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ORIGINAL

Hermeneutical-quantitative model for the analysis of curricular meshes, assisted by artificial intelligence

Modelo hermenéutico-cuantitativo para el análisis de mallas curriculares, asistido por inteligencia artificial

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ABSTRACT

A model that combines quantitative methods with hermeneutical analysis is presented to investigate how the courses of the curriculum of the bachelor's degree in mathematics teaching and learning are related and organized. AI is used to transcribe and classify large volumes of data using semantic networks, centrality measures, and hierarchical groupings. The results indicate that the courses Neurosciences and Education, Cognitive Processes and Didactics of Mathematics in Basic Education function as bridge courses; likewise, the Mathematical-Disciplinary, Pedagogical-Humanistic and Epistemic-Reflective axes show solid internal links, but little interconnection between them. The study suggests a strengthening of bridging courses and reduction of thematic redundancies through the progression and territorialization of learning. From a hermeneutical approach, it is proposed that the balance in curricular content comes from logical dialogue and interpretation, not only technical, but also contextualized. The model shows that AI can enhance the critical understanding of the curricular framework without replacing the presence of the teacher as the subject responsible for interpretation.

Keywords: artificial intelligence; semantic networks; mathematical curriculum; Hermeneutic analysis.

RESUMEN

Se presenta un modelo que combina métodos cuantitativos con análisis hermenéutico para investigar cómo se relacionan y se organizan los cursos del plan de estudios de la licenciatura en enseñanza y aprendizaje de las matemáticas. Se utiliza la IA para transcribir y clasificar grandes volúmenes de datos mediante redes semánticas, medidas de centralidad y agrupamientos jerárquicos. Los resultados indican que los cursos Neurociencias y educación, Procesos cognitivos y Didáctica de las matemáticas en educación básica funcionan como cursos puente; asimismo, los ejes Matemático-Disciplinar, Pedagógico-Humanista y Epistémico-Reflexivo evidencian sólidos vínculos internos, pero poca interconexión entre sí. El estudio sugiere un fortalecimiento de los cursos puente y reducción de las redundancias temáticas mediante la progresión y la territorialización del aprendizaje. Desde un enfoque hermenéutico se plantea que el equilibrio en los contenidos curriculares proviene del diálogo lógico y de la interpretación no solo técnica, también contextualizada. El modelo demuestra que la IA puede potenciar la comprensión crítica del entramado curricular sin sustituir la presencia del docente como sujeto responsable de la interpretación.

Palabras clave: Inteligencia artificial; redes semánticas; currículo matemático; análisis hermenéutico.

INTRODUCTION

A primordial component in good educational practices is critical curriculum analysis; however, this analysis must begin from the territorialized knowledge of reality, that reality that includes us and modifies us. This is relevant in that it allows for a curriculum evaluation and, mainly, a continuous improvement of plans and programs. The model proposed here contributes to educational innovation through the critical use of emerging technologies from a pedagogical perspective, distancing itself from the use of artificial intelligence (AI) as an end in itself, and rather as a facilitator or assistant that amplifies and improves the analytical capacity of any education professional whose interest lies in thoroughly understanding the components of the curriculum and their interrelation.

The curriculum used to be a "black box" in which teaching staff were told what to do, what to teach, and how to teach it, making them subject to reprimands and labor sanctions if they did not comply with certain competency-based approaches, aimed at producing a person who existed for work, positioning the student as a pauper bearer of isolated capacity, as Dussel mentions (1985, p.22), and the teacher as that pauper post festum whose sole purpose is work and reproducibility (Dussel, 1985, p.473). However, since the implementation of the new educational policies that emerged in 2018 with the capabilities approach, it was possible to transform that box into a rhizome that placed in its nodes brave female and male teachers who decided to take one step forward and change education in Mexico, sometimes at the cost of attacks and labor consequences, arising from instituted schools that do not recognize the instituting.

