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ICT in Mathematics Teaching and the Professional Development of Master's Student-Teachers

TIC no ensino da Matemática e desenvolvimento profissional de mestrandos-docentes
TIC en la enseñanza de la Matemática y desarrollo profesional de docentes maestrandos

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Abstract:
This article analyses the effects of the course unit Information and Communication Technologies in Mathematics Teaching, offered within the Master's Degree in Methodology of Mathematics Teaching at ISCED-Benguela, on the professional development of master's student-teachers of Mathematics. The scientific object of the study was defined across three articulated dimensions: the strengthening of participants' perceived pedagogical-technological competences, the observable change between entry and exit levels, and the relationship between perceived gains and satisfaction with the training. The working hypothesis was that participation in the course unit would be associated with a statistically significant improvement in self-assessed competence and high levels of satisfaction. Methodologically, the study is empirical, descriptive-analytical and mixed-methods, based on an initial diagnostic questionnaire and a final exit-profile questionnaire. After data harmonisation, the analysis focused on 24 participants who answered both instruments. Quantitative data were analysed through descriptive statistics and the Wilcoxon test, whereas open-ended responses were subjected to thematic content analysis. Results show a positive and statistically significant evolution between the level retrospectively assigned to the moment before the module and the exit level ($Z = 4.28$; $p < 0.001$), with an average gain of 1.25 points on a five-level scale. The highest mean scores were found in the dimensions of pedagogical understanding of technologies ($M = 4.77$) and lesson planning and didactic integration ($M = 4.68$), while satisfaction with the module was also very high ($M = 4.89$). It is concluded that the course unit contributed positively to the consolidation of competences with potential transfer to teaching practice, although technical and contextual challenges remain.

Keywords:
Information and Communication Technologies; Mathematics Teaching; Teacher Education; Teacher Professional Development; Pedagogical Technology Integration.

Resumo:
Este artigo analisa os efeitos da unidade curricular Tecnologias de Informação e Comunicação no Ensino da Matemática, integrada no Mestrado em Metodologia do Ensino da Matemática do ISCED-Benguela, sobre o desenvolvimento profissional de mestrandos-docentes de Matemática. O objecto científico do estudo foi delimitado em três planos articulados: o reforço das competências pedagógico-tecnológicas percebidas pelos participantes, a mudança observável entre o momento de entrada e o momento de saída e a relação entre os ganhos percebidos e o grau de satisfação com a formação. Partiu-se da hipótese de que a frequência da unidade curricular estaria associada a uma melhoria estatisticamente significativa da autoavaliação de competência e a níveis elevados de satisfação. Metodologicamente, trata-se de um estudo empírico, descritivo-analítico, de abordagem mista, com recurso a um questionário de diagnóstico inicial e a um questionário final de perfil de saída. Após harmonização das bases, a análise incidiu sobre 24 participantes que responderam aos dois instrumentos. Os dados quantitativos foram tratados por estatística descritiva e teste de Wilcoxon, enquanto as respostas abertas foram submetidas a análise temática de conteúdo. Os

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resultados mostram evolução positiva e estatisticamente significativa entre o nível retrospectivamente atribuído ao momento anterior e o nível de saída ($Z = 4,28$; $p < 0,001$), com ganho médio de 1,25 pontos numa escala de cinco níveis. As médias mais elevadas concentraram-se nas dimensões de compreensão pedagógica das tecnologias ($M = 4,77$) e planificação e integração didáctica ($M = 4,68$), mantendo-se também muito elevada a satisfação com o módulo ($M = 4,89$). Conclui-se que a unidade curricular contribuiu positivamente para a consolidação de competências com potencial de transferência para a prática docente, embora persistam desafios de natureza técnica e contextual.

Palavras-chave:
Tecnologias de Informação e Comunicação; Ensino da Matemática; Formação de Docentes; Desenvolvimento Profissional Docente; Integração Pedagógica das Tecnologias.

