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Scientific Thinking Engineering and Health Sciences Students: Competency Analysis in a Mexican University

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Abstract

This article presents the findings of a comprehensive skills-and-competencies analysis conducted among incoming Engineering and Health Sciences freshmen at a leading technological university in Mexico. The primary objective was to determine whether these students possessed an ideal competency profile that would effectively prepare them to meet the evolving demands of their future professional training. The study focuses on evaluating complex thinking macro-competency, recognizing its critical importance in equipping individuals to tackle the multifaceted challenges and intricacies they will encounter in their academic and professional journeys. More precisely, this research focuses on the assessment of scientific thinking as a meta-competency of complex thinking macro-competency and considered a cornerstone competency essential for success in the fields of Engineering and Health Sciences. The statistically significant findings demonstrated marked disparities in the perception and development of complex thinking macro-competency and, specifically, in the meta-competency of scientific thinking among incoming students in the Engineering and Health Sciences domains, as opposed to their counterparts in Humanities and Social Science. This observation gains particular importance in the context of the requisite competency sets for career paths in Engineering and Health Sciences, accentuating the students' proficiency and preparedness to excel in their selected fields. These results emphasize the criticality of conducting competency assessments at early stages and advocate for the modification of educational methodologies to foster the specialized competencies vital for prospective success in these disciplines. The results are analyzed in terms of their suitability for aligning educational goals with the evolving demands of the Engineering and Health Sciences fields. Overall, this study centers on the fundamental aspects of education, highlighting its importance not only due to its relevance but also for its capacity to drive meaningful changes in the future landscape of higher education.

***Keywords**: Educational Innovation, Future of Education, Reasoning for Complexity, Scientific Thinking, Higher Education.*

Introduction

Faced with the needs of a complex world such as the one we live in today; it is necessary for students to develop proportional competencies. It is not enough for universities to provide

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technical information associated with the profession; it is necessary for future professionals to have the ability to adopt this knowledge when making decisions and solving problems (Vázquez-Parra et al., 2023a). A challenge that often occurs in science-focused disciplines is that students may acquire a large amount of knowledge without knowing how to apply it to the challenges they face, resulting in a limited formative process, which involves additional training processes within companies (Alkhatib, 2019).

Unlike theoretical knowledge specific to one discipline, competencies can be transversal and cross different areas of knowledge, providing valuable tools that allow understanding processes and methodologies that impact more than one discipline (Hafni et al., 2020). An example of this is the development of argumentation and scientific thinking, which is of great value to any scholar of engineering, mathematics, technology and science. However, unlike the formation of knowledge that can be evaluated transversally, the development of competencies implies a more longitudinal process, having to consider previous experiences, associated skills, and even the students' level of perceived achievement (Marewski & Gigerenzer, 2022).

In this sense, universities concerned with the development of these cognitive processes pay greater attention to the educational background of their prospective students, valuing the entry profile as an element that can be a determining factor in the use of the training provided in their classrooms (Carol-Ann & Navas, 2021). Specifically, it is considered that the higher the level of argumentation and scientific thinking of an incoming student, the more likely he/she will be to achieve greater educational accomplishments during the rest of his/her educational process (Sistermans, 2020). However, along with the measurement of competencies, it will be necessary for the student to have a proportional perception of achievement about his or her abilities, since, if this is not the case, he or she could be limited by not valuing that he or she has the competencies to respond to a specific need.

Literature Review

The measurement of competencies and 21st Century skills.

In recent years, higher education has paid great attention to integrating competency-based training of its students and the academic community in general. Competency-based models allude to the teaching-learning process oriented to acquiring skills, knowledge, and attitudes that serve the individual to perform optimally in one or more contexts (Cejas et al., 2019). As is natural in any subject that involves the training of individuals, the competency-based approach, its definition, and its implications for content design have been debatable and problematic to assess (Casanova et al., 2018; Opertti, 2022). However, there is a consensus that competencies can be objectives in a strategy that fosters and promotes the development of various skills in students. It should be recalled that the concept of competency emerged in the 1970s as an alternative to intelligence tests, proposing that, unlike the latter, the evaluation of students should reflect changes in their learning and skill acquisition (McClelland, 1973), understanding it as a dynamic process.

More recent literature and the International Bureau of Education define competency as the ability to adequately apply learning results in a defined context (whether in education, work, or personal/professional development) (IBE, 2022a). Thus, this ability can be disciplinary-specific and transversal, implying that the acquired skill or skills will be helpful in contexts not necessarily linked to the students' specialty (UNESCO, 2022); likewise, competencies also include traits specific to the individual (Díaz-Barriga, 2006; Lizitza & Sheepshanks, 2020; Schvartzman, 2004). One of the main characteristics and utilities of competencies, aside from the teaching process (McClelland, 1973), is that they should be oriented to provide solutions to current, everyday, real-life complex problems. In this sense, the so-called 21st Century Skills have been proposed with the aim that society manages to adapt to the constant changes it experiences and can face different contexts variably and effectively (Batelle for Kids, 2022; Ed21, 2022; IBE, 2022b; Irigoyen et al., 2011; Khine & Areepattamannil, 2019; Stroud & Baines, 2019; UNESCO, 2017; van Laar et al., 2020).

The 21st Century Skills are derived from the "21st Century Themes," which are Global Awareness, Financial, Economic, Business, Entrepreneurial Literacy, Civic Literacy, and Health Literacy, classified into the three broad areas of 1) Information, Media, and Technology Skills; 2) Life and Career Skills; and 3) Learning and Innovation Skills (Fadel, 2008). The latter includes more specific competencies that refer to critical thinking and problem solving, creativity and innovation, and communication and collaboration. Acquiring these skills make it ideally possible to adapt to complex contexts and scenarios for the benefit of all (González-Pérez & Ramírez-Montoya, 2022; IBE, 2022c; Tamimi, 2024).