In this Kafkaesque metamorphosis, in which educational policies shift from "black box" to "rhizome", where new questions, needs, and responsibilities arise, since, by positioning the teacher as an active agent of social change and empowering him over things – never over individuals –, we are given the opportunity to desire other possible realities.

It is in desire that new educational modes are born, which, being nascent, have the responsibility of being coherent and having solid arguments. The systematic analysis of the curriculum allows us to argue which subjects serve as a bridge, which subjects have a probable redundancy and, mainly, which subjects to propose to achieve territorialized learning. This last assertion is – in the opinion of the present author – the most important, since it positions the education professional as an agent of social change, of the very reality to which they belong.

It is in the positioning of the teacher as one subject within the reading of reality where the ethical development of curricula and programs is glimpsed. This depends on a critical analysis that is argued and promotes educational innovation. Therefore, in the present study, AI is used as a device that helps analyze large volumes of data. But no more than that, since the responsibility of reading the curricula and programs and absorbing the feelings of the teaching and student community falls on that educational professional who makes use of the model. The above is coupled with a meticulous review of the results obtained and their epistemic congruence.

Having clarified the previous points, we can now proceed to the evolution of the model as a narrative:

In 2023, the hermeneutic-quantitative model (Salazar, 2025) was proposed, which, through three main steps summarized in hermeneutic analysis, correlation matrix, and dendrogram of Euclidean distances, was used to analyze the curriculum of the bachelor's degree in biology. However, this model required countless person-hours in the manual transcription of each of the components of more than 40 programs from only a curriculum among the several curricular structures. Therefore, the use of AI stems from a real and contemporary need to transcribe large volumes of information.

It is here, dear colleague, that the current model is presented as a viable option to support the differences and repetitions of the contents of the programs of the curricular grids, and thus to discern those intricate relationships that exist between each program and that reflect the reality of the people who created them.

Background

The effort to unite methodologies to overcome the purist paradigms in which the aim is to be faithful to only a method (qualitative or quantitative) began to gain prominence in the 90s. Uniting both antagonistic methods broadens the research landscape. As Teddlie and Tashakkori (2010) mention, mixed methods evoke the strengthening of the results.

To make explicit the hermeneutic part of the model, we take the definition of Gadamer (2004):

"Understanding is not a subjective act of the individual, but participation in a living tradition, a dialogue between the present and the past in which both are transformed" (p. 311).

This approach positions us within the living word and removes us from that logical dialogue of knowledge that Jonathan Swift masterfully exemplifies in his book Gulliver's Travels by establishing a metachronological dialogue between the main character and the deceased Aristotle:

"Aristotle appeared with a modest bearing and a calm spirit, surprised to see what his doctrines had become after so many centuries of glosses and disputes" (Jonathan Swift, Los viajes de Gulliver, Parte III, Capítulo VIII).

With the above, we approach this dialogical dialogue with the authors, whether current or previous, contrasting ideas, seeking resonances and assonances. For this reason, the quantitative hermeneutic model carried out using hermeneutic methods and Euclidean distances (Salazar, 2025) is taken as a reference, and we seek to streamline the analysis through AI, to subsequently compare the results obtained; likewise, the definition of model from the same article is used, which consists of "a simplified representation of the reality of the person as part of a community, which is given meaning from a real problem and in this case allows us to delve into the microcosm of curricular complexity".

STATE OF THE ART

There are recent curricular studies, such as that by Barba et al. (2021), in which a university-level curriculum is analyzed using networks, managing to identify central and disciplinary courses. Likewise, in the study by Cho and Kim (2021), network analysis is used to reveal interdisciplinary relationships, concluding how modules act as bridge nodes between fields of knowledge, and finally, Ma et al. (2025), using network analysis methods, find weaknesses in the curricular structure and propose strategies to improve it.

Regarding curricular studies, such as that by Gómez (2002, pp. 268-279), which takes as its basis phenomenological analysis and models, combining cognitive analysis and analysis of instructions, taking as axes the cultural/conceptual, cognitive/developmental, ethical/formative, and social dimensions. The aforementioned article shows a high influence of the social part. However, it starts from an already created curriculum and the adjustments that can be made are a posteriori by the teacher in the classroom. This differentiates it from the current work in that the present model can be carried out throughout the entire curricular creative process.

