



Reflective practice and emotional engagement in mathematics teacher development: A qualitative multiple-case study in Panama

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Abstract

Situated professional development may help mathematics teachers connect didactic analysis with regulation of practice and the emotional demands of classroom work. This qualitative multiple-case study examined how metacognitive regulation and socio-emotional engagement were expressed across six dimensions of didactic-mathematical knowledge and competence in two Panamanian primary teachers completing the four-module EDEM diploma. The source inventory comprised 20 written pedagogical and mathematical task responses, eight reflective essays, two brief final-project video clips (three minutes combined), and 10 anonymised institutional-feedback records. A framework-informed codebook analysis combined deductive DMKC coding—epistemic, cognitive, affective, interactional, mediational, and ecological—with cross-cutting analysis of planning, monitoring, evaluation, empathy, resilience, motivation, and classroom climate. Teacher-produced, institutional, audiovisual, and researcher-interpreted evidence were distinguished throughout. Short source-linked excerpts are reported in the original Spanish with checked English translations. Across chronological artefacts, both cases displayed differences in the explicitness of planning, noticing, and redesign, although prompt and genre differences prevent treating chronology as a direct measure of development. Teacher A foregrounded dialogic interaction, collaboration, and contextual connections; Teacher B foregrounded cognitive structuring, representational and material choices, and fear reduction. Mediational and ecological evidence was less consistent. The findings document two differentiated patterns of expressed professional reasoning; they do not establish causal programme effects, sustained change, or student achievement gains. The study supports professional development that integrates didactic analysis, metacognitive prompts, and attention to classroom relationships while remaining responsive to local constraints.

Keywords: didactic-mathematical knowledge; emotional engagement; mathematics teacher education; reflective practice; situated professional development

Abbreviations: DMKC, didactic-mathematical knowledge and competence; EDEM, Estrategias Didácticas para la Educación Matemática; GIEM21, Grupo de Investigación en Educación Matemática; NVivo, qualitative data-analysis software; SENACYT, Secretaría Nacional de Ciencia, Tecnología e Innovación

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1. Introduction

Mathematics education in Panama enters the post-pandemic period with persistent learning challenges alongside mixed academic and socio-emotional signals. The ERCE Pospandemia study collected tests and questionnaires in Panama between December 2023 and April 2024 and reported national results in 2025. In mathematics, 43.9% of Grade

3 students and 10.1% of Grade 6 students reached or exceeded the minimum performance standard. Relative to ERCE 2019, Panama showed improvement in Grade 3 reading and mathematics, while important challenges remained in Grade 6; the same post-pandemic evidence documented declines in school self-regulation, empathy, and openness to diversity, and a positive association between perceived teacher support and learning (1). These

national indicators provide context for the study but are not used as outcome evidence for EDEM or for either case.

Recent reviews describe mathematics teachers' professional development as most productive when it is sustained, connected to recurring tasks of teaching, and organised around analysis of practice rather than isolated transmission of techniques (2, 3). Reflection is therefore not simply retrospective narration. It involves setting goals, anticipating student thinking, noticing evidence during instruction, evaluating consequences, and redesigning subsequent action. Professional learning also has an emotional and relational dimension: teacher socio-emotional competence is associated with classroom processes and student engagement, although recent meta-analytic evidence indicates that the average relationship is positive but modest and context dependent (4–6).

Panamanian research provides a particularly relevant foundation. An educational experience in mathematical modelling showed the value of contextualized design and reflection with Panamanian teachers (7). A 2025 study of primary teachers in Panama reported that task redesign can make didactic-mathematical reasoning more explicit (8). Another 2025 study documented how Lesson Study and didactic suitability criteria can structure collaborative analysis and pedagogical innovation in mathematics teacher education (9). These contributions establish the relevance of situated, analytically guided professional development, but broader programme evaluations cannot by themselves reveal the micro-processes through which individual teachers interpret evidence, regulate decisions, and negotiate emotional demands.

This article addresses that gap through an intensive comparison of two information-rich cases from EDEM (*Estrategias Didácticas para la Educación Matemática*), a continuing professional development diploma developed in Panama. The analysis integrates the Didactic-Mathematical Knowledge and Competence model (DMKC) with metacognitive regulation and socio-emotional engagement. The research question was: How were metacognitive regulation and socio-emotional engagement expressed across DMKC dimensions in two EDEM participants during the diploma, and how did the cases differ? The purpose is analytical rather than statistical generalisation: to identify credible patterns and contrasts that may inform programme design and future longitudinal study.