Complex thinking

Regarding the educational field, critical thinking, creativity, and innovation stand out as desirable skills, not in isolation, but as part of the macro-competency of complex thinking. This macro-competency refers to the set of critical, scientific, innovative, and systemic thinking skills (González-Pérez & Ramírez-Montoya, 2022; Ramírez-Montoya et al., 2022). In this frame of reference, these skills are called meta-competencies and are seen as formative tools for proposing creative and evidence-based solutions.

Each meta-competency fulfills particular purposes that together produce comprehensive training for the individual. For example, *critical thinking* focuses on differentiating evidence from opinions, using an interdisciplinary perspective, and facilitating real-world decision-making (Baena-Rojas et al., 2022; Liang & Fung, 2021; van Laar et al., 2020). *Systemic thinking* refers to a theoretical-practical, interdisciplinary skill related to problem-solving and decision-making (Gallón, 2019; Grohs et al., 2018; Hossain et al., 2020). Likewise, it considers the possible consequences of one's actions and the ability to make contextual judgments (Djunaidi & Farichah, 2022; van Laar et al., 2020). It includes the skills of observation, thinking, analysis, synthesis, and making connections and interrelationships. It is integrative thinking, as it considers the interaction of the subject with the environment and conceives that nothing happens in isolation but that everything is part of an ordered system (Barcelata-Eguiarte, 2021; Kriswandani et al., 2022).

Innovative thinking is related to creative processes and various ways of proposing solutions that lead to successful outcomes. Like the rest of the meta-competencies, innovative thinking has an interdisciplinary character for process and knowledge management (Lettry & Echegaray, 2020). The important thing is not to forget that this skill (or set of skills) should focus on proposing practical solutions that address complex current problems (Chimbunde et al., 2023; Morad et al., 2021; Ramírez-Montoya et al., 2022; Steyn & Vanyoro, 2023; Yudha & Yuliati, 2018).

The Relevance of Scientific Thinking Formation to the Sciences

For its part, *scientific thinking* is more promoted in engineering and science for obvious reasons. However, one of the primary purposes of promoting 21st Century skills in higher education is that this competency is not exclusive to that training area but that the subjects of any discipline require this skill for the benefit of their professional training and the subsequent impact it has in the world of work. Scientific thinking is the opposite of speculation; it is based on logical reasoning and decision-making through fact-checking (Koerber & Osterhaus, 2019; Osterhaus et al., 2021; Vázquez-Parra et al., 2022). Problem-solving is an essential aspect of the scientific approach, but it is not considered the only one. It gives much importance to forming critical and creative thinking (Mayor, 1999), so its relationship with the other meta-competencies is clear.

Likewise, scientific thinking is associated with approaching knowledge through the ability to think or act to improve the understanding of what happens in the world. The development of scientific thinking increases social participation in events of world interest, such as global warming or the crisis in health areas, through exchanging complex discourses or informed decision-making based on socio-scientific problems. Some authors consider that scientific thinking is composed of scientific understanding that involves different explanations about a phenomenon across various domains; scientific reasoning can encompass the reasoning process involved in the construction of scientific knowledge (Li et al., 2022; Uus et al., 2022). On the other hand, the presence of critical meta-competencies that shape such thinking has also been highlighted, such as scientific literacy, autonomous problem-solving, and academic literacy (Andrews et al., 2020; Gravett & Kinchin, 2021; Suárez-Brito et al., 2022) and digital literacy and transformation (Aditya et al., 2022; Baytak, 2022; Díaz, 2022; Eurostat, 2022).

Part of the rationale for promoting scientific thinking is that its counterpart, anti-scientific thinking, is linked to students' subject preferences within courses and subjects in the educational context. Scientific bases or foundations do not support the latter type of thinking. It may include superstitious behavior and beliefs in the supernatural, the existence of extraordinary beings or premonition, which are also known as magical beliefs and are not exclusive to non-civilized communities or atypical populations (Caldera et al., 2017; Guerrero, 2007). Although anti-scientific thinking is observed to a greater extent in the socio-cultural context, the educational context is also essential for its construction through the influence of teachers in middle and higher education.

Previous literature has shown that in the teaching of social sciences and the perspectives that students in training have towards it, there is a marked rejection of it as a science, which comes from high school education and is reinforced by the presence of anti-scientific teaching elements. However, anti-scientific bias is not just present in social sciences. It has been discovered that in the humanities, similar considerations are expressed within populations and feed into popular beliefs and, in many cases, generate new forms of anti-scientific currents or beliefs (Bruner & Acuña, 2006). In contrast, more encouraging data has found an association between the preference for subjects belonging to "hard" sciences such as physics and chemistry with a positive attitude towards science (Murtonen & Balloo, 2019). Thus, the development of scientific thinking in training professionals will determine how, in the future, the conceptual and methodological frameworks that support the knowledge bases in the scientific community and the general population can be built. Arriving at problem-solving based on evidence and scientific reasoning will mediate decision-making and solution proposals to the various global problems afflicting society (Li et al., 2022; Uus et al., 2022).

Teaching scientific thinking as a critical competency allows students to broaden their panoramas and become professionals who transmit, from this reaffirmed vision, values that comply with international goals, thus expanding the coverage of a quality, inclusive, meaningful, and lifelong education for each student and teacher, as promulgated by Sustainable Development Goal # 4 (SDGs) (UN, 2022a) regarding Quality Education. SDG 4 states the need to improve education at different levels of application based on higher education; it establishes the improvement of teaching staff, teaching-learning environments, and curricula as targets (UN, 2022b).