General Objective

Analyze the complexity of the curriculum (internal coherence and articulation) of the degree program in Mathematics Teaching and Learning, using a hermeneutic-quantitative model assisted by AI that integrates network analysis methods, centrality, and hierarchical clustering, with the aim of identifying bridge nodes, gaps, and redundancies among the Mathematical-Disciplinary, Pedagogical-Humanistic, and Epistemic-Reflexive axes, in order to propose territorialized adjustments and improvements.

Specific objectives

1. Descriptive objective: To encode (OCR) and classify the topics and skills in the courses of the curriculum of the bachelor's degree in mathematics, and to examine how they relate to the three main axes: epistemic-reflexive, pedagogical-humanistic, and mathematical-disciplinary.

2. Quantitative objective: To apply semantic network analysis techniques and centrality measures (degree, betweenness, closeness, and structural density) assisted by artificial intelligence, to recognize the internal structure of the courses and detect the bridge nodes that unite them through the features and domains of the graduate profile.

3. Interpretive objective: To establish a logical and dialogical dialogue to interpret the quantitative results from a hermeneutic perspective, promoting a critical approach between the data, the theory, and the social and educational context, to formulate proposals for curricular adjustment that strengthen the internal coherence (transversality) and external coherence (territoriality) of the curriculum of the bachelor's degree in mathematics and, therefore, the teacher-becoming of the same.

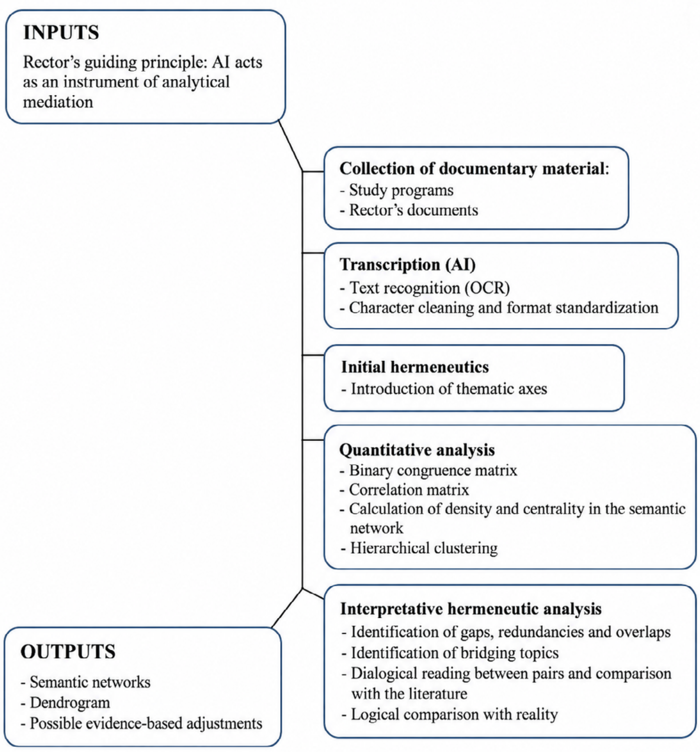
METHODS

The present work is based on a socio-critical paradigm, with a mixed methodology that involves the entire population, which gives it the characteristics of one deterministic study. ChatGPT 5 was used for transcription (OCR), quantitative analysis, and semantic networks. Next, this methodology will be explained:

Methodological Flow

Below, the scheme of the methodological flow of the model is presented, with the inputs and outputs (Figure 1).