2. Theoretical framework

2.1 Didactic-mathematical knowledge and competence

The Onto-Semiotic Approach interprets mathematical teaching and learning as systems of practices in which objects, representations, meanings, norms, people, and institutions interact. Within this approach, the DMKC model distinguishes six connected dimensions of didactic

suitability and professional reasoning: epistemic, cognitive, affective, interactional, mediational, and ecological (10, 11). The epistemic dimension concerns the adequacy and articulation of mathematical meanings; the cognitive dimension concerns fit with students' knowledge, reasoning, and learning needs; the affective dimension concerns interests, attitudes, emotions, and values; the interactional dimension concerns discourse, participation, feedback, and negotiation of meaning; the mediational dimension concerns time, material, and technological resources; and the ecological dimension concerns alignment with curriculum, context, and institutional conditions.

The framework is useful for teacher development because it moves reflection beyond generic judgments such as whether a lesson 'worked.' It prompts teachers to connect mathematical content, student thinking, interaction, resources, emotion, and context. Studies in Panama have used these criteria to evaluate learning sequences and redesign tasks (8, 12). Recent work has also explored the criteria as a disciplined basis for reformulating tasks with digital and artificial-intelligence tools (13). In the present study, the six dimensions organize the deductive analysis; they are not treated as a numerical scale.

Figure 1 synthesizes these relationships as a school-level system in which mathematical knowledge, analysis competencies, and intervention competencies are coordinated through a system of practices, onto-semiotic configurations, didactic trajectories, and normative conditions. The six facets are represented as mutually dependent analytical lenses rather than as sequential stages, emphasizing that professional reasoning emerges through their interaction (Figure 1).

Understood in this way, the representation provides a transferable analytical architecture for subsequent studies of task design, Lesson Study, technology-mediated instruction, reflective practice, and socio-emotional engagement. Its purpose is not to prescribe a single model of effective teaching, but to support theoretically coherent comparisons across programmes, educational levels, and territorial contexts, with operational definitions adapted to the evidence and conditions of each study.

2.2 Reflective practice and metacognitive regulation

Reflective practice is defined here as systematic analysis of instruction before, during, and after classroom activity, grounded in task features, anticipated or observed student responses, and teachers' reasons for action. This definition parallels the planning, performance monitoring, and self-evaluation phases of self-regulated learning (14). In teacher education, these phases become visible when participants explain goals and anticipated difficulties, notice evidence that challenges an initial plan, and evaluate a lesson sufficiently specifically to propose a revision.