Resumen:
Este artículo analiza los efectos de la unidad curricular Tecnologías de la Información y la Comunicación en la Enseñanza de la Matemática, integrada en la Maestría en Metodología de la Enseñanza de la Matemática del ISCED-Benguela, sobre el desarrollo profesional de docentes maestrandos de Matemática. El objeto científico del estudio fue delimitado en tres planos articulados: el fortalecimiento de las competencias pedagógico-tecnológicas percibidas por los participantes, el cambio observable entre el momento de entrada y el momento de salida, y la relación entre las ganancias percibidas y el grado de satisfacción con la formación. Se partió de la hipótesis de que la frecuencia de la unidad curricular estaría asociada a una mejora estadísticamente significativa de la autoevaluación de competencias y a niveles elevados de satisfacción. Metodológicamente, se trata de un estudio empírico, descriptivo-analítico, de enfoque mixto, con uso de un cuestionario de diagnóstico inicial y un cuestionario final de perfil de salida. Tras la armonización de las bases, el análisis incidió en 24 participantes que respondieron a ambos instrumentos. Los datos cuantitativos fueron tratados mediante estadística descriptiva y prueba de Wilcoxon, mientras que las respuestas abiertas fueron sometidas a análisis temático de contenido. Los resultados muestran una evolución positiva y estadísticamente significativa entre el nivel atribuido retrospectivamente al momento anterior y el nivel de salida ($Z = 4,28$; $p < 0,001$), con una ganancia media de 1,25 puntos en una escala de cinco niveles. Las medias más elevadas se concentraron en las dimensiones de comprensión pedagógica de las tecnologías ($M = 4,77$) y planificación e integración didáctica ($M = 4,68$), manteniéndose también muy elevada la satisfacción con el módulo ($M = 4,89$). Se concluye que la unidad curricular contribuyó positivamente a la consolidación de competencias con potencial de transferencia a la práctica docente, aunque persisten desafíos de naturaleza técnica y contextual.

Palabras clave:
Tecnologías de la Información y la Comunicación; Enseñanza de la Matemática; Formación Docente; Desarrollo Profesional Docente; Integración Pedagógica de las Tecnologías.

INTRODUCTION

The teaching of mathematics has been progressively impacted by demands that go beyond the transmission of content, calling on teachers to engage in more reflective, contextualized, and technologically demanding didactic work . The presence of digital

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technologies in schools, although uneven, has altered the landscape of teaching practice and made the discussion about the quality of their pedagogical integration unavoidable. In this regard, the problem no longer lies solely in access to tools, but in the ability to select , adapt, and articulate them with learning objectives , student profiles, and the real conditions of each context.

In the field of Mathematics Education, this issue takes on particular importance. Digital tools, teaching support platforms, visualization applications, and interactive environments can expand the possibilities for representation, exploration, simulation, communication, and problem-solving. However, the literature has shown that the educational potential of these technologies does not automatically materialize . Their effectiveness depends on how the teacher integrates them into lesson planning , classroom management, learning mediation, and assessment (MISHRA; KOEHLER, 2006; HARRIS; MISHRA; KOEHLER, 2009).

It is within this framework that the curricular unit Information and Communication Technologies in Mathematics Teaching is situated, integrated into the Master's Degree in Methodology of Mathematics Teaching at ISCED-Benguela. The Course's Pedagogical Project presents the master's degree as an institutional response oriented towards strengthening the methodological, scientific, and professional skills of mathematics teachers, with a particular focus on secondary education, and includes among its specific objectives the expansion of the professional pedagogical skills necessary for the use of information and communication technologies in the teaching and learning process of mathematics (ISCED-BENGUELA, 2022).

The scientific object of this study was therefore defined as the formative effectiveness of the aforementioned curricular unit, understood on three interconnected levels: the reinforcement of the skills perceived by the participants, the observable change between the initial diagnosis and the exit level, and the relationship between the perceived gains and the degree of satisfaction with the training. Based on this delimitation, the research was guided by three research questions:

- PI1 — To what extent did the Information and Communication Technologies in Mathematics Education course unit contribute to strengthening the pedagogical-technological skills perceived by the master's students?
- PI2 — What changes are observed between the initial diagnosis and the self-assessed exit level of the participants?
- PI3 — How do perceived gains relate to the participants' level of satisfaction with the course unit?