Figure 1. Methodological flow of the quantitative hermeneutic model



Checklist

A checklist is provided to facilitate systematization. 10 points are proposed based on the complexity of the model:

Table 1. Checklist for the systematization of the hermeneutic-quantitative model

Stage	Task
Collect the documentary material.	Gather all necessary governing documents.
Digitization and cleaning.	Apply character recognition (OCR).
Initial coding.	Categorize the textual units according to the thematic axes (epistemic, ethical, and mathematical).
Binary congruence matrix.	Generation of the binary congruence matrix and the correlation matrix.
Semantic analysis.	Density and degree centrality.
Hierarchical clustering.	Euclidean distances for detecting affinities.
Calculate the error.	Calculate the structural density error of the network to measure how far the network is from being completely connected:
Interpretive hermeneutic analysis.	To contrast the results in a logical dialogue of knowledge with the literature.
Validation process.	Peer review.
Final report	Reasoned and territorialized modifications that reflect reality.
Transformation of reality.	Let us imagine a transformative reality and ask for clarifications.

Mathematical methodology

The following equations were used to calculate the distances between nodes, to identify how connected the nodes are and which are the most influential nodes:

The equation was used for the calculation of the density of the semantic network, which measures the general degree of connection of the network:

$$D = \frac{2E}{N(N-1)}$$ (Newman, 2010)

Where E is the number of existing links (course and domain relationships), N is the total number of nodes (courses, axes, domains). If the resulting value approaches 1, it indicates a very dense network with high integration among nodes; if the value approaches 0, it is a sparse network with fragmentation.

The degree centrality calculation equation was used to establish which nodes are the most influential within the semantic network:

$$C_D(v) = \frac{\deg(v)}{N-1}$$ (Freeman, 1978)

Where deg(v) is the number of links or direct connections that node v has within the network, N is the total number of nodes (courses, axes, domains) and N-1 is the maximum number of links that a node could have if it were connected to all the others.

Betweenness centrality indicates which nodes function as conceptual bridges; it is given by the following equation:

$$C_B(v) = \sum_{s \neq v \neq t} \frac{\sigma_{st}/v)}{\sigma_{st}}$$ (Freeman, 1978)

Where s and t are pairs of distinct nodes, σst is the number of possible shortest paths from node s to node t, and σst(v) is the number of times node v acts as an intermediary in the communication between other nodes. The sum ∑s≠v≠t spans all pairs s and t to evaluate how many times node v serves as an intermediate step in such connections. The resulting values carry greater weight as they approach 1.

The equation for calculating closeness centrality was also used to establish how close a node is to the rest of the network (the shortest possible distance):

$$C_c(v) = \frac{N-1}{\sum_{u} d(v,u)}$$ (Freeman, 1978)

Where N is the total number of nodes, d(v,u) is the length of the shortest path connecting node v with node u, and ∑u denotes the summation of all distances from v to every other node.

Error calculation

Because this is not an inferential study but a descriptive deterministic one (non-sampling), there is no classic error. However, for comparative purposes, the structural density error of the network can be calculated, which measures how far the network is from being fully connected:

$$E_D = 1 - D$$ (Freeman, 1978)

Where:

$$D = \frac{2E}{N(N-1)}$$

Where D is equal to the density of the semantic network.

RESULTS

The results of the analysis are presented below, following the guidelines previously described in the model and the formulas from the methodology section.

Semantic network density

The calculation yielded a result of 0.10, indicating a moderately connected network; that is, there are solid groupings within each axis, but cross-links are limited, which underscores the importance of bridge courses to strengthen this density.

Degree centrality

To understand the level of connection between the nodes (axes or domains), Table 2 shows the direct links of each node. Both the mathematical-disciplinary axis and the bridge course Neuroscience and Education have the highest degree.

Betweenness centrality

The calculation yielded the highest values for the bridge courses Neuroscience and Education (0.5-0.6), Didactics of Mathematics in Basic Education (0.45-0.55), and Cognitive Processes (0.55-0.65). In contrast, disciplinary courses such as Integral Calculus and theoretical courses such as Philosophy of Education had low values (less than 0.25), indicating specialization rather than integration.

Table 2. Degree centrality, showing the values for each axis and the bridge courses.