The distinction is important because description alone is

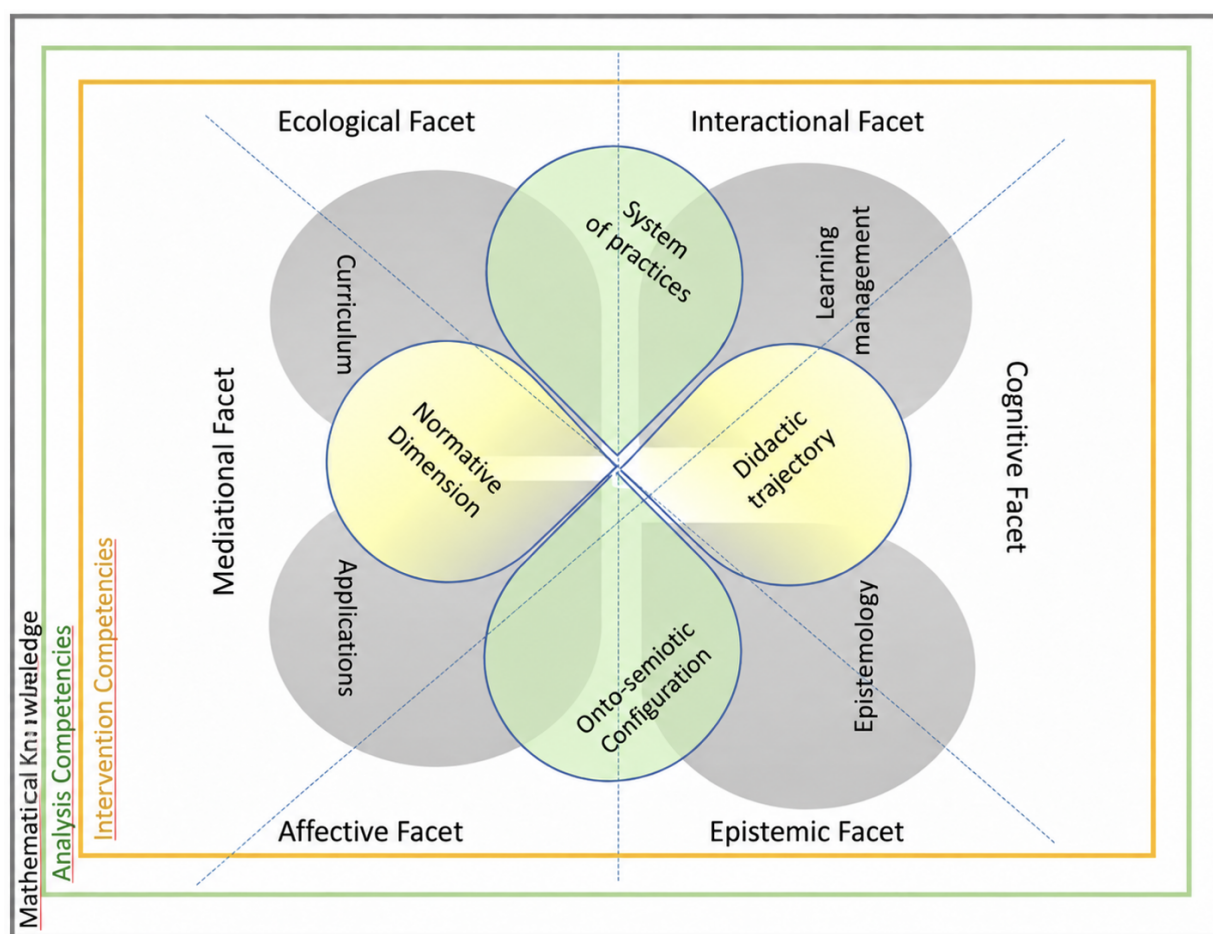


Figure 1: Systemic articulation of professional reasoning within the Onto-Semiotic Approach and the DMKC framework. *Note.* Original conceptual synthesis created for this manuscript from the constructs described in (10, 11). It does not reproduce a published figure. The six facets are presented as interdependent analytical lenses rather than as a linear sequence or numerical scale.

not necessarily reflection. A statement that students were unmotivated reports a condition; a reflective statement links that observation to evidence, considers an instructional decision, and proposes an alternative. Research on prospective mathematics teachers has shown that structured analytic tools can deepen attention to mathematical errors and the reasoning behind teaching decisions (15, 16). EDEM sought to create repeated opportunities for this movement from description to evidence-informed regulation.

2.3 Socio-emotional engagement in mathematics teaching

Emotional engagement refers to teachers' explicit attention to affect in teaching: recognising and regulating their own emotions, responding empathically to students, sustaining participation when difficulties arise, and intentionally cultivating a psychologically supportive climate. The prosocial classroom model positions teachers' social and emotional competence as a mechanism linking teacher well-being, relationships, classroom management, and student outcomes (4). Situational-judgment research further indicates

that this competence includes context-sensitive interpretation and regulation rather than stable disposition alone (17).

Systematic reviews show that socio-emotional competencies have received less attention than cognitive and pedagogical knowledge in teacher preparation and that intervention designs vary considerably in duration, measures, and theoretical grounding (18, 19). Recent work on teacher-perceived competence and validated Spanish-language measurement also reinforces the need to distinguish self-perception from demonstrated practice (6, 20). Accordingly, the present study does not infer a latent trait or clinical change. It identifies qualitative traces of empathy, resilience, motivational support, and relational decision-making in programme artefacts.

3. Materials and methods

3.1 Design and setting

A qualitative multiple-case design was used to examine professional learning in context (21). Each case comprised one

in-service primary teacher's chronological EDEM artefacts and associated institutional feedback. Comparison was used to identify shared patterns and case-specific configurations. Consistent with naturalistic inquiry (22), credibility was addressed through source comparison, member reflection, and analytic challenge; transferability through bounded contextual description; dependability through a documented codebook and decision trail; and confirmability through reflexive memoing and explicit attention to disconfirming evidence. These procedures support analytical rather than statistical generalisation. Table 1 summarises the design.

EDEM is a four-module diploma for in-service mathematics teachers who remain active in their classrooms while completing the programme. Across modules, participants analyse mathematical tasks, anticipate student reasoning, design or adapt activities, document implementation, and evaluate instructional decisions through written and audiovisual reflection. The programme combines DMKC and Onto-Semiotic tools with situated task design and peer discussion. The module artefacts were not equivalent repeated measures: early work emphasised task analysis, mathematical meanings, and anticipated difficulties; later work placed greater emphasis on design, enactment, evaluation, and final-project reflection. Consequently, differences across the chronology may partly reflect prompt wording, artefact genre, expected elaboration, assessor feedback, or growing familiarity with programme vocabulary. Chronology is therefore used descriptively and not as an independent measure of professional development.

3.2 Case selection and data corpus

Two participants, identified as Teacher A and Teacher B, were purposively selected from rural and semi-urban school contexts in Panama. Eligibility required completion of all four modules, completion of the final classroom-based project, and availability of sufficiently rich written and audiovisual materials for within-case and cross-case analysis. 'Information-rich' therefore referred to continuity across the diploma and the availability of multiple artefact types, not to higher performance. The small sample was chosen for intensive reconstruction and was not intended to represent the EDEM cohort or Panamanian teachers generally. To reduce re-identification risk in a two-case study, the manuscript does not link the pseudonyms to a named school, community, or other combinations of demographic characteristics not necessary to the analytic argument. The retained source inventory does not support a defensible retrospective count of how many members of the wider cohort met each successive eligibility criterion; no such denominator is inferred here.