This article presents the following research question: What is the perceived level of achievement in the competencies of scientific thinking among students entering scientific disciplines, and can a distinction be identified between these students and those pursuing degrees in other fields? The hypothesis posits that there are statistically significant differences in the perceived mastery of scientific thinking competencies between incoming freshmen majoring in science and those in non-science disciplines.

This article sets out to detail the findings of an exploratory study conducted among first-year students in scientific and technological disciplines at a university in Western Mexico. The study's primary goal is to assess the initial level of perceived achievement in complex thinking competencies among these students, particularly to discern if significant differences exist between students from scientific fields and those from other disciplines. The focus is specifically on the meta-competency of scientific thinking, a crucial element for students in STEM (Science, Technology, Engineering, and Mathematics) related professions. Methodologically, the study employs a multivariate descriptive analysis on a sample of 86 incoming students, categorized into two groups: one comprising students from scientific disciplines and the other from social and humanistic fields. The analysis includes the calculation of arithmetic means, standard deviations, boxplot analysis, principal component analysis, and Biplot analysis to comprehensively understand the data's characteristics.

Though exploratory in nature, this study aims to offer valuable insights into whether students from scientific disciplines have a higher perceived competency compared to their counterparts in other fields. This understanding is considered crucial for shaping their ongoing educational journey.

Method

Research Design

An exploratory quantitative study was performed with the objective of determining the level of perceived achievement of the complex thinking macro-competency and the scientific thinking meta-competency in a group of first-year students of a technological university in Mexico.

The motivating research questions for this study are: What is the initial perceived level of achievement in the meta-competency of scientific thinking among students entering scientific disciplines, and can a differentiation be discerned between these students and those pursuing careers in other fields?

The hypothesis posits that there are significant perceptual differences in the macro and meta competencies of first-year students specializing in science-oriented disciplines compared to those in other fields. Specifically, the study contrasts the perceptions of students in Engineering and Health Sciences with those in Social Sciences and Humanities.

Participants

A convenience sample of 86 students in a technological university in the western region of Mexico that had adopted a competency-based educational model collected information from two populations. The first population comprised 35 men and 19 women from different careers (curricula) of scientific disciplines, specifically in the areas of Engineering and Health Sciences. This population includes students of electronics, mechatronics, robotics, and mechanics from the engineering discipline, as well as medical and biotechnology students from the health sciences discipline. The second population comprised 16 male and 16 female students from the Social Sciences and Humanities disciplines. Within the Humanities discipline are students of international relations, law, communication and education.

Data Collection

The study was carried out in August 2022. The students answered voluntarily a self-administered questionnaire digitalized on the Google Forms platform. All participants expressed their consent for the use of their responses for academic purposes.

Table 1 shows the characteristics by gender of each group.

Table 1.

Participant data by gender.

	Men		Women		Total	
	n	*%*	*n*	*%*	*n*	*%*
Group 1. Engineering and Health Sciences	35	65%	19	35%	54	100
Group 2. Social Sciences and Humanities	16	50%	16	50%	32	100

Considering this is an exploratory study involving individuals, the implementation was regulated and approved by the interdisciplinary research group R4C, with the technical support of the Writing Lab of the Institute for the Future of Education at Tecnologico de Monterrey. Since it was an exploratory implementation, the committee suggested that the population be limited to two groups of students, with the commitment to expand the sample if the results were positive and the repetition of the implementation was warranted.

Data Collection Tools

For this study, the E-Complexity instrument was applied, which is a validated instrument for the evaluation of the level of perception of achievement of the complex thinking macro-competency and its meta-competencies. This questionnaire consists of 25 statements that are rated on a 5-level Likert scale, ranging from "Completely disagree" (1) to "Completely agree" (5) (Castillo-Martínez et al., 2022). This instrument has undergone a three-stage validation process: theoretical validation, content validation with experts, and validation by means of a structural equation model. The theoretical validation was based on the analysis of other instruments that measure complex reasoning macro-competency and its meta-competencies, revealing the lack of an integrative instrument. The design of E-Complexity was based on the conceptualization of complex reasoning macro-competency and its meta-competencies (Castillo-Martínez et al., 2022). As for content validation with experts, three criteria were used: clarity, coherence, and relevance (Escobar-Pérez & Cuervo-Martínez, 2008). Experts were asked to rate the items according to these criteria. The instrument showed high scores on all three criteria, with scores above 60%, indicating a high level of validity (3-4). Also, a validation was performed by means of Partial Least Squares Structural Equation Modeling (PLS-SEM), which allowed confirming that the instrument is statistically valid and reliable, both for its educational contribution, and in terms of its ability to measure the perception of achievement of the Complex Thinking macro-competency and the relationships between its meta-competencies, showing a greater impact by Systemic and Scientific Thinking (Vázquez-Parra et al. 2023b).

Data Analysis

Regarding data processing, a multivariate descriptive analysis was carried out using R (R Core Team, 2017) and Rstudio (RStudio Team, 2022) computer software. The descriptive statistical analysis for the present study was based on arithmetic means, standard deviations, boxplot analysis, principal component analysis, and Biplot analysis of shape ($\alpha = 1$).

The arithmetic means analysis aimed to obtain a representative sample value for each meta-competency in the macro-competency of complex thinking. Similarly, the standard deviations were intended to describe the behavior of sample components around the mean of each variable analyzed. As a complement, the boxplot analysis allowed visualizing the behavior of the mean values obtained from the sample by quartiles or percentiles of each meta-competency. This tool is handy for observing data symmetry, dispersion patterns, and outliers (Williamson, 1989).