Nodo	Centralidad de grado
Matemático-disciplinar	0.65
Pedagógico-humanista	0.60
Epistémico-reflexivo	0.55
Neurociencias y educación	0.35
Procesos cognitivos	0.33
Didáctica de las matemáticas en educación básica	0.30

Closeness centrality

This analysis corroborates what was mentioned above; for example, the "Mathematical-disciplinary" axis is directly connected with other courses (0.75); however, the course Integral Calculus (0.25) is connected only with its axis.

Semantic network

Using the data from the previous equations, the semantic network was constructed to graphically summarize the results of the previous analyses and facilitate their interpretation. In the semantic network, the three axes (largest nodes) are shown in orange, the bridge nodes (Neuroscience and Education, Didactics of Mathematics in Basic Education, Cognitive Processes) in red, and the peripheral courses (Integral Calculus, Philosophy of Education, etc.) in blue (Figure 2).

To facilitate visualization, a geometric approach was applied to the nodes with the highest weight (Figure 3).

Dendrogram by Euclidean distances

The dendrogram represents the following:

a) The geometric distance between courses allows grouping them into the 3 axes: Mathematical-disciplinary, pedagogical-humanistic, and epistemic-reflexive (Figure 4).

b) It highlights the bridge courses, ensuring their integration and avoiding theoretical, practical, and research fragmentation (Figure 4).

Structural density error of the network

The structural density error is 90%, indicating that the network is far from being totally interconnected. This reflects good dispersion, since not all courses belong to the same axes, and it highlights the complexity of the conceptual networks.

Figure 2. Semantic network showing the three axes (largest nodes) in orange, the bridge nodes (Neuroscience and Education, Didactics of Mathematics in Basic Education, Cognitive Processes) in red, and the peripheral courses (Integral Calculus, Philosophy of Education, etc.) in blue.

