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Between the Epistemic and the Affective: Mapping Didactic Suitability in Mathematics Education from a Territorial Perspective

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ABSTRACT

This article examines the perceived development of didactic suitability among in-service mathematics teachers in Panama, drawing on the Onto-Semiotic Approach to Mathematical Knowledge and Instruction (OSA; Spanish: Enfoque Ontosemiótico, OSA). Using a mixed-methods, interpretative design, we integrate a post-training self-assessment survey (five-point Likert scale) with territorial participation metadata from the national EDEM program (2017–2022). The sample comprises 420 in-service teachers from all ten provinces and three indigenous comarcas. Visual analytics—radar charts, violin plots, boxplots, and time-series/heat maps—were used to map variability across the six interrelated dimensions of didactic suitability: epistemic, cognitive, interactional, affective, ecological, and mediational. Mean perceived growth was highest in the epistemic and affective dimensions, while greater dispersion appeared in the ecological and mediational dimensions, particularly in underserved regions. The expanded discussion interprets these patterns vis-à-vis didactic suitability didactic suitability criteria and place-responsive teacher education, highlighting tensions between centralized policies and local constraints. Implications include strengthening context-sensitive resource ecologies, scaffolding dialogic classroom practices, and prioritizing territorial targeting for equity. Methodological transparency is enhanced by detailing the instrument, sampling frame, visualization pipeline, and ethics safeguards. This paper presents the first nationwide, OSA-aligned territorial map of teachers' didactic suitability in Panama, operationalizes the six OSA dimensions with a reproducible instrument and visual analytics, and provides policy-ready indicators to monitor teacher development and steer equity-oriented e-learning and professional learning that balances conceptual rigor with affect, mediation, and context.

Keywords: Didactic Suitability, Mathematics Teacher Education, Affective Dimension, Epistemic Knowledge, Territorial Equity, Professional Development

INTRODUCTION

In contemporary mathematics education, it has become increasingly necessary to interpret teaching and learning processes through complex theoretical frameworks that move beyond merely instrumental or behaviorist approaches. Understanding the classroom as a sociocultural, cognitive, and emotional space has led to the development of comprehensive models that allow for a situated analysis of teaching practices and their impact. In this regard, the Onto-semiotic Approach to Mathematical Knowledge and Instruction (OSA), developed by Godino and collaborators, offers a robust theoretical framework that conceptualizes mathematical activity as an institutionalized, culturally mediated, and historically situated practice (Godino, Batanero & Font, 2007; Godino, 2009).

A cornerstone of the OSA is the concept of didactic suitability, defined as the degree of adequacy of a teaching and learning process in relation to a set of didactic suitability criteria that assess its coherence, effectiveness, and contextual relevance. This construct is operationalized through six interrelated dimensions: epistemic, cognitive, interactional, affective, ecological, and mediational (Godino, 2011). Each dimension sheds light on a specific facet of educational activity. For instance, the epistemic dimension evaluates the quality and pertinence of the mathematical content; the cognitive dimension assesses its accessibility to learners; and the affective dimension examines emotions, attitudes, and beliefs involved in the learning process (Pino-Fan, Font & Breda, 2017).

This theoretical model has been further developed in various studies that converge on the necessity of adopting a more comprehensive approach—one that understands pedagogical decisions not as isolated acts, but as interpretive and value-laden processes embedded in context (Sánchez Aguilar, 2022; Espinoza Vargas & Rico, 2022). Of particular importance in recent years is the affective dimension, not only due to its influence on classroom climate, but also because it directly affects both teachers' and students' willingness to engage with mathematical tasks. Epistemological beliefs, math anxiety, and motivation are among the affective factors shown by the literature to significantly influence teaching quality (Parra Salcedo, 2021; Sánchez Aguilar, 2022).

Likewise, recent studies have begun to address didactic suitability from a territorial perspective, acknowledging that the where of teaching matters just as much as the what and how. Territory—as a social, cultural, and symbolic construct—shapes both the expectations surrounding learning and the resources available, as well as the forms of interaction that take place in classrooms. Latin American research has highlighted the tension between centralized teacher training policies and the diverse contextual realities of schools, advocating for more locally responsive and context-sensitive education policies (Gómez-Flores, Méndez-López & Ortiz-Navarro, 2023; Rico & Lupiáñez, 2008).

Accordingly, teacher professional development, particularly in mathematics, must not only aim to enhance disciplinary knowledge but also foster the capacity to make pedagogically sound decisions in specific socio-territorial contexts. This requires not only epistemic expertise but also attentiveness to affective and ecological dimensions, which are often neglected in conventional training models. A situated understanding of the didactic process, as proposed by the OSA, demands the integration of technical, epistemological, and human elements to support more equitable, reflective, and culturally relevant educational practices (Font, Godino & Gallardo, 2013).