On the other hand, the principal component analysis reduces the complexity of the raw data by identifying a new set of uncorrelated components (called principal components) that capture the maximum variability of the data and avoid collinearity problems (O'Sullivan & Unwin, 2002). There are as many principal components as variables analyzed.

A Biplot analysis of form ($\alpha = 1$) was performed because of its goodness of representation in the behavior of the observations (students) based on the two components that capture the maximum variability of the data (Gabriel, 1971; Cruz-Sandoval et al., 2020).

Finally, we have conducted a t-test to determine whether the differences in average values regarding the perceptions of students from various study areas are significant. This was particularly focused on the level of the macro-competency of complex thinking and the meta-competency of scientific thinking.

It is important to note that this study assumes normality in the dataset. The normality assumption underpins the validity of the subsequent interpretations and conclusions drawn from the statistical analyses.

Findings

Table 2 shows the results of the arithmetic means and total standard deviations, in total and by gender, of the perception of the Engineering and Health Sciences students in the complex-thinking meta-competencies and macro-competency. In both genders, the meta-competency with the highest perception of development was critical thinking. This meta-competency had a mean perception value of 4.16 with a standard deviation of 0.40. In second place, students of both genders perceived a high development of scientific thinking (mean 4.15, SD 0.40).

Table 2.

Mean values and standard deviations of Engineering and Health Sciences students' perception of the meta-competency of complex thinking, in total and by gender.

	Men		Women		Total	
	Mean	Sd	Mean	Sd	Mean	Sd
Complex thinking macro-competency	4.09	0.40	4.12	0.40	4.10	0.40
Scientific thinking meta-competency	4.16	0.39	4.14	0.43	4.15	0.41
Critical thinking meta-competency	4.10	0.41	4.25	0.38	4.16	0.40
Innovative thinking meta-competency	4.04	0.45	4.07	0.49	4.05	0.46
Systemic Thinking meta-competency	4.07	0.36	4.01	0.25	4.05	0.32

Likewise, Table 2 shows that by gender, males perceived the highest development in the meta-competency of scientific thinking. The mean value for males in this meta-competency was 4.16. Women perceived themselves to be more developed in the meta-competency of critical thinking (mean 4.25). On the other hand, the lowest student meta-competency perception was innovative thinking for men (mean value of 4.04) and systemic thinking for women (mean value of 4.01).

To better understand the above results, Figure 1 shows the boxplot analysis of the perception of Engineering and Health Sciences students of the macro-competency of complex thinking by gender. Regarding scientific thinking, the boxplot shows that women's data was more dispersed, while the men had compact dispersion. Likewise, similar behavior of the students (i.e., compact) occurred in the perception of systemic thinking. It should also be noted that there are values with a higher perception in the fourth quartile of this meta-competency, mainly on the part of men. Similarly, male critical thinking had more dispersion, with more men in the lowest quartile.

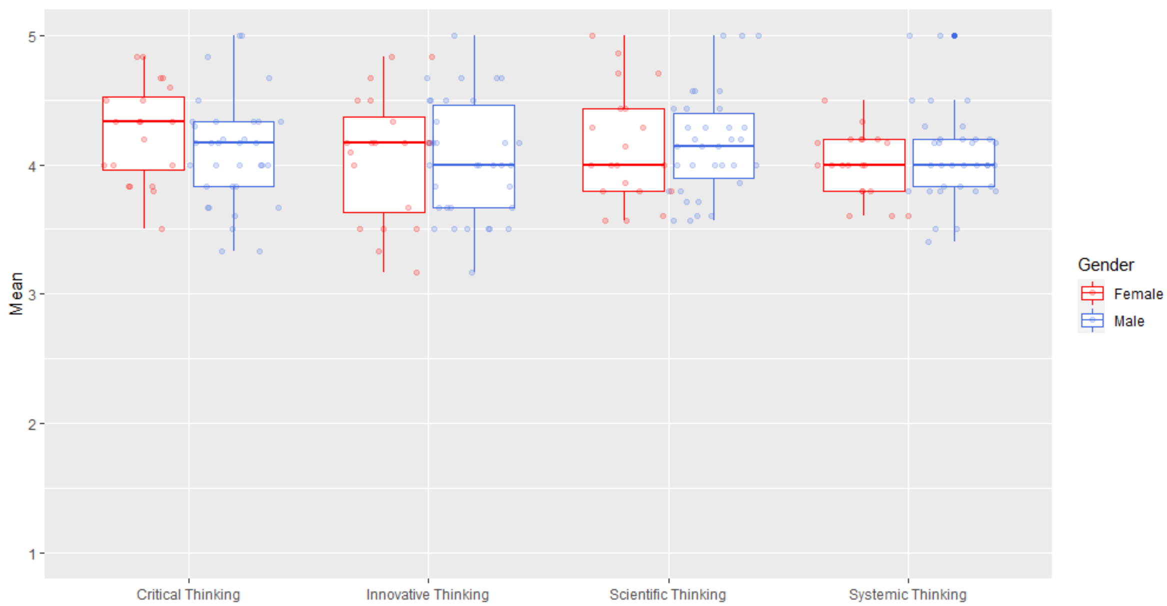

Figure 1. Boxplot analysis: Engineering and Health Sciences students' perception of the meta-competencies of complex thinking macro-competency, in total and by gender.