The corpus comprised four source types: (1) teacher-produced responses to pedagogical and mathematical tasks across the four modules; (2) teacher-produced reflective essays; (3) brief videos linked to the final classroom-based projects; and (4) anonymised institutional-feedback

records produced by school leaders and programme evaluators familiar with the teachers' work. The institutional records originated as evaluative or programme-related feedback rather than as independent classroom observations; they were therefore used only as contextual evidence and were not weighted as independent confirmation of teachers' accounts. Throughout the analysis, intended practice, teacher-reported enactment, institutional report, brief audiovisual evidence, and researcher interpretation were distinguished explicitly. No direct measures of student achievement or student perception were included.

The final source-level inventory comprised 40 records: 20 written pedagogical and mathematical task responses distributed across the four EDEM modules, eight reflective essays, two final-project video clips with a verified combined duration of three minutes, and 10 anonymised institutional-feedback records. The videos were one brief clip linked to each case's final project and were treated as supplementary contextual evidence rather than as an independent triangulation leg because of their limited duration. The source inventory records the total audiovisual duration but not a defensible case-specific timing breakdown, so no individual duration is fabricated. The 40 records are source documents, not meaning-unit counts, and no quantitative weighting or frequency inference was applied to the number of coded units.

3.3 Analysis

Analysis used a framework-informed codebook approach. In the first analytic layer, a deductive codebook operationalised the six DMKC dimensions: epistemic, cognitive, affective, interactional, mediational, and ecological. In the second, cross-cutting layer, the team identified patterns of metacognitive regulation (planning, monitoring, and evaluation) and socio-emotional engagement (empathy, resilience, motivation, and classroom climate). This combination is consistent with framework analysis, in which a priori domains and inductively refined categories can be charted systematically across cases (23). A meaning unit consisted of one or more contiguous sentences, or an audiovisual segment, expressing a coherent teaching decision, interpretation, emotional response, or reflection. Meaning units could receive more than one binary code when the evidence genuinely connected analytical domains; the codes were not mutually exclusive.

Materials were organised chronologically within each case in NVivo and analysed in Spanish, the language in which the source materials were produced. DMKC codes functioned as first-layer descriptive dimensions, whereas planning, monitoring, evaluation, empathy, resilience, motivation, and classroom climate were treated as cross-cutting interpretive categories rather than as a second numerical scale. Researchers wrote case memos, charted source-linked evidence in a cross-case matrix, and deliber-

Table 1: Methodological overview

Component	Description
Design	Qualitative, interpretive multiple-case study; analytical rather than statistical generalisation.
Setting	Four-module EDEM continuing professional development diploma; participants remained active in their own classrooms.
Cases	Two in-service primary teachers from rural and semi-urban contexts, purposively selected for complete participation, final-project completion, and information-rich longitudinal artefacts; pseudonym-to-context linkage withheld to reduce re-identification risk.
Sources	Forty source records: 20 written task responses distributed across four modules; eight reflective essays; two brief final-project video clips (3:00 combined); and 10 anonymised institutional-feedback records from school leaders/programme evaluators.
Deductive framework	Six DMKC dimensions: epistemic, cognitive, affective, interactional, mediational, and ecological.
Inductive focus	Cross-cutting interpretive categories: planning, monitoring, evaluation, empathy, resilience, motivation, and classroom climate.
Process	Framework-informed codebook analysis in Spanish; source-linked coding, within-case memoing, cross-case matrix, disconfirming-evidence search, and checked translation of selected excerpts.
Trustworthiness	Source comparison; member reflection; overlapping independent coding for codebook calibration; reflexive memos; audit trail. No single omnibus Cohen kappa is interpreted because the coding was multi-label.
Boundary	No direct student-achievement measure, student-report measure, or independent classroom observation. Brief videos and institutional feedback are supplementary/contextual rather than independent confirmation.

Note. Counts are source-level records. The two video clips total 3:00 and are treated as supplementary contextual evidence. Meaning units were analytic segments rather than quantitative observations; no frequency-based weighting or omnibus multi-label kappa is reported.