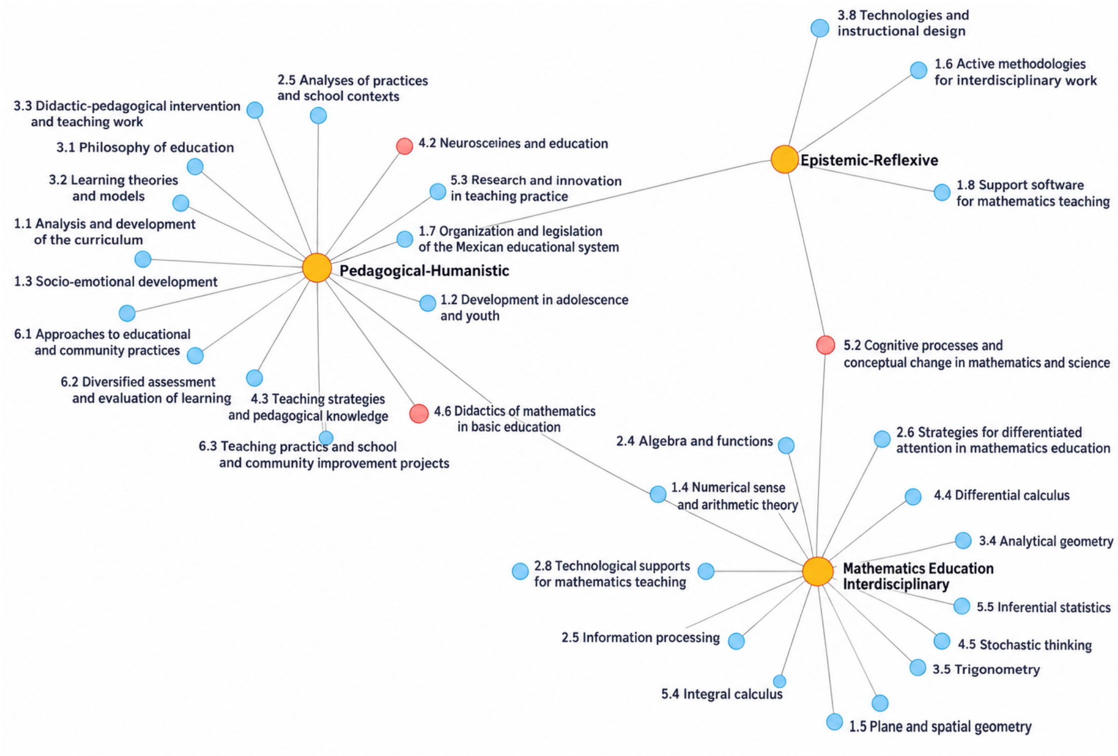


Figure 3. Geometric approach to the semantic network showing the 3 axes (largest nodes) in orange, the bridge nodes (Neuroscience and Education, Didactics of Mathematics in Basic Education, Cognitive Processes) in red, and the peripheral courses (Integral Calculus, Philosophy of Education, etc.) in blue.