Table 3 highlights the analysis of the perception of the development of the meta-competency of scientific thinking of students belonging to Engineering and Health Sciences disciplines by gender. The table shows that male Engineering students perceived themselves as higher in scientific thinking than their peers in Health Sciences. In contrast, female Health Science students perceived themselves as higher in scientific thinking than female Engineering students.

Table 3.

Scientific thinking meta-competency by science discipline.

	Men		Women		Total	
Discipline	Mean	Sd	Mean	Sd	Mean	Sd
Engineering Sciences	4.17	0.41	4.10	0.41	4.14	0.40
Health Sciences	4.11	0.36	4.23	0.49	4.18	0.42

Figure 2 shows the boxplot analysis of the perception of developing the meta-competency of scientific thinking among the Engineering and Health Sciences students. The analysis shows more dispersion in the Engineering students' data, with students at the two extremes, that is, in the first and fourth quartiles. On the other hand, the Health Sciences students had more compact dispersion and a higher mean value in scientific thinking.

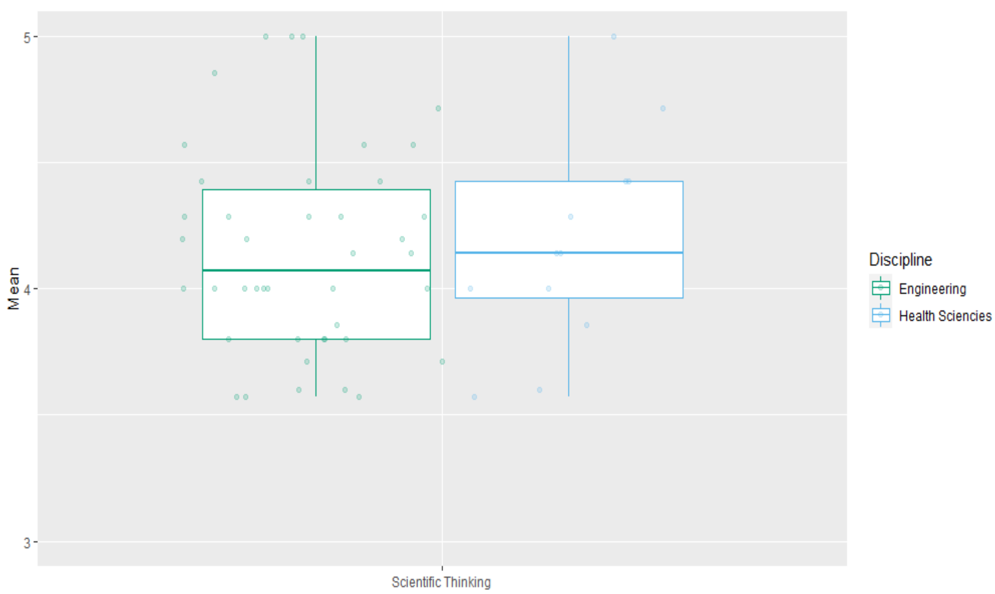

Figure 2. Boxplot analysis: Scientific thinking by discipline

On the other hand, Table 4 shows the analysis of means and deviation (s) results for the Social Sciences and Humanities students' perception of their development of the macro-competency of complex thinking. The results showed that these students generally perceived themselves better in developing the meta-competency of systemic thinking (mean value of 4.19). On the other hand, the lowest perceived development was scientific thinking (mean 3.76). By gender, men perceived themselves better in systemic thinking (mean 4.13), followed by critical thinking (4.06), while their lowest perception was scientific thinking (3.73). Similarly, women perceived themselves best in systemic thinking (mean 4.26), followed by critical thinking (3.96), and lowest development in scientific thinking (3.79).

Table 4.

Mean values and standard deviations of the Social Sciences and Humanities students' perception of complex thinking by gender and meta-competency.

	Men		Women		Total	
	Mean	Sd	Mean	Sd	Mean	Sd
Complex thinking macro competency	3.92	0.50	3.98	0.43	3.95	0.47
Scientific thinking meta-competency	3.73	0.62	3.79	0.40	3.76	0.51
Critical thinking meta-competency	4.06	0.39	3.96	0.33	4.01	0.36
Innovative thinking meta-competency	3.75	0.55	3.92	0.55	3.83	0.55
Systemic Thinking meta-competency	4.13	0.26	4.26	0.29	4.19	0.28

To better understand the above table, Figure 3 shows the boxplot analysis of the Social Sciences and Humanities students' perception of the meta-competencies of complex thinking. This analysis mainly shows the dispersion and behavior of the data. It shows a large dispersion of men's data in scientific thinking and their presence in its lowest quartile. Women, on the other hand, had more compact dispersion in this meta-competency. Students of both genders perceived themselves as high in developing systemic thinking, with a more compact dispersion of male data.