Table 2: Analytic framework and observable indicators

Domain	Operational focus	Illustrative indicator in the corpus
Epistemic	Adequacy and articulation of mathematical meanings	Clarifies concepts, compares procedures, or justifies the mathematical purpose of a task.
Cognitive	Fit with student knowledge and learning needs	Anticipates misconceptions, invokes prior knowledge, or modifies an explanation or representation.
Affective	Interest, attitude, emotion, and value	Identifies fear, confidence, motivation, enjoyment, or emotional safety as relevant to participation.
Interactional	Dialogue, participation, feedback, and negotiation	Uses questions, group structures, listening, or feedback to elicit and develop student thinking.
Mediational	Time, material, and technological resources	Selects or adapts manipulatives, visual supports, technology, pacing, or task sequence.
Ecological	Curriculum, culture, context, and institutional conditions	Connects tasks with curriculum or local experience and recognizes contextual constraints.
Planning	Prospective regulation	States goals, anticipates responses or difficulties, and selects an approach before enactment.
Monitoring	Regulation during problem solving or reported enactment	Notifies mismatch, confusion, engagement, or evidence requiring adjustment.
Evaluation	Retrospective appraisal and redesign	Judges a decision against evidence and specifies a revision or next step.
Socio-emotional engagement	Cross-cutting relational and emotional attention in didactic decisions	Expresses empathy, resilience, fear reduction, motivational support, or climate-building action; interpreted as expressed reasoning unless independently observed.

Note. DMKC dimensions form the first coding layer; metacognitive and socio-emotional categories cut across those dimensions. Segments could receive multiple binary codes when one teaching decision connected two or more domains. Evidence provenance was retained for each coded unit.

ately searched for weaker or disconfirming evidence before selecting final claims. Overlaps were retained when one meaning unit supported more than one dimension, but the evidentiary status of each unit—teacher statement, reported enactment, institutional feedback, video evidence, or researcher inference—was preserved in the matrix. Short quotations selected for publication were translated into English by the bilingual research team and checked against the Spanish original by a second team member.

Worked example. A Teacher B task response states in Spanish, “Espero que me aporte nuevos métodos y técnicas para que los estudiantes aprendan matemáticas de una manera más fácil y no le tengan miedo, que se interesen, les llame la atención, se diviertan y aprendan.” The checked translation is: “I hope it gives me new methods and techniques so that students can learn mathematics more easily and are not

afraid of it, become interested, pay attention, enjoy themselves, and learn.” [B-M1-TR01, Module 1, teacher-produced task response]. The raw unit was coded as affective and as prospective planning/motivational support; the case memo treated it as an expressed intention to reduce fear, and the cross-case matrix compared that intention with Teacher A’s more interaction-centred evidence. It was not interpreted as proof that student fear actually decreased.

3.4 Trustworthiness

Three researchers independently coded a purposively varied overlapping set of meaning units spanning the available source types as a codebook-calibration exercise. Coders contributed to iterative clarification of the codebook, and disagreements were discussed until the operational definitions were sufficiently clear for the main analysis. Be-

cause the coding architecture was multi-label, this report does not use a single omnibus Cohen's kappa as an interpretable reliability statistic; coder convergence is treated as calibration rather than as proof that qualitative interpretation is objective (24). Credibility was further supported through comparison of teacher-produced and contextual records, member reflection on case descriptions, and attention to contrary or comparatively weak evidence. The audit trail contains source-code mappings, codebook versions, coding-decision notes, reflexive memos, cross-case matrices, and translation checks, and can be made available to editors under the same confidentiality restrictions that govern the underlying data.

3.5 Researcher positionality and reflexivity

EDEM was developed and coordinated within the GIEM21 research programme, and members of the author team have contributed to EDEM-related programme and research activities. This insider position provided contextual knowledge but also created plausible risks of expectancy effects, programme-language uptake, and confirmation bias when interpreting artefacts produced in a formative setting. The research team selected the cases using the eligibility criteria described above; participants did not select themselves for publication. To address these influences, the analysis retained source provenance, used reflexive memos and team challenge discussions, included overlapping independent coding for codebook calibration, sought disconfirming evidence, and used member reflection on the case descriptions. Institutional feedback was treated as evaluative contextual material, not as independent corroboration.

3.6 Ethics and data governance

Participants were adults who received information about the research and provided written informed consent for research use of anonymised materials. Names of teachers, schools, and potentially identifying contextual details were removed. Earlier phases of the broader programme were reviewed under Universidad de Panamá protocols CBUP/298/2019, CBUP/279/2021, and CBUP/448/2021. The 2025 secondary analytic extension was subsequently approved by the Bioethics Committee of Universidad de Santander under protocol CBI-USantander-M-087-2025 on 1 July 2025. The Santander review provided ethics oversight for the continuing secondary analysis while the original Panamanian data collection remained anchored in the Universidad de Panamá approvals. The present study used historical adult-teacher materials, including written artefacts, the brief final-project clips, and anonymised institutional feedback; it involved no new contact with minors and no new student-data collection. Data were de-identified before analysis, stored with restricted access, and are reported only through bounded descriptions and short anonymised excerpts because the small sample creates a material re-identification risk.