From this standpoint, the present article aims to contribute to the theoretical discussion on didactic suitability in mathematics education by emphasizing the articulation between epistemic and affective dimensions, while underscoring the role of territorial context. This articulation reflects recent scholarship that stresses the mutual influence between conceptual understanding and emotional engagement in mathematics classrooms (Sánchez Aguilar, 2022; Parra Salcedo, 2021; Hannula et al., 2004; McLeod, 1989). Likewise, the emphasis on territorial context aligns with research highlighting the importance of place-based teacher education and locally responsive pedagogies (Gómez-Flores, Méndez-López, & Ortiz-Navarro, 2023; Rico & Lupiáñez, 2008). Additional contributions from the Onto-semiotic Approach underline the necessity of interpreting didactic actions as situated and meaning-driven (Font, Godino, & Gallardo, 2013; Godino, 2011), while other studies reaffirm that integrating affective and epistemological dimensions is crucial for equitable, motivating, and culturally relevant mathematics instruction (Espinoza Vargas & Rico, 2022; Leder & Forgasz, 2006; Zan et al., 2006). By bringing these elements together, the work seeks to enrich the understanding of mathematics teaching and learning processes and to generate more just and context-aware didactic suitability criteria for public policy, teacher education, and curriculum design.

THEORETICAL FRAMEWORK

The analysis of mathematics teaching from a didactic perspective necessitates the adoption of comprehensive and context-sensitive models that go beyond linear or fragmented understandings of the instructional process. In

this regard, the Onto-semiotic Approach to Mathematical Knowledge and Instruction (OSA), developed by Godino and collaborators (Godino, Batanero & Font, 2007; Godino, 2009), provides a robust epistemological and methodological foundation. The OSA is grounded in the assumption that mathematical activity, whether in academic, educational, or applied settings—is a human and institutionalized practice that involves systems of signs, social norms, tools, and intentions.

Central to the OSA is the notion of didactic suitability, which refers to the degree to which a teaching and learning process aligns with a set of quality indicators defined through theoretical and educational lenses. Didactic suitability is not reduced to academic performance or efficiency; rather, it is a multidimensional construct aimed at evaluating the internal coherence and contextual relevance of instructional processes (Godino, 2011; Font, Godino & Gallardo, 2013). These dimensions are interrelated and should be interpreted as facets of a single complex system, not as isolated indicators.

The epistemic dimension assesses the relevance, richness, and coherence of the mathematical content being taught in relation to the curricular goals and the disciplinary structure of mathematics. It considers whether the mathematical objects mobilized during instruction reflect rigorous and meaningful content (Pino-Fan, Font & Breda, 2017). The cognitive dimension examines the compatibility between the cognitive demands of the task and the developmental characteristics of the learners. It addresses the alignment between students' prior knowledge and the learning opportunities provided by the instructional design.

The interactional dimension focuses on the forms of communication, discourse, and participation established in the classroom. It considers the type of interactions (e.g., dialogic, monologic, cooperative) and how these facilitate or hinder the joint construction of mathematical meaning. The affective dimension, gaining increasing relevance in recent literature, refers to emotions, beliefs, attitudes, and motivations that influence both teachers' and students' relationships with mathematics. As noted by Sánchez Aguilar (2022), affective factors such as math anxiety, self-efficacy, and emotional climate significantly affect didactic decisions and learning outcomes.

In turn, the ecological dimension emphasizes the contextual adequacy of teaching practices, taking into account cultural, institutional, and community-based realities. Teaching mathematics in rural areas, indigenous communities, or urban peripheries presents unique challenges and possibilities that must be recognized and valued in any pedagogical analysis (Gómez-Flores, Méndez-López & Ortiz-Navarro, 2023; Rico & Lupiáñez, 2008). Finally, the mediational dimension considers the use and functionality of tools, artifacts, and technological resources. It includes physical manipulatives, digital platforms, visual representations, and other symbolic systems used to support mathematical reasoning and learning.

This six-dimensional model facilitates a holistic and critical understanding of the teaching and learning process. It encourages educators and researchers to examine how instructional decisions resonate with educational goals, student needs, and sociocultural contexts. Moreover, it opens the possibility of conducting didactic analyses that are not only diagnostic but also transformative, by identifying strengths and areas for development within teaching practices (Espinoza Vargas & Rico, 2022). Recent studies reinforce this interpretative potential by showing how didactic suitability criteria such as epistemic, mediational, and affective dimensions can guide reflection on unit planning and teacher argumentation (Calle et al., 2024; Campuzano et al., 2024; Campo-Meneses et al., 2024).

Therefore, the OSA and its framework of didactic suitability serve as a powerful theoretical lens through which to understand and improve mathematics education. By integrating epistemological, cognitive, affective, and ecological considerations, the approach transcends reductionist evaluations and moves toward a vision of teaching as a situated, reflective, and humanized practice. Recent contributions have expanded this model's explanatory power, highlighting its application in diverse teaching contexts and its relevance in evaluating digital creativity, emotional engagement, and context-sensitive instruction among preservice and in-service teachers (Carvajal et al., 2024; D'Amore, 2024; Sol, Ledezma & Breda, 2024).

METHODOLOGY

This study adopts a descriptive and interpretative design grounded in the Onto-semiotic Approach to Mathematical Knowledge and Instruction (OSA) and the multidimensional construct of didactic suitability (Godino et al., 2007; Godino, 2011). Its objective is to examine the perceived development of mathematics teachers across the six dimensions of didactic suitability—epistemic, cognitive, interactional, affective, ecological, and mediational—emphasizing the articulation between epistemic content and affective engagement, while considering the territorial diversity of the Panamanian context. The methodology was constructed to enable qualitative-dominant interpretation supported by quantitative visualizations that reflect the complexity of teacher learning processes.