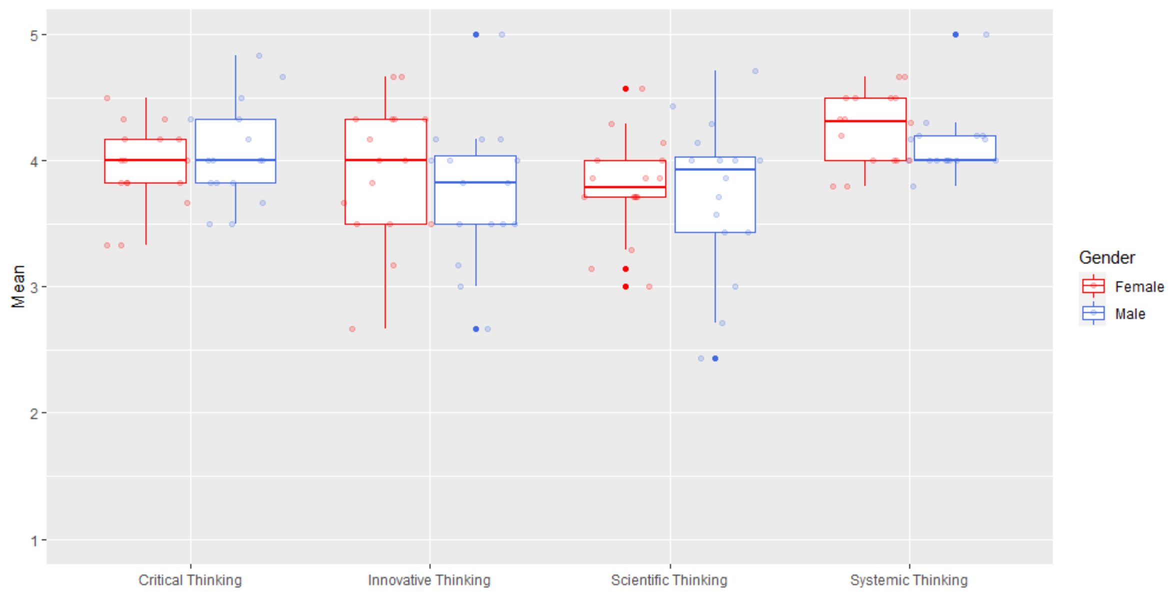

Figure 3. Boxplot analysis: Social Sciences and Humanities students' perception of complex thinking by gender and meta-competency.

Table 5 is a comparative analysis between Engineering and Health Sciences and Social Sciences and Humanities students to observe their differences in perceiving the macro-competency of complex thinking and the meta-competency of scientific thinking. The table shows that Engineering and Health Sciences had higher mean values in the perception of scientific thinking and the macro-competency of complex thinking compared to Social Sciences and Humanities students. Likewise, the standard deviations of Engineering and Health Sciences students were lower both in the macro-competency of complex thinking and in the meta-competency of scientific thinking.

Table 5.

Mean values and standard deviations of the perception of Engineering and Health Sciences and Social Science and Humanities students by scientific thinking and complex thinking.

	Men		Women		Total	
Complex Thinking	Mean	Sd	Mean	Sd	Mean	Sd
Engineering and Health Sciences	4.09	0.40	4.12	0.40	4.10	0.40

Social Sciences and Humanities	3.92	0.50	3.98	0.43	3.95	0.47
Scientific Thinking	Mean	Sd	Mean	Sd	Mean	Sd
Engineering and Health Sciences	4.16	0.39	4.14	0.43	4.15	0.41
Social Sciences and Humanities	3.73	0.62	3.79	0.40	3.76	0.51

In this context, Figure 4 shows the boxplot analysis of the perception of the development of scientific thinking of students in Engineering and Health Sciences and Social Sciences and Humanities. This analysis shows that students in Science and Engineering had high mean values, while Social Sciences and Humanities students attained low mean values.

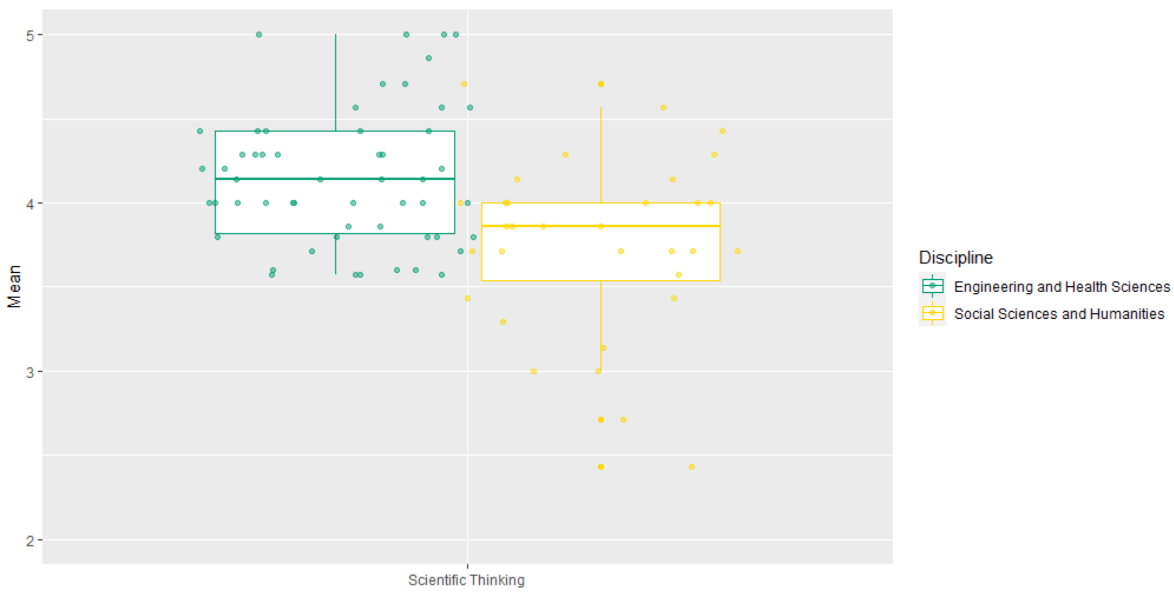

Figure 4. Boxplot Analysis of Scientific thinking: Comparison between Sciences and Engineering and Social Sciences and Humanities.

