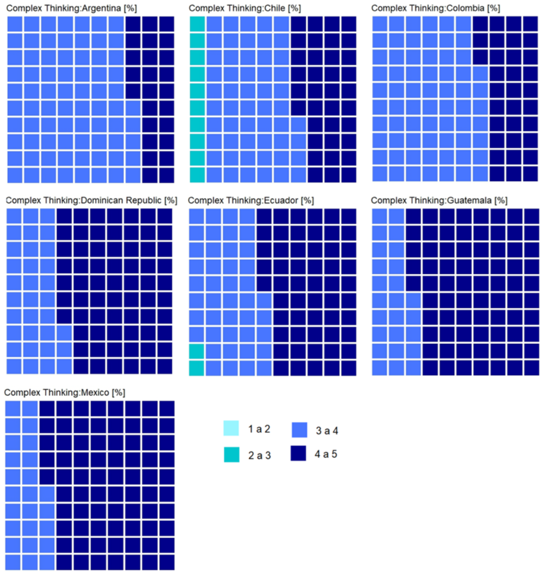


Figure 1: Mean values in the perception of the development of complex thinking in [%] by country. Source: Created by the authors.

Given that the above results could yield spurious analyses, a more in-depth analysis has been made. In this sense, Table 2 shows the mean values and standard deviation (s) with respect to the perception of the development of complex thinking competency in Latin American students by gender. From the table it can be observed that men are perceived as having a higher development than their female peers, presenting higher mean values. Likewise, the standard deviation value indicates how dispersed the behavior is with respect to the mean value. In this sense, the deviation in men (0.50), being lower than in women (0.61), would indicate that there is less dispersion around the value of perception in men.

Table 2: Complex Thinking. Mean values and standard deviation in perception of the development of complex thinking by gender. Source: Created by the authors.

Gender	Mean	Sd
Male	4.02	0.50
Female	3.80	0.61

In this context, Figure 2 illustrates the previous results in a better way. It shows Latin American male students with a higher perception in the development of complex thinking and with a smaller dispersion with respect to the mean value compared to their female peers.

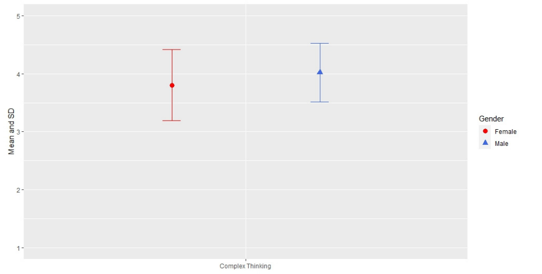
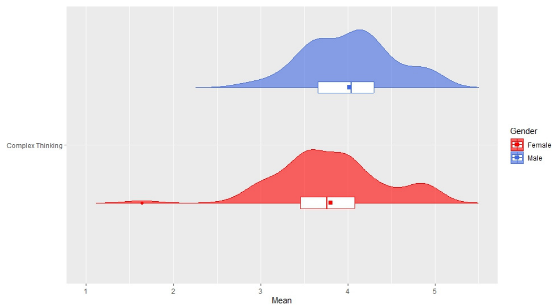


Figure 2: Complex thinking. Overall results. Mean values and standard deviation in perception of the development of complex thinking by gender. Source: Created by the authors.

On the other hand, Figure 3 shows the empirical Kernel-type distribution density analysis in a smoothed diagram. From the figure it can be observed that in men the distribution density is higher at mean values of perception between 4 and 4.5, while in women the distribution density is higher at values of 3 and 3.5.



Source: Created by the authors.

Figure 3: Flat violinplot. Distribution density. Kernel density. Smoothed histogram of perception in the development of complex thinking by gender.

On the other hand, in order to understand if there is a significant difference in the perception of the development of complex thinking between men and women, an ANOVA analysis was performed. The results of the analysis (see Table 3) , show that there are significant differences ($p<=0.05$) between male and female students in how they perceive themselves with respect to this competency in the Latin American context.