An in-service post-training self-assessment questionnaire aligned with the six didactic-suitability criteria of the Onto-Semiotic Approach (OSA)—epistemic, cognitive, interactional, affective, ecological, and mediational—was administered on a 1–5 Likert scale. The sample comprised n = 420 in-service mathematics teachers (primary and

secondary) who completed EDEM between 2017 and 2022, with participation from Panama's 10 provinces (Panamá, Panamá Oeste, Colón, Coclé, Herrera, Los Santos, Veraguas, Chiriquí, Bocas del Toro, and Darién) and three indigenous comarcas (Guna Yala, Ngäbe-Buglé, and Emberá-Wounaan); in 2020, cohorts operated in hybrid/online mode. Data quality was ensured via listwise deletion when missingness was <5% and by anonymization/aggregation at the provincial level. The analysis combined descriptive statistics and visual analytics (radar charts, violin plots, boxplots, time series, and heat maps, 2017–2022) to characterize territorial variation. The instrument's internal consistency was $\alpha = 0.89$ (good), estimated with Cronbach's alpha; additional alphas were computed for each OSA dimension. Content validity was supported by explicit alignment with OSA criteria and expert review; analysis scripts are available upon request. Human participation received ethical approval from the University of Panama Bioethics Committee in initial phases (CBUP/298/2019; CBUP/279/2021; CBUP/448/2021) and, subsequently—owing to a conflict of interest in the Mathematics academic area—oversight was transferred to CBI–USantander (M–087–2025), with no new interventions conducted prior to its resolution.

The data analyzed come from 420 in-service mathematics teachers who participated in the national training program Estrategias Didácticas para la Enseñanza de la Matemática (EDEM) between 2017 and 2022. The program was implemented by academic institutions in collaboration with the Ministry of Education of Panama, and it aimed to strengthen teaching competencies with an emphasis on didactic reflection, situated practice, and curricular innovation. Teachers from all ten provinces—Panamá, Panamá Oeste, Colón, Coclé, Herrera, Los Santos, Veraguas, Chiriquí, Bocas del Toro, and Darién—were included, as well as participants from the indigenous comarcas of Guna Yala, Ngäbe-Buglé, and Emberá-Wounaan. This national representation ensures a broad territorial lens through which results may be analyzed.

Participants taught primarily at the primary and lower secondary levels in public and semi-public schools, with teaching experience ranging from 5 to over 20 years. Approximately 65% of the teachers identified as women, reflecting the gender composition of the national teaching force. Most had not previously been exposed to structured didactic frameworks like the OSA, which made the EDEM experience foundational in developing a common language for reflecting on mathematics teaching. The training included theoretical modules, practice-oriented workshops, and classroom-based implementation projects.

At the end of the training cycle, participants completed a self-assessment survey based on the six dimensions of didactic suitability. The instrument employed a five-point Likert scale and was adapted from the indicators developed by Godino (2011), validated through expert review by mathematics educators. Each dimension was evaluated through reflective prompts that encouraged participants to consider both their pedagogical decisions and their context-specific challenges and achievements.

For analysis, descriptive statistics were calculated to examine central tendencies and variability in perceived competence across each dimension. The data were then visualized using violin plots to capture the distributional density of responses, and a radar chart was constructed to synthesize the average perceived performance per dimension. These graphical tools allowed for a comparative and integrative understanding of teachers' development, making visible the relationships between dimensions such as epistemic and affective, and revealing areas with greater dispersion—such as the ecological and interactional dimensions—where further support might be necessary.

Finally, data were disaggregated by province to explore patterns linked to geographic and institutional diversity. The visual and statistical results informed a critical reflection on how professional development initiatives like EDEM can contribute to a more equitable and contextually responsive mathematics education. Rather than seeking generalizable claims, the methodology foregrounds interpretation and relevance, offering insights that can inform both policy and future research on teacher development within and beyond Panama.

In addition to survey-based self-assessment, the methodological design integrated territorial participation data to contextualize the reach and evolution of the EDEM program over time. This complementary dataset enabled the construction of Figures 6, 7, and 8, which depict temporal trends, geographic intensity, and annual provincial distributions of teacher engagement in the program between 2017 and 2021. These visualizations serve a dual methodological purpose: first, to evidence the progressive territorial expansion of the program; and second, to foreground structural inequalities that may influence didactic development. By mapping participation patterns alongside self-perception data, the methodology embraces a mixed-methods logic that strengthens both the interpretative richness and the policy relevance of the study.

RESULTS AND DISCUSSION

The results obtained from the self-assessments of the 520 in-service mathematics teachers who participated in the EDEM program (2017–2022) demonstrate a positive perceived development in their teaching competencies, as analyzed through the lens of didactic suitability. The generated visualizations offer comparative interpretations

of these advancements, highlighting strengths in certain dimensions while identifying areas that require differentiated support according to territorial contexts.