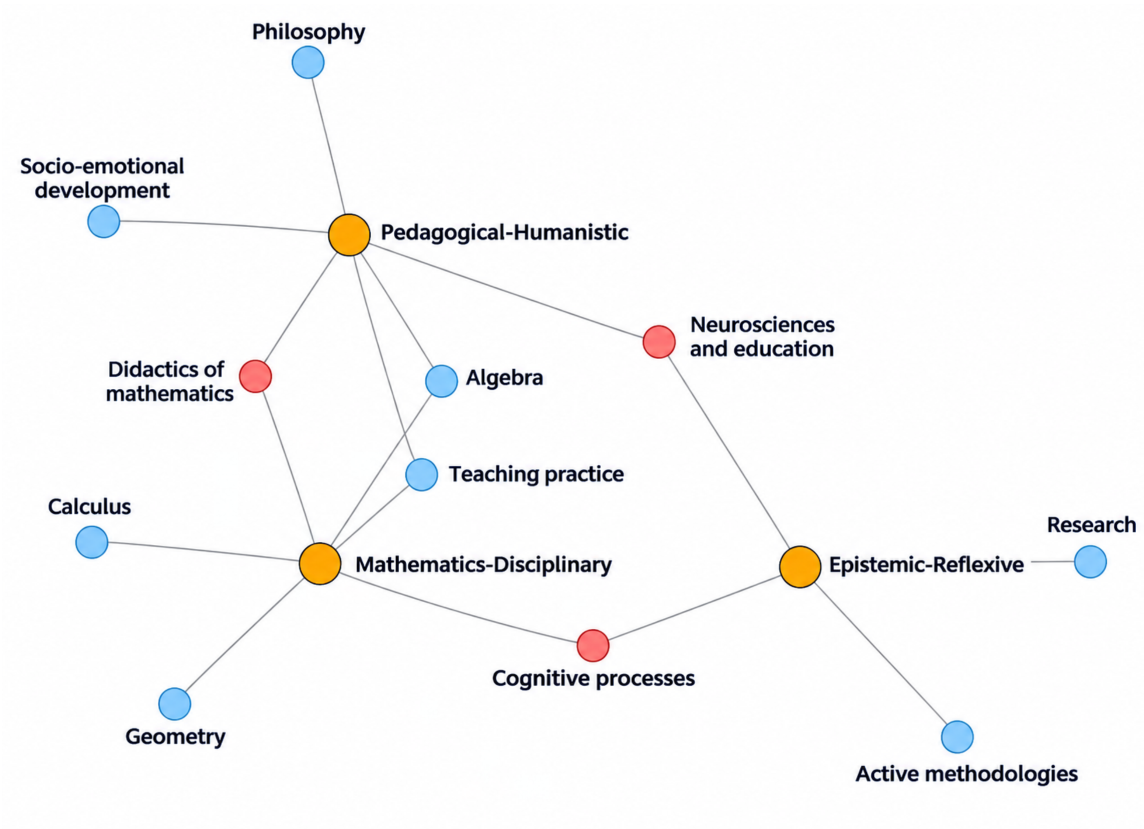
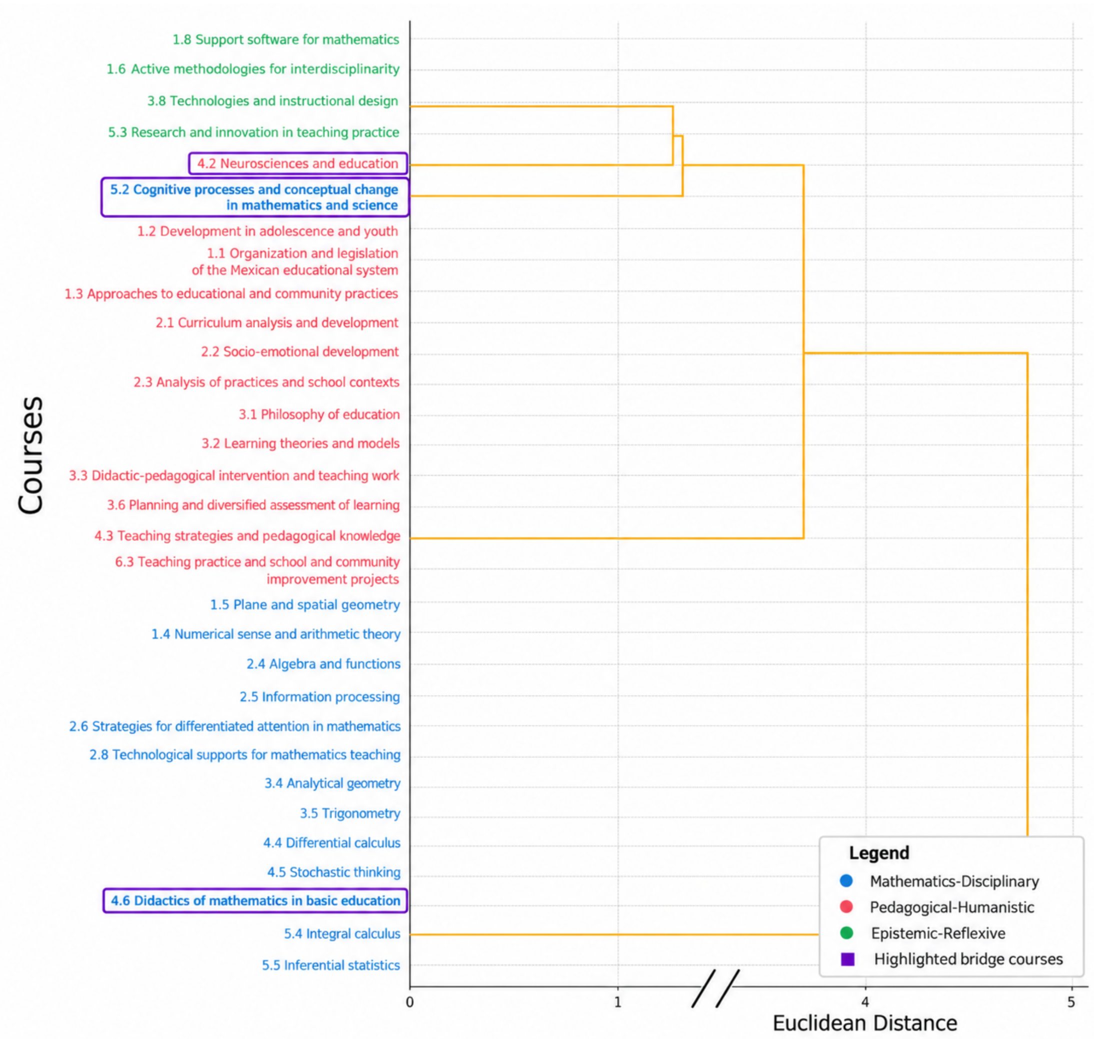


Figure 4. Dendrogram of Euclidean distances, showing the clustering of the courses on the 3 axes and the bridge courses.