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Based on these questions, five objectives were defined : to analyze the participants' initial level; to verify the evolution between the pre-test and the post-test; to identify the dimensions with the greatest progress; to analyze the degree of satisfaction with the curricular unit; and to discuss the formative effectiveness of the module in light of the literature and regulatory documentation of the course. As an analytical hypothesis, it was assumed that participation in the curricular unit would be associated with a statistically significant improvement in self-assessment of competence and high levels of satisfaction.

The relevance of this study is evident on three levels. Pedagogically, it offers evidence on the technological training of mathematics teachers in a postgraduate context. Curricularly, it allows for a comparison of empirical results with the exit profile and objectives expressed in the course syllabus. And scientifically, it contributes to the discussion on teacher professional development, the pedagogical integration of technologies, and the evaluation of training activities in higher education (DESIMONE, 2009; GUSKEY, 2002).

2. THEORETICAL FRAMEWORK

2.1 Teacher training, professional development and reflective practice

Teacher training, especially at the postgraduate level, has been increasingly understood as a continuous process of professional development and not merely as a one-off updating of techniques. Nóvoa (2009) emphasizes that quality training is built upon the profession, collective work , and the teacher's ability to critically reflect on their own practice. Similarly, Tardif (2014) reminds us that teaching knowledge is not solely academic; it is also experiential knowledge, reconfigured by practice, context, and professional interactions .

This perspective helps to understand why training actions aimed at practicing teachers tend to produce better results when they are linked to concrete problems of the profession. Schön (2000) showed that the reflective professional learns when confronting the complexity of practice, revising their assumptions and reconstructing their repertoire of action . In courses aimed at teachers, training effectiveness thus depends on the possibility of linking new content to real situations of planning, conducting the class and evaluating learning.

In the specific case of mathematics teacher training, professional development involves the articulation between mathematical knowledge, didactic knowledge , sensitivity to students' difficulties, and the ability to select relevant resources. When technology enters this framework,

it does not replace pedagogical work; rather, it demands an even more refined level of professional decision-making from the teacher.

2.2 Digital technologies and mathematics education

International literature has shown that the educational integration of technologies requires a type of teaching knowledge that goes beyond the technical mastery of the tools. The TPACK model, formulated by Mishra and Koehler (2006), argues that teachers need to articulate technological, pedagogical, and content knowledge, avoiding both technicality and the simple digital transposition of traditional practices. In Mathematics Education, this articulation is crucial because technology only becomes pedagogically fruitful when it helps to give meaning to concepts, representations, and problem-solving activities .

Harris, Mishra , and Koehler (2009) reinforce this idea by arguing that learning planning should start from pedagogical goals and types of activity , and not from the tool itself. Instead of asking which application to use, the teacher needs to ask what learning experience they want to promote, what reasoning they want to develop, and what role technology will play in that process. This shift in focus is particularly important in Mathematics, a discipline in which dynamic visualization, experimentation, and conjecture can be strongly enhanced by appropriate software and platforms.

However, the integration of ICT faces persistent obstacles. Bingimlas (2009) highlights, among the most recurring barriers, insufficient training, infrastructure limitations , technical insecurity, and the difficulty of converting digital resources into pedagogically consistent learning situations. Consequently, training programs that simultaneously address pedagogical understanding, professional confidence, and practical experimentation tend to be more promising than actions focused solely on operational training.

2.3 Evaluation of training programs and use of diagnostic and exit questionnaires

The evaluation of training programs should answer not only the question of participant satisfaction, but also what has actually changed as a result of the training process. Guskey (2002) argues that analyzing the effectiveness of training actions requires multiple levels of observation, including reaction , learning, and implications for practice. Desimone (2009), in turn, draws attention to the need for conceptually robust models and instruments that allow for monitoring changes between the initial and final situations.

In this context, diagnostic and exit questionnaires serve a dual purpose. On the one hand, they allow mapping the starting point, expectations, and training needs of the participants; on the other hand, they offer indicators of perceived change, satisfaction, and self-assessment of the exit level. Although they do not replace external performance measures, these instruments are particularly useful in postgraduate training contexts, where the analysis of teachers' perception of their own development constitutes a relevant part of understanding the training process.