4. Results

4.1 Shared patterns across DMKC dimensions

Across the chronological artefacts, both cases contained explicit explanations of mathematical purpose, anticipated student difficulties, and reasons for modifying instruction, but the degree of explicitness varied by source type and module prompt. Epistemic evidence was identified when teachers clarified meanings, compared procedures, or justified why a task represented the intended mathematics. Cognitive evidence was identified when they anticipated misconceptions, connected explanations with prior knowledge, or described representational changes in response to reported difficulty. These patterns recur across the available teacher-produced records, but the analysis treats them as differences in expressed reasoning within the corpus—not as direct tests of content knowledge or as a repeated-measures demonstration of growth.

Affective evidence was also prominent in the teacher-produced materials, particularly references to interest, anxiety or fear, confidence, and participation. Interactional evidence differed more clearly between cases, whereas mediational and ecological evidence was less consistent. Resource use was often discussed in relation to access and conceptual clarity, but technology use and broader curricular or institutional alignment appeared unevenly. Claims in Table 3 therefore distinguish direct participant language from analytical paraphrase and do not treat institutional feedback or the short video clips as equivalent to direct observation.

4.2 Metacognitive regulation across the modules

The chronological matrix suggests a movement from stated intentions toward more elaborated planning-monitoring-evaluation language, but this is interpreted cautiously because later prompts and artefact genres themselves invited more explicit reflection. Teacher A provides a source-linked example of strategic reasoning in a mathematical task: “Estrategias: ensayo y error; descomponer el problema en pequeños problemas; deducir y sacar conclusiones” [A-M1-TR-CR, Module 1, teacher-produced task response]. The checked translation is: “Strategies: trial and error; break the problem into smaller problems; deduce and draw conclusions.” The same source records the correct resolution of the ‘chickens and rabbits’ problem. This unit supports evidence of deliberate strategy selection within that artefact; it is not, by itself, evidence of longitudinal development.

Teacher B's artefacts emphasised curricular fit, task sequencing, and calibration of certainty. In everyday inquiry tasks, the case materials contrasted intuitive approximations with verifiable methods and linked representational and material choices to anticipated numerical reasoning and assessment goals. These records support an interpretation of increasingly explicit metacognitive language within

Table 3: Cross-case evidence synthesis by DMKC dimension

Dimension	Teacher A	Teacher B	Bounded cross-case interpretation
Epistemic	Source-linked task evidence: “Estrategias: ensayo y error; descomponer el problema en pequeños problemas; deducir y sacar conclusiones” [A-M1-TR-CR].	Emphasised conceptual clarity and verification of procedures.	Direct excerpt documents strategy selection in Teacher A; other epistemic comparisons remain interpretive summaries of coded artefacts, not external knowledge tests.
Cognitive	Anticipated confusion and revised activities after noticing difficulty.	Foregrounded numerical reasoning, prior knowledge, sequencing, and anticipated procedural difficulty.	Both attended to student thinking; Teacher B made cognitive structuring more central.
Affective	Connected anxiety, motivation, attitude, and emotional safety with engagement.	Direct intention: “...aprendan matemáticas de una manera más fácil y no le tengan miedo...” [B-M1-TR01].	Teacher-produced language supports expressed attention to fear/motivation; it does not establish student emotional change.
Interactional	Used questioning, dialogue, collaboration, differentiated grouping, and roles.	Emphasised attentive listening and deliberate exchange of ideas.	More elaborated and recurrent in Teacher A's corpus.
Mediational	Used visual and potentially meaningful resources; adjusted pace and grouping.	Made systematic choices about materials, representations, sequence, and supports.	Evidence concerns teachers' described resource choices. Uneven visibility may reflect both local constraints and what programme prompts elicited.
Ecological	Used cultural and historical references and recognized local constraints.	Connected some problems with everyday experience and curricular fit.	Contextual links were present but uneven; institutional records are treated as contextual/evaluative, not independent corroboration.

Note. This matrix is an evidence synthesis rather than a rating scale. Direct quotations are marked with source codes; other cells are bounded analytical summaries and should not be read as equivalent to direct observation.

the available chronology; however, the interpretation remains compatible with rival explanations such as more directive later prompts, longer artefacts, assessment expectations, or increasing familiarity with EDEM terminology. Table 4 therefore presents the chronology descriptively rather than as a causal developmental scale.

4.3 Socio-emotional engagement

Teacher A's socio-emotional orientation was closely tied to interaction. Across teacher-produced records, games, small-group work, differentiated grouping, and collaborative roles were described as ways to reduce tension and accommodate heterogeneous learning rhythms. Autonomy and collaboration were framed as mediational and interactional choices intended to move students from individual effort toward shared goals. The case also connected mathematical activity with cultural and historical references. These statements document the teacher's pedagogical reasoning and reported intentions; without independent classroom observation or student voice, they do not establish how those practices were experienced by students.