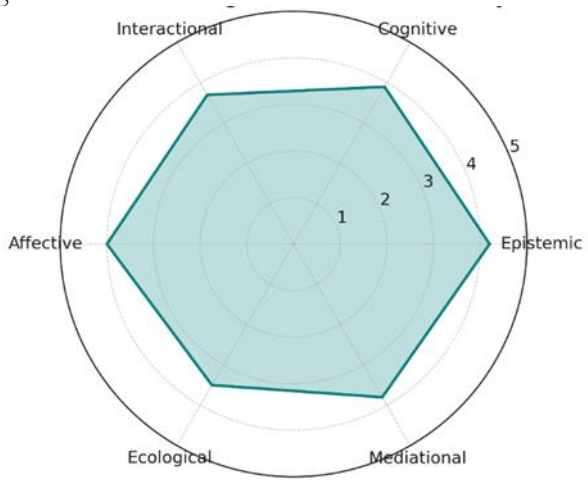

Figure 1. Perceived Averages in Didactic Suitability Dimensions

Figure 1 displays a radar chart illustrating the average perceived performance across the six dimensions of didactic suitability: epistemic, cognitive, interactional, affective, ecological, and mediational. High levels of development were reported in the epistemic (4.2) and affective (4.0) dimensions, suggesting that participants strengthened both their conceptual mastery of mathematics and their ability to create emotionally supportive and motivating learning environments. In contrast, lower average scores in the ecological (3.5) and interactional (3.7) dimensions reveal persistent challenges in culturally contextualizing instruction and promoting dialogical classroom dynamics.

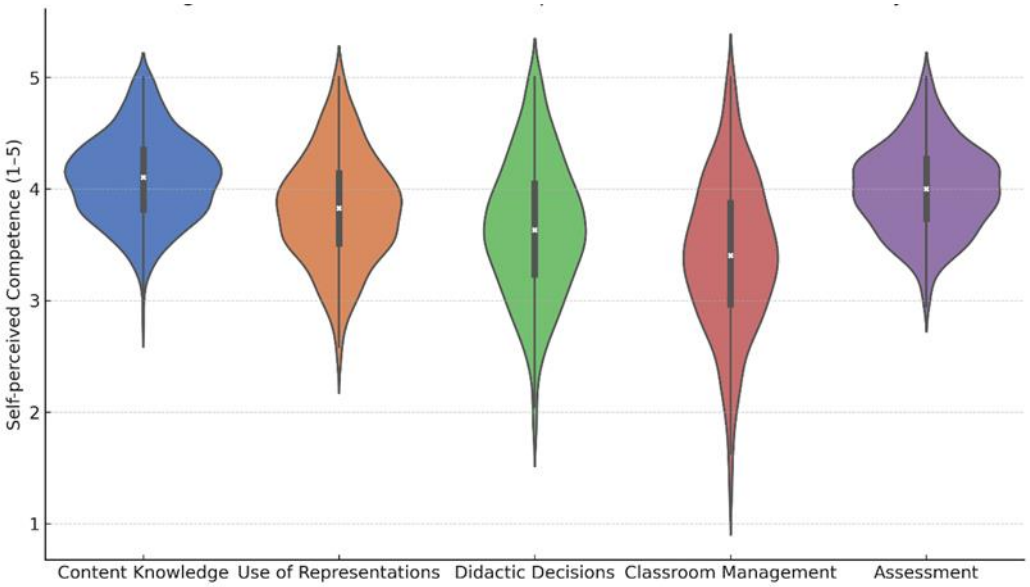

Figure 2. Distribution of Subcompetencies in Didactic Suitability

Figure 2 presents violin plots representing the distribution of perceived development in key sub-competencies, including content knowledge, use of representations, didactic decision-making, classroom management, and assessment techniques. These plots reveal high concentrations of scores above 3.5 in content and assessment domains, reinforcing the trend toward strong conceptual grounding. However, greater variability is observed in classroom management and didactic decision-making, likely reflecting differences in pedagogical experience and prior training.

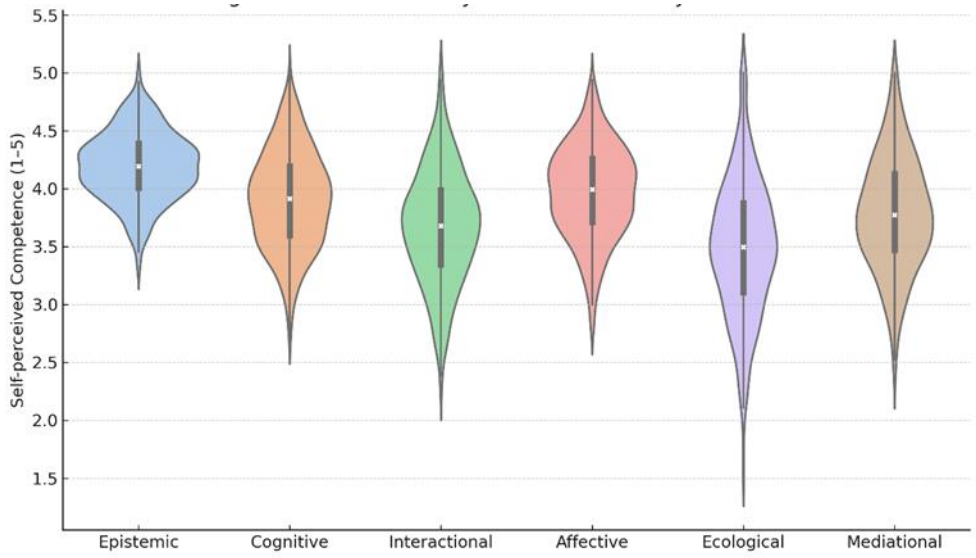

Figure 3. Distribution by Didactic Suitability Dimensions

Figure 3 continues the analysis with violin plots for each of the six OSA dimensions. The epistemic and affective dimensions show tight distributions around high scores, confirming consistency across participants. Meanwhile, the mediational and ecological dimensions exhibit broader distributions and greater dispersion, highlighting uneven perceptions of competence—likely influenced by access to teaching resources and localized implementation challenges.