On the other hand, the analysis by country is shown in Table 4. It shows that the countries with high average values in the perception of the development of complex thinking are the Dominican Republic, Guatemala and Ecuador. On the other hand, development of this competency are Argentina, Mexico, Chile and Colombia. Similarly, the table shows the analysis of the average values of perception

Table 3: Complex thinking. ANOVA analysis. Men vs Women. Source: Created by the authors.

Complex Thinking	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Men vs Women	1	1.782	1.782	5.66	0.018

by gender according to the country to which they belong. The table shows that, with the exception of the Dominican Republic and Guatemala, men are perceived as having a greater development of complex thinking.

Table 4: Complex thinking by country and gender. Source: Created by the authors.

	Men		Women	
Country	Mean	Sd	Mean	Sd
Argentina	3.86	0.59	3.30	0.20
Chile	4.02	0.59	3.67	0.51
Colombia	3.95	0.20	3.84	0.08
Dominican Rep.	3.88	0.80	4.65	0.36
Ecuador	4.16	0.47	4.04	0.59
Guatemala	3.72	0.62	4.56	0.28
Mexico	3.76	0.37	3.41	0.67

As a complement to the previous results, Figure 4 illustrates the behavior in perception of mean values and deviation(s) of students with respect to complex thinking by country. The figure shows a similar behavior between Guatemala and Ecuador. Likewise, Colombia and Chile show a similar trend. On the other hand, Mexico and Argentina show the lowest mean values. It should also be noted that although the Dominican Republic is the country with the highest mean value in perception, it is the one that shows the greatest standard deviation with respect to the mean value.

In this context, in order to learn more about the students' perception of complex thinking competency, a boxplot analysis by country has been performed. The interesting thing about this analysis is that it helps to understand the dispersion of our

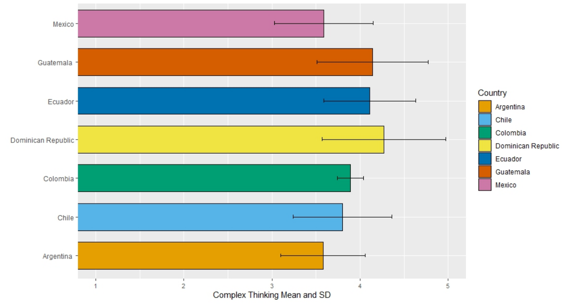


Figure 4: Complex thinking. Mean and standard deviation by country with respect to the perception in the development of complex thinking. Source: Created by the authors.

data and the outliers (see Figure 5). In this sense, it is possible to observe that the Dominican Republic, Chile and Ecuador show a more dispersed behavior, while Argentina and Colombia show less dispersion in the students' perception of the development of complex thinking.

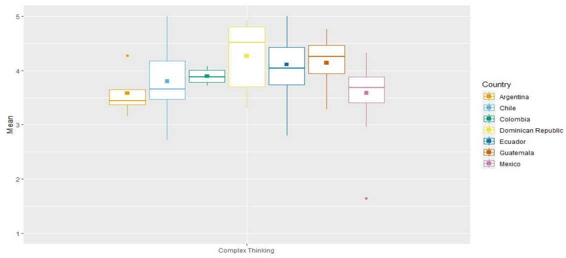


Figure 5: Boxplot analysis of the perception in the development of complex thinking by country. Source. Created by the authors.

On the other hand, Figure 6 illustrates the Boxplot analysis by gender of each country with respect to their perception of the development of complex thinking. The figure shows that the general behavior (with the exception of the Dominican Republic,

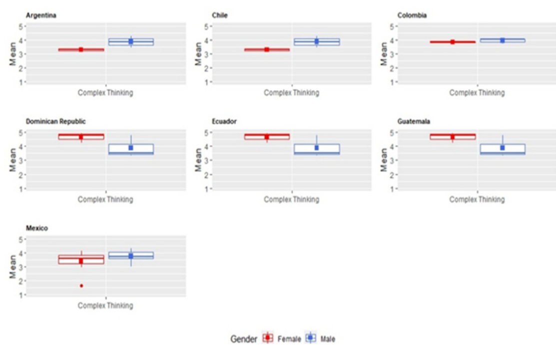


Figure 6: Boxplot analysis of the perception in the development of complex thinking by country and by gender. Source: Created by the authors.