Teacher B explicitly linked didactic improvement to fear reduction. One task response stated: “Espero que me aporte nuevos métodos y técnicas para que los estudiantes aprendan matemáticas de una manera más fácil y no le tengan miedo, que se interesen, les llame la atención, se diviertan y aprendan” [B-M1-TR01, Module 1, teacher-produced task response]. The checked English translation is: “I hope it gives me new methods and techniques so that students can learn mathematics more easily and are not afraid of it, become interested, pay attention, enjoy themselves, and learn.” This is direct evidence of an expressed socio-emotional intention, not evidence that students' fear decreased. Other artefacts described attentive listening,

exchange of ideas, and resource sequencing as intended means of sustaining interest and confidence.

4.4 Cross-case contrast

The cross-case contrast is best understood as a difference in emphasis within the documented corpus. Teacher A more often foregrounded dialogic interaction, collaboration, socio-emotional attention, and contextual references; Teacher B more often foregrounded cognitive structuring, representational and material design, and explicit fear reduction. Both cases combined didactic and emotional reasoning, but the evidentiary point of entry differed. The comparison does not rank the teachers, infer latent traits, or demonstrate that one pathway developed more than the other.

This contrast shows why a common analytical framework should not be interpreted as a uniform developmental trajectory. DMKC made comparable dimensions visible, while the case design preserved differences in professional history, artefact genre, and school context. The evidence supports differentiated patterns of expressed reasoning within EDEM. It does not warrant averaging the profiles, inferring prevalence in the wider cohort, or attributing chronological differences solely to the programme.

5. Discussion

The findings show how reflective practice, metacognitive regulation, and emotional engagement can be analysed together without collapsing them into a single measure. Across the source record, goal setting, noticing, and re-design were visible in ways consistent with self-regulation theory (14), while attention to mathematical errors, task features, and teacher reasoning aligns with studies using structured reflection in mathematics teacher education (15, 16).

Table 4: Descriptive chronological matrix of metacognitive regulation across EDEM modules

Module	Teacher A: planning, monitoring, and evaluation	Teacher B: planning, monitoring, and evaluation	Cross-case reading
1	Identified student needs; observed misconceptions; reflected on reported outcomes.	Analysed curricular fit; monitored group work; compared results with goals.	Early artefacts named needs and goals but offered relatively concise rationales.
2	Outlined learning goals; gathered student feedback; discussed decisions with peers.	Designed contextual problems; took anecdotal records; incorporated student self-assessment.	Monitoring became more explicitly connected with evidence from participation.
3	Prepared visual supports; adjusted pace; reformulated activities.	Selected manipulatives; tracked task completion; used a teacher journal.	Both cases connected noticing with a concrete mediational adjustment.
4	Revised instructional materials; noted engagement patterns; evaluated strategy fit.	Aligned tasks with assessment goals; noted emotional responses; synthesized learning in the final video.	Later artefacts articulated more complete planning-monitoring-evaluation cycles.

Note. Module entries summarise non-equivalent artefact genres and prompts. Earlier artefacts emphasised task analysis and anticipation; later artefacts more explicitly solicited design, enactment, evaluation, and final-project reflection. The matrix therefore supports chronological description but not a repeated-measures or causal developmental inference.

The contribution of this study is to locate these processes within the six DMKC dimensions and to compare two distinct configurations in Panamanian school contexts. Because module prompts and artefact genres changed over time, the study interprets chronology as evidence of how reasoning was expressed at different points, not as a direct estimate of programme-induced growth.

The case patterns also complement recent Panama-aligned research. Task-redesign research emphasises making mathematical and didactic criteria explicit (8), and Lesson Study research emphasises collaborative examination of planned and enacted instruction (9). The present cases add a close view of how individual teachers articulate monitoring, evaluation, empathy, fear reduction, and resource constraints across a programme sequence. Together, these studies suggest that professional development designs should connect common analytic criteria with repeated opportunities to revisit participants’ own classroom evidence.

The socio-emotional findings require careful interpretation. Teacher A’s emphasis on psychological safety and Teacher B’s effort to reduce fear are compatible with the prosocial classroom model (4) and with intervention research showing that explicit socio-emotional learning can influence teacher and classroom processes (25). However, recent meta-analysis cautions against assuming large or automatic effects on student engagement (5). In this study, no student-report, observation, or achievement measure was available. The evidence supports claims about teachers’ expressed attention and reasoning, not effects on students.

The less consistent mediational and ecological evidence has practical importance, but it should not automatically be attributed to local constraints or to individual teachers. A rival interpretation is that the programme prompts and available artefact genres made some dimensions easier to articulate than others; mediational and ecological weakness may therefore reflect, at least partly, the design of EDEM’s evidence opportunities. At the same time, unequal access to technology, materials, time, or institutional support can constrain what teachers are able to enact. Future programme evaluation should separate these explanations

by using common prompts across modules, independent classroom observation, and explicit documentation of resource and organisational conditions. The 2025 Panamanian ERCE results reinforce the system-level relevance of such work but are not an outcome measure for EDEM (1).