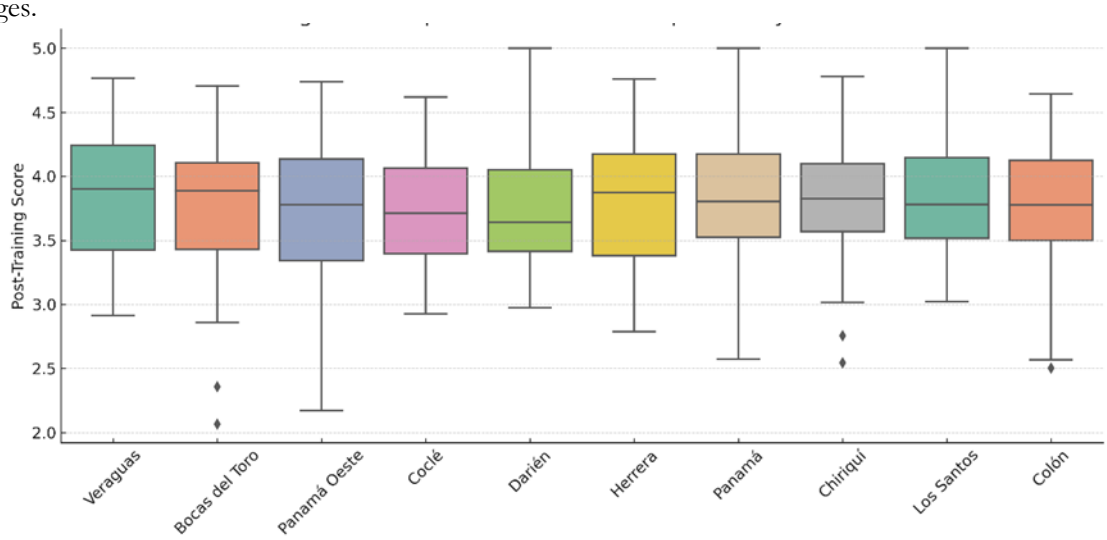

Figure 4. Self-perceived Didactic Competence by Province

In terms of territorial variability, Figure 4 presents boxplots by province, revealing geographic disparities in post-training self-assessments. Provinces such as Panamá and Chiriquí display higher medians and lower dispersion, possibly reflecting stronger local implementation or better baseline preparation. Conversely, Darién and Herrera show lower median scores and greater variability, pointing to structural barriers affecting equitable access to quality professional development and educational resources.

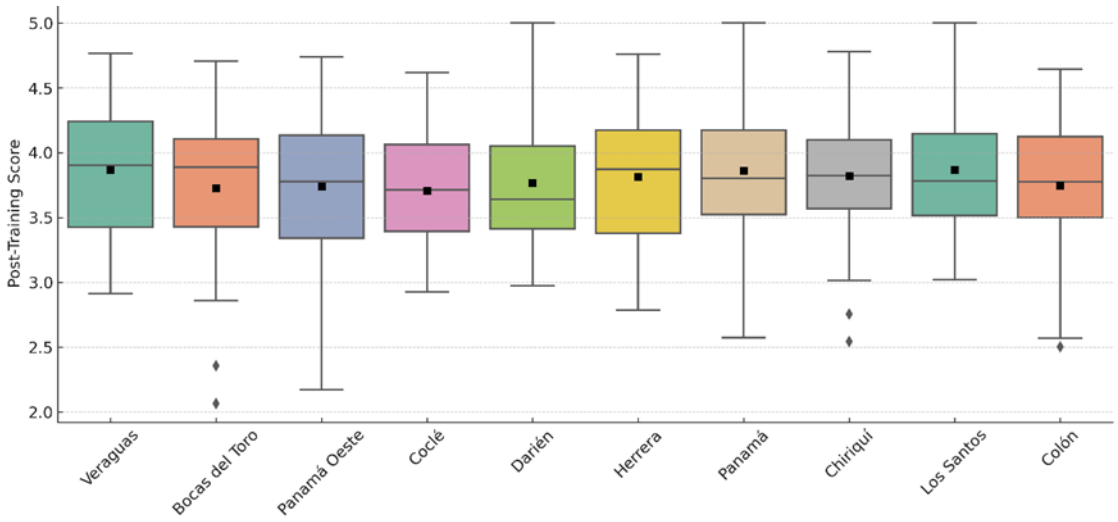

Figure 5. Self-perceived Competence by Province with Individual Distribution

Figure 5 complements this analysis by overlaying individual data points on the provincial boxplots, providing a more nuanced view of intra-regional variation. This figure underscores the importance of adopting localized strategies that respond to the specific characteristics of each region, particularly those with the widest data dispersion, such as the eastern and indigenous territories.