Guatemala and Ecuador) is that men perceive themselves better in the development of complex thinking competencies. Likewise, it is important to highlight that women show less dispersion in perception than men, that is, although the mean values in women in some countries are low, the dispersion is lower than in their male peers (despite the fact that men present higher mean values).

Finally, Figure 7 shows the analysis of complex thinking by type of discipline, showing how students from the social sciences are perceived as having the greatest development of complex thinking. On the other hand, students belonging to engineering and technology disciplines are those who are perceived as having the least development in complex thinking. On the other hand, students of humanities, medical sciences and natural sciences show a similar behavior in the average value of perception.

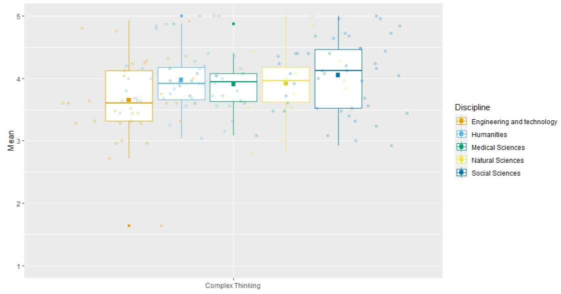


Figure 7: Complex thinking. Boxplot analysis by discipline. Source: Created by the authors.

4 DISCUSSION

Students in Latin America in technological disciplinary areas are perceived with a lower degree of development of high-order thinking skills. The analysis of complex thinking in students by discipline shows how those in social sciences are perceived with greater development, while those in areas related to technology are perceived with less development of complex thinking. This deficiency could be related to the lack of technological developments that are linked to the development of student involvement, as pointed out by Sanabria-Z et al. (2022). This scenario suggests that the stereotype of the study of technological areas where it focuses heavily on practice leaving aside the context may still be governing despite the educational evolution.

Latin American male students tend to have self greater perception in the development of complex thinking. Based on what is represented in the BoxPlot analysis, the perception in the development of complex thinking by country and gender differs in favor of males, with less dispersion of the data. This finding, seen from the perspective of instructional design, is supported by what Maturo (2009) points out about Latin America, calling for the importance of considering the cultural aspects of historical reality when constructing narratives for the development of thought. As a whole, the contextual nature of educational environments where high-order thinking skills are sought to be developed, plays a fundamental role that is highly considered by those who design learning activities and seek to measure the development of competencies.

5 CONCLUSIONS

The impact of the identification of thinking skills is of great value in the context of education 4.0, which strongly links skills with the use of technologies. In this study, we sought to present the state of the perception of students from different disciplines about the reasoning competence due to complexity, considering the difference between disciplinary areas with and without a technological base. Among the main findings we identified that there is a higher degree of perception of male students in Latin America about complex thinking competence and that this pattern occurs in most of the sample countries.

The implications of this study for best practices show that it is necessary to continue strengthening the way of constructing reasoning development activities for complexity considering the inclusion in the instructional design of activities. Likewise, the analyses give rise to reflection on how the research has a wide area of application that ranges from knowing the perception of students and instructors, teaching conditions, and instruments for measuring competencies.

Some limitations of the study are limited to the type of sample that is limited to a group of countries but not to the entirety of Latin America; the broad definition of the disciplinary areas between technological and non-technological without specifying the particularities of the subject of study; and the lack of observation of perception over time to identify the passage of low-order thinking skills towards high-order skills in students. Some limitations of the study are limited to the type of sample that is limited to a group of countries but not to the entirety of Latin America; the broad definition of the disciplinary areas between technological and non-technological without specifying the particularities of the subject of study; and the lack of observation of perception over time to identify the passage of low-order thinking skills towards high-order skills in students.

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