From a qualitative point of view, content analysis of open-ended responses broadens the understanding of numerical data, allowing the identification of core meanings, convergences, and divergences in how participants interpret their gains and difficulties. Bardin (2016) demonstrates that this procedure is especially fruitful when the aim is to capture the meanings attributed by subjects to learning processes, changes in perception, and formative experiences.

3. METHODOLOGY

3.1 Nature and design of the study

The study is empirical in nature, descriptive-analytical, with a mixed-methods approach. The quantitative component focused on closed-ended responses collected at two points in the training process, while the qualitative component was based on open-ended responses regarding training needs, expectations, perceived gains, remaining difficulties, and suggestions for future editions.

From a design perspective, this is a pre- and post-training study. Two instruments were used: an initial diagnostic questionnaire, applied before the start of the course unit, and a final questionnaire on perception of the exit profile, applied after its completion. The instruments are not entirely symmetrical, since the final questionnaire includes retrospective items about the situation prior to the module and specific satisfaction items. Even so, both allow for a substantive comparison around the central object of the study.

3.2 Context, participants and regulatory documentation

This research was developed within the scope of the curricular unit Information and Communication Technologies in Mathematics Teaching, belonging to the 1st year, 1st semester of the Master's Degree in Methodology of Mathematics Teaching at ISCED-Benguela.

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According to the Course's Pedagogical Project , this curricular unit integrates the transversal structure of the study plan, with 75 hours and 5 credit units, and was designed to contribute to the professional development of master's students in the pedagogically oriented use of technologies (ISCED-BENGUELA, 2022).

The analytical sample resulted from harmonizing the two databases and consisted of 24 participants who responded to both instruments. All were master's students and, considering the entry profile and target audience of the course, were treated as master's students-teachers of Mathematics. In terms of occupation, 20 participants (83.3%) worked in secondary education, 3 (12.5%) in higher education, and 1 (4.2%) in school management or pedagogical coordination.

The course syllabus, also considered in this study, defines as its general objective understanding the importance of ICT and using them as cognitive tools capable of enhancing the teaching and learning process of Mathematics. Among the planned contents are the pedagogical integration of technologies, barriers to their use, assessment of learning, teaching support platforms, data processing, resource production, and the exploration of specific tools, such as GeoGebra (ISCED-BENGUELA, n.d.).

3.3 Instruments, procedures and data processing

The initial diagnostic questionnaire collected information on profile, professional experience, general ICT proficiency, frequency of use, familiarity with platforms, contact with Artificial Intelligence, training needs, and learning expectations, the latter recorded in open-ended, free-response questions. The final questionnaire focused on retrospective self-assessment of the situation prior to the module, exit level, learning gains in 32 Likert -type items , overall perception of progress, exit profile, and satisfaction with the curricular unit, including single-choice items on the main perceived gain, the area of greatest improvement, the main remaining difficulty, and the aspect to be reinforced in future editions.

After data collection, the databases were harmonized to ensure correspondence between the same subjects at both time points. Cases without responses in both instruments were excluded, and a comparable database of 24 matched respondents was constructed. Quantitative data were treated using descriptive statistics, including frequencies, percentages, means, standard deviations, and grouping of items into analytical dimensions. The Wilcoxon test for paired samples was also applied, as this was an ordinal comparison between two assessment points. The open-ended, free-response questions in the initial diagnostic questionnaire were

subjected to thematic content analysis; the single-choice items in the final questionnaire relating to gains, difficulties, and suggestions were treated as categorical data using descriptive frequency statistics.

The items in the final questionnaire were organized into four analytical dimensions: pedagogical understanding of technologies; didactic planning and integration ; applied and operational use; and critical evaluation and adaptation. The internal consistency of these dimensions was estimated using Cronbach 's alpha . The open-ended questions from the initial diagnostic questionnaire were subjected to thematic content analysis, through floating reading, initial coding, grouping by categories, and interpretation of recurring core meanings (BARDIN, 2016).