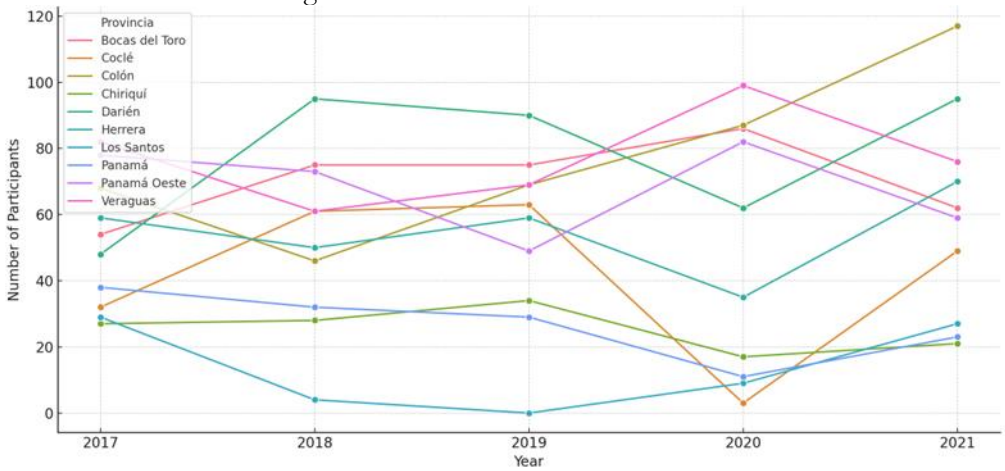

Figure 6. Time Series of EDEM Participation by Province (2017–2021)

Figure 6 presents a time series graph of teacher participation per province across the 2017–2021 period, offering a longitudinal perspective on the implementation of the EDEM program. The data reveal a steady upward trend in participation from 2017 through 2019 across most provinces, indicating a period of expansion and institutional consolidation. Notably, provinces such as Panamá, Chiriquí, and Veraguas show continuous engagement and annual increases in the number of enrolled teachers, suggesting the presence of robust local coordination and support mechanisms. In contrast, Darién and Bocas del Toro exhibit lower and more irregular levels of participation throughout the five years, pointing to persistent barriers in access or institutional outreach. The drop observed in 2020 corresponds with the onset of the COVID-19 pandemic, which likely disrupted in-person training and posed logistical challenges for remote engagement, especially in underserved regions. The subsequent stabilization or recovery in 2021 for certain provinces reflects a degree of institutional resilience and adaptation to hybrid or virtual delivery modes. Overall, the time series offers a macro-level validation of the program's territorial reach, while also exposing inequities in its diffusion across the country.