For programme design, three implications follow. First, each module should include an explicit planning-monitoring-evaluation prompt linked to evidence from teaching. Second, socio-emotional questions should be integrated into mathematical task analysis—for example, which students are likely to withdraw, what representation may reduce unnecessary anxiety, and how feedback can preserve intellectual risk-taking. Third, programme evaluation should combine artefacts with classroom observation, student voice, and follow-up at 3, 6, and 12 months. This would allow future studies to examine enactment and sustainability rather than relying primarily on teachers’ accounts.

6. Limitations

This study has several principal limitations. First, two purposively selected information-rich cases support analytical insight, not prevalence estimates or statistical generalisation. Second, case selection partly depended on the availability of complete materials and may underrepresent interrupted participation. Third, source genres and prompts differed across modules, so chronological differences in explicitness may reflect task design, expected length, assessor feedback, or uptake of programme vocabulary as well as professional learning. Fourth, much of the corpus is teacher-produced and the institutional feedback is evaluative contextual material rather than independent observation. Fifth, the two final-project video clips total only three minutes and were therefore treated as supplementary evidence rather than an independent triangulation source. Sixth, no student interviews, student achievement measures, or independent classroom observations were analysed. Seventh, the research team’s insider relationship with EDEM may have influenced artefact production, case selection, and interpretation despite the reflexive procedures described above.

Finally, the exact persistence of the documented patterns beyond the diploma is unknown, and the socio-emotional analysis identifies expressed practices and concerns rather than validated change in a latent competence.

7. Conclusion

The two cases document how a situated mathematics professional development programme can make different forms of teacher reasoning visible. Across the EDEM artefacts, both teachers articulated mathematical purposes, anticipated student difficulties, monitoring decisions, and possible revisions, although the explicitness and genre of those articulations varied across modules. Teacher A's corpus more strongly foregrounded dialogue, collaboration, socio-emotional safety, and contextual connections; Teacher B's foregrounded cognitive structuring, mediational choices, and fear reduction. These are differentiated patterns within a common DMKC framework, not scores on a single developmental scale and not causal estimates of programme impact.

For mathematics teacher education, the central implication is that didactic rigor and emotional engagement should be designed together. Reflection becomes more useful when teachers connect mathematical meanings, student thinking, interaction, resources, emotion, and context to specific evidence and a next instructional decision. Larger and longitudinal studies should now test the transfer and durability of these patterns using observations, student perspectives, and learning indicators. Until then, the present study offers a bounded, practice-based account from Panama rather than a causal evaluation of programme impact.

Declarations

Author contributions

Keila Chacón-Rivadeneira: Conceptualization, methodology, data curation, investigation, visualization, writing—original draft, writing—review and editing. Orlando García-Marimón: Conceptualization, methodology, formal analysis, investigation, visualization, writing—original draft, writing—review and editing. Luisa Morales-Maure: Conceptualization, project administration, resources, supervision, validation, writing—original draft, writing—review and editing. Agustín Alfredo Torres-Rodríguez: Data curation, software, formal analysis, validation, visualization, writing—review and editing.

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Competing interests

Luisa Morales-Maure serves as a Section Editor of Global Science Today. For this submission, she had no access to reviewer identities, confidential reviewer reports, editorial deliberations, or decision-making. Editorial handling and decision responsibility were assigned independently by the journal. The other authors declare no competing interests.

Ethics approval and consent to participate

Ethics procedures and protocol status are reported in Section 3.6. All participants were adults and provided written informed consent. Earlier programme phases were covered by Universidad de Panamá protocols CBUP/298/2019, CBUP/279/2021, and CBUP/448/2021; the continuing secondary analytic extension was approved by the Bioethics Committee of Universidad de Santander under CBI-USantander-M-087-2025 on 1 July 2025. No direct contact with minors or collection of new student data occurred in this analysis.

Consent for publication

Participants provided written consent for research use of their anonymised adult-participant materials and for publication of de-identified excerpts. Publication is limited to short de-identified excerpts and bounded contextual descriptions; school, community, and personally identifying information has been withheld to minimise re-identification risk.

Data availability

The dataset contains context-rich written and audiovisual materials from two teachers and evaluative institutional records. Public release could permit re-identification of participants or schools and is therefore restricted under the applicable ethics approvals. De-identified excerpts supporting the principal interpretations are included in the manuscript. Additional bounded materials may be considered by the corresponding author for editorial verification, subject to participant confidentiality, ethics restrictions, and institutional data-governance requirements.

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