DISCUSSION

Regarding the structure and density of the network, the results found (0.1) correspond to those reported by Barba et al. (2021) of 0.15-0.20, to those of Cho and Kim (2021) of 0.08 and 0.12, and to those of Ma et al. (2025) of 0.18, thereby coinciding with the observation of a dispersed structure, which evidences the difficulty of interdisciplinary articulation; however, the hermeneutic approach of the present hermeneutic-quantitative model reflects an "epistemic conflict" rather than a technical failure. However, having low connections indicates that the mesh, analyzed in the present research work, presents strong connections within each axis, but weak ones between them; that is, there is fragmentation, which indicates a lack of dialogic–epistemic communication between the axes; for example, courses of a philosophical or ethical nature are not explicitly linked with those of a mathematical disciplinary nature. Likewise, the initial courses do not logically dialogue with the final courses, lacking a line of flight that unites learning throughout the semesters, beyond the technical or institutional part.

Following the same line regarding structural redundancies, it is observed that some courses of the Pedagogical-Humanistic axis present high lexical concurrence (for example, Cognitive Processes, Human Development). However, they have very little functional differentiation, which generates conceptual redundancy or overlapping of discourses rather than a progression in learning.

Regarding bridge courses or bridge nodes: Barba et al. (2021) find courses such as Linear Algebra and Mathematical Analysis; Cho and Kim (2021) identify the courses Scientific Communication and Sustainable Design. Ma et al. (2025) find courses such as Project Engineering and Quality Management. The above leads us to agree that these courses are nodes with high betweenness;

however, in the present study the bridge courses are pedagogical and cognitive, not only disciplinary, which reinforces the epistemic-reflexive component of the model.

Regarding the interpretive part of the model from a hermeneutic perspective, Barba et al. (2021) propose reorganizing the core and peripheral subjects to improve the curriculum from a technical-structural viewpoint; Cho and Kim (2021) suggest the formation of interdisciplinary projects for collaboration among the different areas, from an interinstitutional perspective, and Ma et al. (2025) propose eliminating redundancies from a management perspective. Recall that the present study takes a capabilities approach, unlike the competencies approach; therefore, to maintain epistemic congruence, the hermeneutic-quantitative model moves away from interpreting texts only as a graph and moves toward an interpretation as both a graph and a cultural text. There is agreement with the others in improving the connections between courses, but a critical and territorialized reading is added to the curricular articulation, consistent with Gadamer and the sociocritical approach.

CONCLUSIONS

Regarding the general objective of analyzing the structure, internal coherence, and articulation of the curriculum of the Bachelor's Degree in the Teaching and Learning of Mathematics using the hermeneutic-quantitative model, the combination of network analysis, centrality measures, and hermeneutic reading enabled the identification of bridge courses (bridge nodes), thematic gaps, and structural redundancies, which allows the curriculum to be observed as a system of interconnected knowledge.

A precise characterization of the domains and performances was achieved through the coding of the governing documents, which evidenced that each axis has a clearly defined semantic identity; however, this limits the interconnections between them.

The internal structure of the curriculum was quantified, obtaining low interconnection consistent with similar studies; the degree measures identified bridge courses such as Didactics of mathematics in basic education, Cognitive processes and Neurosciences and education, which act as mediators.

The structural density error is at 90% of being fully interconnected, which indicates adequate dispersion, since not all courses have the same axes and, therefore, describes the same nature of complex conceptual networks.

Regarding the hermeneutic interpretation of the results, thematic gaps are identified not only as absences, but as a lack of shared meaning among the knowledge of the contents. Redundancies are not technical failures, but representations of discursive dispersion without progression in learning, which leads us to a curricular network that requires mediations between courses to balance the epistemological, the pedagogical, and the disciplinary.

In conclusion, it is proposed to strengthen and add more bridge courses as integration spaces together with transversal courses, reduce redundancies by promoting progressions in learning, and create transversal projects that foster articulation between courses.

Finally, the balance or imbalance of the curriculum is given by hermeneutics, reflection through the socialization of results, dialogic dialogue, logical dialogue, and the territorialization of knowledge. The above leads us to the importance of curricular flexibility subjects that each academic body or knowledge community must propose per state.

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