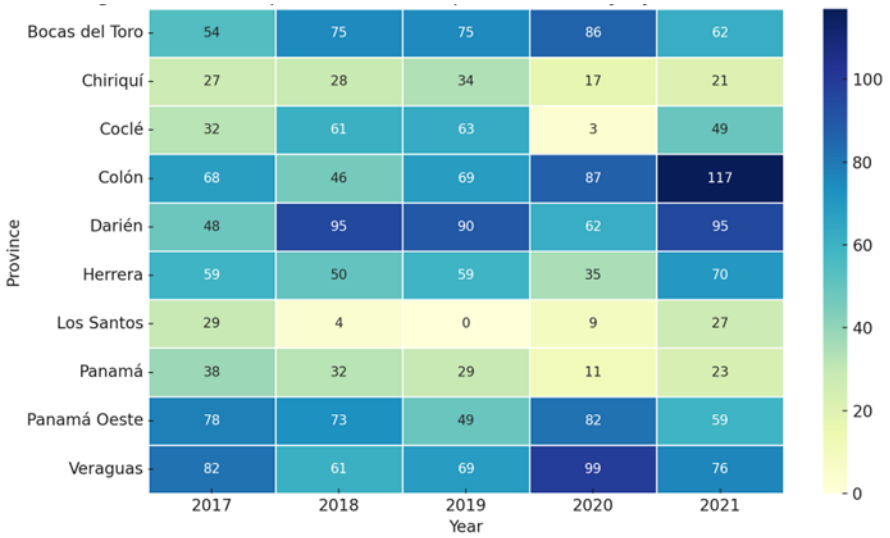

Figure 7. Heat Map of EDEM Participation Intensity by Province and Year

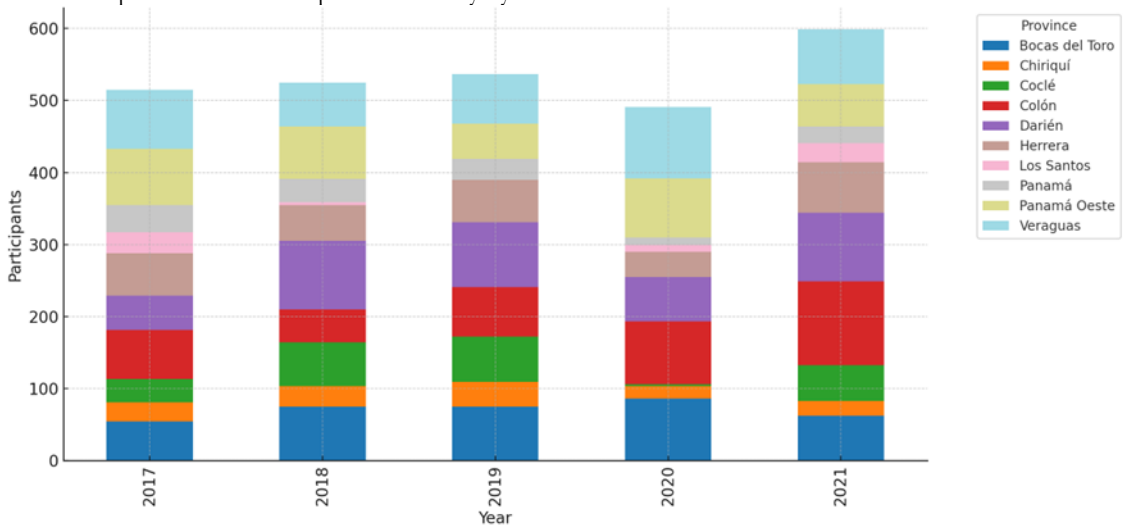

Figure 8. Annual Distribution of EDEM Participants by Province

Figure 7, which presents a heat map of participation by province and year, clearly reveals territorial disparities in the program's reach. While 2019 stands out as the year with the broadest coverage, provinces such as Coclé, Herrera, and Veraguas maintain a steady yet moderate level of participation across the five-year period, suggesting consistent but not necessarily expansive implementation. In contrast, Darién and Bocas del Toro consistently show lower participation levels, reinforcing previous findings on the need for differentiated policies in regions with limited connectivity or institutional infrastructure (Gómez-Flores, Méndez-López, & Ortiz-Navarro, 2023). The general decline observed in 2020 is also reflected in this figure, reaffirming the pandemic's negative impact on training continuity—particularly in rural and semi-urban areas with weak digital infrastructure.

Figure 8, a stacked bar chart of annual participation by province, enables a clearer view of each region's relative contribution to the national total. Panama consistently maintains a dominant and stable presence, likely due to its population density and stronger institutional capacity. In years with lower absolute participation (e.g., 2020), provinces such as Veraguas or Los Santos increase their proportional visibility, which may signal opportunities to strengthen their roles in the regional decentralization of teacher professional development. These patterns align with the observations of Rico and Lupiáñez (2008), who emphasize the need for contextualized training strategies that respond to socio-territorial realities. Together, these figures not only complement the analysis of self-perceived competencies but also highlight areas of opportunity for a more equitable and strategically distributed implementation of the program.

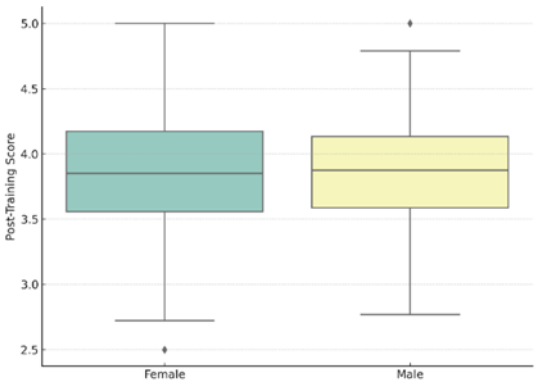

Figure 9. Post-training Didactic Competence by Gender

Figure 9 compares self-perceived competence by gender. The boxplot indicates similar medians between male and female teachers, although the distribution among female participants is slightly wider. This suggests an overall equitable impact of the training program, while also raising the need to further explore factors such as confidence in mathematics or previous training trajectories, particularly within the affective dimension.

These findings align with prior research under the OSA framework. Godino (2011) and colleagues note that the epistemic and affective dimensions tend to develop more readily when training includes structured task analysis, collaborative reflection, and real-world application. Similarly, in a study of Colombian teachers, Parra Salcedo (2021) identified the ecological and mediational dimensions as the most complex to develop, consistent with the areas of greatest variation in this study.

Considered collectively, the results indicate that the concurrent elevation of the epistemic and affective dimensions likely reflects the combined effects of structured task analysis and collaborative reflection, which consolidate mathematical meanings while fostering supportive socioemotional learning climates. In contrast, the dispersion observed in the ecological and mediational dimensions points to unequal access and functionality of—material and digital resources, as well as variation in local capacity to sustain technology-mediated practices; this pattern is consistent with territorial heterogeneity accentuated in 2020 under hybrid/online delivery. From a policy and professional-learning perspective, the evidence supports differentiated interventions: (i) an equity index prioritizing jurisdictions with the largest ecological/mediational gaps; (ii) provincial hubs to circulate instructional sequences, resources, and peer coaching; and (iii) mentoring cycles focused on mathematical argumentation and classroom discourse to stabilize the interactional dimension. A key limitation is the reliance on self-report, which warrants triangulation with classroom observations and analyses of student work in future research to strengthen external validity.

Internationally, Pino-Fan, Font, and Breda (2017) found that effective integration of mediational tools requires not only technical access but also sustained methodological support, explaining, in part, the lower scores in rural or under-resourced provinces. In Mexico, Sánchez Aguilar (2022) emphasizes that the affective dimension is not merely complementary but a transversal axis in shaping teaching practice—a finding reinforced by the high scores achieved in this domain among EDEM participants.