Table 6 shows the results of the component analysis performed on the perception of the meta-competencies of complex thinking of students in Science and Engineering and Social Sciences and Humanities. The table shows that principal component 1 (PC1) captured 57% of the data variability, while principal component 2 (PC2) captured 17%. That totals 74% of our total variability. Likewise, there is a high correlation between PC1 and innovative thinking. In this sense, PC1 would explain students' perception of the mental process of searching for and discovering original and feasible solutions. On the other hand, the table shows a high correlation between PC2 and scientific thinking. This component would explain students' perception regarding their ability to analyze problems with standardized and validated methods that produce solutions within a framework of arguments and concrete evidence.

Table 6.

Principal Component Analysis Matrix: Complex thinking macro-competency of Engineering and Health Sciences and Social Sciences and Humanities students.

	PC1	PC2	PC3	PC4
Scientific thinking meta-competency	0.50	0.61	-0.20	-0.57
Critical thinking meta-competency	0.46	-0.56	-0.67	0.05
Innovative thinking meta-competency	0.54	0.31	0.17	0.75
Systemic thinking meta-competency	0.48	-0.45	0.68	-0.31
Standard Deviation	1.51	0.82	0.78	0.63
Proportion of Variance	0.57	0.17	0.15	0.11
Cumulative Proportion	0.57	0.74	0.89	1.00

Figure 5 shows the biplot analysis of form ($\alpha = 1$) of the perception of the macro-competency of complex thinking in Engineering and Health Sciences and Social Sciences and Humanities students. This analysis presents students' behavior in their perception while avoiding collinearity problems of the analyzed variables. In the figure, each color-coded dot represents a student according to their discipline.

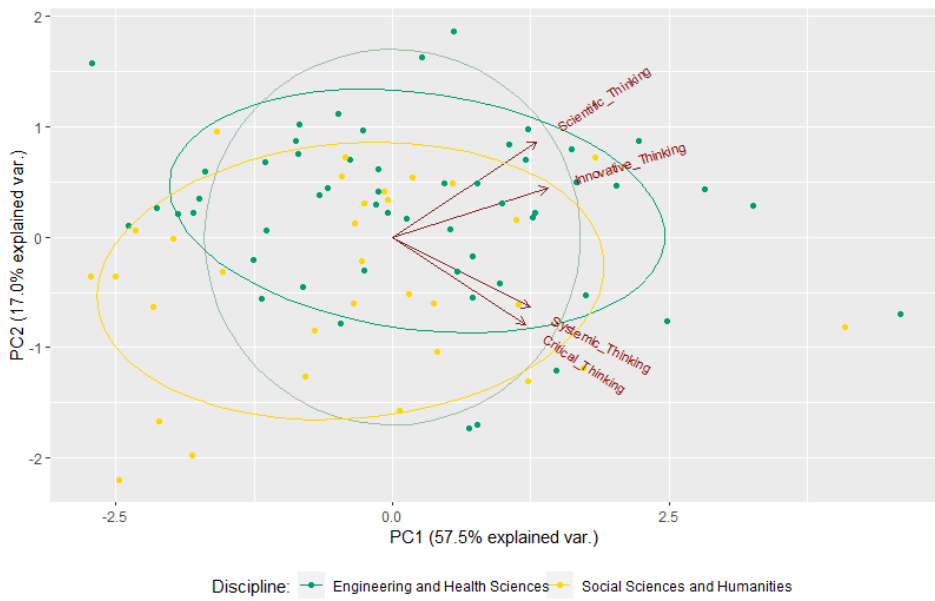

Figure 5. Principal Component BiPlot explaining 74.5% of our data variability. Biplot of form (α = 1).

The results show that Engineering and Health Sciences students perceived themselves much better in the meta-competencies of scientific and innovative thinking. Likewise, Engineering and Science students perceived themselves better in the meta-competencies of systemic thinking and critical thinking. On the other hand, the analysis highlights the low perception of Social Sciences and Humanities students in developing the meta-competency of scientific thinking.

Finally, Table 7 presents the analysis of significant differences between the mean values obtained in the perception of complex thinking macro-competency and each of its meta-competencies among students of Engineering and Health Sciences, and Social Sciences and Humanities. The results indicate that there are significant differences between the two disciplines at the level of complex thinking macro-competency and in the meta-competencies of scientific thinking and systemic thinking.

Table 7.

t-test analysis. Complex thinking macro-competency and meta-competencies among Engineering and Health Sciences, and Social Science and Humanities students.

Engineering and Health Sciences vs Social Sciences and Humanities	**T**	***df***	***p-value***
Critical Thinking	1.7418	71.619	0.08584
Innovative Thinking	1.8972	56.239	0.06295
Scientific Thinking	3.7189	53.918	0.000478
Systemic Thinking	-2.165	71.854	0.03371
Complex Thinking	2.1598	63.155	0.03459

Discussion, Conclusion, and Implications

As part of the results, the first thing analyzed was the global data on the Complex Thinking macro-competency in the Engineering and Health Sciences group. Table 2 shows that the overall result was considerably high since the means of the macro-competency and meta-competencies exceeded 4 in all cases, i.e., the group's perceived performance was high. As for the gender variable women had a higher overall average than men (4.12 vs. 4.09). Even when the results were examined in greater depth, this balance occurred in most of the meta-competencies, the only exception being critical thinking, in which women showed a considerably better perception than men (4.25 vs. 4.10) and attained the highest result of the group. In contrast, the men's score for innovative thinking was the lowest (4.04), although, as noted above, this is still a high level of perception.

Noteworthy in Figure 1 is that the means show disparate results between men and women but balance out when analyzing their standard deviations. An example is critical thinking, where women have a better mean, but their standard deviation tends towards negative responses, or in scientific thinking, where women have a lower mean but present a higher standard deviation towards positive results. Thus, it can be argued that, in these results, gender is not an indicator with a statistically significant impact.