Taken together, the results not only validate the OSA-based model as a useful evaluative and formative framework but also reinforce calls for territorially differentiated public policies. As Gómez-Flores, Méndez-López, and Ortiz-Navarro (2023) argue, recognizing cultural and regional diversity is key to closing equity gaps in teacher training. This study contributes robust evidence on the effectiveness of OSA-informed professional development processes while also identifying clear directions for deepening and sustaining teacher education across diverse educational landscapes.

CONCLUSIONS

This study analyzed the perceived development of didactic suitability among mathematics teachers in Panama from a territorial and multidimensional perspective, grounded in the Onto-semiotic Approach to Mathematical Knowledge and Instruction (OSA). By examining six key dimensions—epistemic, cognitive, interactional, affective, ecological, and mediational—the research offered a deeper and more structured understanding of the impact of the EDEM professional development program. Based on self-assessments from 520 in-service teachers between 2017 and 2022, the study revealed both areas of significant growth and dimensions requiring differentiated support, with careful consideration of the country's contextual diversity.

Among the most relevant findings were the high scores in the epistemic and affective dimensions, indicating notable progress in both conceptual mastery of mathematics and the ability to foster emotionally supportive

learning environments. These results confirm that the program's emphasis on reflective practice and task analysis was effective in strengthening disciplinary knowledge and teacher attitudes, consistent with findings from Godino (2011) and Sánchez Aguilar (2022). However, greater variability in the ecological and mediational dimensions suggests that territorial inequalities—such as access to resources and contextually relevant materials—remain important challenges.

The use of data visualizations—such as violin plots, boxplots, and radar charts—enabled a clear and comparative representation of trends, variability, and regional contrasts in teachers' self-perceived development. Provinces like Panamá and Chiriquí showed more homogeneous and higher scores, while regions such as Darién and Herrera displayed lower medians and broader dispersion. These differences underscore the need for educational policies that are territorially responsive and that recognize the structural and cultural limitations teachers face, particularly in rural or indigenous areas.

The gender analysis indicated overall equity in perceived professional development between male and female participants, although a slightly wider distribution among women raises questions for future research. Factors such as teaching trajectories, workload, and confidence in mathematics may influence affective and mediational dimensions differently. While not statistically significant in terms of averages, these nuances offer meaningful insights into how professional development programs can further empower women in mathematics education, especially in decision-making and instructional resource use.

In sum, this study confirms the value of didactic suitability as a conceptual and evaluative framework for improving teacher education. It highlights the necessity of designing training processes and public policies that integrate epistemic content with affective and contextual dimensions. Mathematics education in the 21st century demands teachers who can skillfully combine knowledge, emotions, technologies, and local realities. The Panamanian case documented here provides a valuable experience that can inspire and inform similar initiatives across Latin America seeking a more equitable, situated, and transformative approach to teacher development.

Beyond the self-assessment data, the inclusion of territorial and longitudinal analyses enriched the study's capacity to evaluate the EDEM program in its full complexity. By incorporating visualizations of participation trends and regional distribution, the research moved beyond individual perceptions to consider the structural and geographic dimensions of professional development access. This broader perspective allowed for a more comprehensive understanding of how teacher learning is shaped not only by pedagogical content but also by institutional presence, regional infrastructure, and sociocultural context. As such, the study underscores the value of integrating both perceptual and implementation data in the evaluation of nationwide training initiatives, particularly in settings marked by territorial inequality.

Funding Statement

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Transparency Statement

All authors had full access to the coded dataset and analysis scripts, verified the accuracy of the results, and approved the final manuscript. The study was not preregistered; the instrument, processing steps, and robustness checks (e.g., Cronbach's α and item–total diagnostics) are documented in the Methodology. Any deviations from the initial analytic plan are disclosed therein.

Data Availability Statement

De-identified, province-level aggregate data and analysis scripts will be made available in an open repository upon acceptance of the manuscript; until then, they are available from the corresponding author on reasonable request, subject to ethical and institutional restrictions. Individual-level responses cannot be shared due to confidentiality obligations under CBI–USantander approvals. The survey instrument and codebook will be provided as supplementary material upon acceptance.

Institutional Review Board Statement

The study was approved by the Bioethics Committee of the University of Panama (CBUP/298/2019; CBUP/279/2021; CBUP/448/2021). Oversight for the 2025 analytical extension was transferred to CBI–USantander (CBI–USantander–M–087–2025; under review). Participation was voluntary with informed consent, and all data were anonymized and reported in aggregate.

Authors' Contributions: Luisa Morales-Maure: Conceptualization; Methodology; Writing—original draft; Supervision; Orlando García-Marimón: Formal analysis; Visualization; Software; Writing—review & editing; Keila Chacón-Rivadeneira: Investigation; Data curation; Writing—review & editing; Berenice Alfaro Ponce: Resources; Project administration; Writing—review & editing; Vicenç Font Moll: Theoretical framing (OSA); Validation; Writing—review & editing.

All authors read and approved of the final manuscript.

Disclosure of AI Use

No AI tools were used in the conception, design, data collection, analysis, writing, or editing of this manuscript. All content was produced by the authors; only standard office and statistical software were employed for document preparation and data analysis.

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