These results are novel in contrast to previous research conducted in engineering groups, where gender was a factor that showed significant differences (Cruz-Sandoval et al., 2023). It should be noted that the aforementioned study considered engineering students only, which could be a differentiating factor with these results that consider students from Health Sciences.

Focusing on the study objective, Table 3 and Figure 2 provide more information on the meta-competency of scientific thinking and how this is perceived by discipline. Although this study was approached in the academic area of Engineering and Health Sciences, we wanted to divide it by discipline since, as discussed in the theoretical framework, the study of sciences can encompass engineering, mathematics, technology, and even health sciences. Considering the range of careers offered by the university where the study was conducted, we divided Engineering Sciences and Health Sciences. In this sense, Table 3 shows that, Health Sciences had the higher mean (4.18) in comparison with the Engineering Sciences students (4.14). Regarding the gender variable, women in Health Sciences had a higher mean (4.23). Figure 2 presents these results graphically by discipline.

This result contrasts with other studies conducted in populations from different disciplines, in which health sciences students tend to show a higher level of perception than their engineering peers (Vázquez-Parra et al., 2022). It is believed that this difference in the results responds to the fact that, unlike previous studies, the population considers only first-year students. This is a relevant point since it opens the possibility of future studies to identify the reason for these changes in perception during the training process.

To address the objective of this study, which is to determine whether students in professions related to Engineering and Health Sciences perceived more developed skills in the meta-competency of scientific thinking compared to their peers in other curricula (i.e., Social Sciences and Humanities), a t-test was conducted to determine significant differences (see Table 7). The results show that there are significant differences at the level of the macro-competency of complex thinking and the meta-competency of scientific thinking. The results indicate that incoming students in Engineering and Health Sciences enter with a higher set of competencies to face the future challenges they will encounter in their university degrees.

These results are in line with previous studies conducted in populations from different disciplines, where there is a better perception by students from scientific areas than from other disciplines, with women showing the best results (Cruz-Sandoval et al., 2022).

To better describe these results, Table 6 and Figure 5 show how the results showed a different trend between the two groups. In this Biplot graph, it is possible to observe a tendency on the part of the Engineering and Health Sciences group toward the meta-competencies of scientific and innovative thinking. In contrast, the Social Sciences and Humanities group tended toward systemic and critical thinking meta-competencies.

Thus, considering all these results, the hypothesis that motivated the present study is viable because sufficient results confirm that incoming students in Engineering and Health Sciences had a better perception of scientific thinking than their peers in other disciplines, providing them with a platform of more relevant skills to meet the challenges involved in their professional careers.

Theoretical and practical implications

These results are especially valuable because they contribute to the study of argumentation and scientific thinking as relevant skills for training in disciplines focused on science and technology. Although there are previous studies that analyze the importance of these competencies, there are few quantitative results that focus on evaluating the way in which students arrive at universities. Thus, the findings presented in this study highlight the relevance of not only seeking a desirable entry profile for the study of this discipline, but also the need to carry out measurements that verify the status of these competencies at the time of entering a scientific career. As a relevant differentiator of this article, the relevance of not only measuring the level of achievement of scientific competencies is highlighted, but also the need to consider the self-perception that students have of their own skills, as this is a valuable point at the time of exercising them in the face of concrete challenges.

In a practical way, the fact that universities can have more information on the situation with which incoming students arrive in terms of skills and competencies associated with scientific disciplines, opens the possibility of proposing more focused training activities and practices, which can have an impact on the curricular designs of the first semesters, with the intention of taking advantage of those students with high levels of achievement and leveling those who come with deficiencies. Additionally, it is important to point out that scientific thinking is a relevant meta-competency for any future professional, so being able to have clarity about the differences between scientific careers and other areas, poses a practical challenge for universities, which implies the need to design efficient tools that allow a balance in the perception of achievement of complex thinking among all students, regardless of their discipline.

Limitations and future lines of research

It is recognized that the present study may be limited by the small size of the population, as well as the lack of a larger comparative study with more disciplines; however, it is considered that, even so, the results are valuable, since they shed light on the importance of assessing competencies and skills as part of the initial orientation and professional selection process of future students. If we associate these results with the entry profile of both disciplines, it is possible to identify trends that favor the needs of their associated careers, as in this case, the preparation of professionals in engineering and health sciences.

It will be relevant to consider new studies that are not only based on the perception of achievement, but that allow contrasting the perception with the level of competency of the students. As noted, perception of ability is seen as having its own benefits; however, it would be an excellent future study if this analysis could be extended to the objective measurement of complex thinking macro-competency. Finally, it is also seen as a possible line of study to extend this analysis to other disciplines.

Conclusions

The purpose of this article was to present the results of an analysis of the skills and competencies with which a group of incoming students arrive, seeking to differentiate between the way in which they self-perceive their level of achievement of the scientific thinking meta-competency. In its hypothesis, the possibility of finding statistically significant differences between incoming students from scientific disciplines and those from social and humanistic areas of knowledge was raised. In conclusion, the hypothesis was proved, demonstrating that there are differences in the level of perception of both groups of students.

These results are not only part of studies related to education, training processes and the development of competencies and skills for life, but also may be valuable for research related to the development of scientific argumentation and engineering and science education. This article is an invitation to pay more attention to the university entrance profile, focusing not only on the level of knowledge with which they arrive from previous educational levels, but also on their experiences and competencies, as well as their perceived ability in skills relevant to their future professional training.

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Data availability

Data available upon reasonable request.

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