3.4 Methodological limitations

The study has limitations that should be considered when interpreting the results. The sample size (n = 24), although sufficient for the non-parametric tests applied, is small and results from a convenience sampling process—the participants who responded to both instruments—which limits the generalizability of the results to other cohorts or institutional contexts.

Secondly, the design does not include a control or comparison group, so the observed evolution cannot be reliably attributed exclusively to the curricular unit, and it is not possible to completely exclude maturation effects, concurrent training experiences, or other uncontrolled variables throughout the semester.

Thirdly, the study relies predominantly on self-assessment and retrospective perception measures, without triangulation with objectively observed performance indicators, such as the analysis of lesson plans actually produced or direct observation of classes taught using technology. Associated with this point, a certain risk of social desirability in the responses cannot be excluded, particularly in the satisfaction items, given that the survey was applied in the context of the evaluation of the curricular unit itself by its managers.

Finally, the two instruments used are not entirely symmetrical, insofar as the final questionnaire includes retrospective items and satisfaction items absent from the initial diagnosis, which requires some caution in interpreting the pre-post comparison as a strictly equivalent measure at both time points.

4. RESULTS

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4.1 Entry situation and training needs

The initial diagnostic data shows that the participants did not start from a completely elementary level of contact with technologies. Nine participants (37.5%) rated their overall ICT proficiency as good, eight (33.3%) as average, three (12.5%) as low, two (8.3%) as very low, and two (8.3%) as very good. Regarding the frequency of using technologies to prepare classes or academic activities , 12 participants (50.0%) reported doing so frequently, 6 (25.0%) rarely, 5 (20.8%) sometimes, and 1 (4.2%) always.

The open-ended responses to the diagnostic questionnaire reinforce the idea that the group already had some familiarity with the digital world, but felt concrete shortcomings in its pedagogical appropriation. The most recurrent themes focused on five areas: pedagogical use of ICT; mastery of Google Classroom ; exploration of specific tools, such as GeoGebra and Google Forms ; educational use of AI; and assessment with digital support. Convergingly, learning expectations pointed to a desire to deepen the responsible use of technologies, align digital resources with pedagogical objectives , and produce materials applicable to mathematics classes. The following excerpts, taken from the open-ended responses to the diagnostic questionnaire and anonymized, illustrate this pattern of expectations:

- "Overall, I hope to develop strong skills in handling tools that will allow me to make math classes more dynamic, adopting active methodologies ." (Participant in the initial assessment, Mathematics teacher)
- "To deepen the work with GeoGebra , producing audio and video resources to support the teaching of mathematics." (Participant in the initial diagnosis, mathematics teacher)
- "Aligning the use of technologies with pedagogical objectives , contributing to a more dynamic, inclusive, and student-centered teaching approach." (Participant in the initial assessment, Mathematics teacher)

These results suggest that the curricular unit focused on an audience that already used technology to some extent, but still lacked greater pedagogical confidence, more didactic intentionality , and a greater repertoire for transforming digital resources into meaningful learning experiences.

Table 1 — Occupational characterization of the harmonized sample (N = 24)

Professional situation	n	%

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Year VII, v.1 2026 | Submission: 06/28/2026 | Accepted: 06/01/2026 | Publication: 07/03/2026

Mathematics teacher in secondary education	20	83.3
Professor of Mathematics in higher education	3	12.5
School manager or pedagogical coordinator	1	4.2

Source: research data, 2026.

4.2 Evolution between the moment prior to the module and the output level

In the final questionnaire, participants were asked to retrospectively assess their mastery of technologies applied to mathematics teaching before attending the module and then to rate the level achieved after its completion. This strategy allowed for obtaining a comparable measure of perceived change, albeit based on ordinal self-assessment.

The mean retrospective self-assessment at the previous time point was 2.42 (SD = 0.72), while the mean exit level reached 3.67 (SD = 0.56), on a scale of 1 to 5. The average perceived gain was 1.25 points (SD = 0.68). In individual terms, 22 of the 24 participants showed progress and only 2 remained at the same level, with no cases of regression.

Wilcoxon test confirmed that the difference between the two time points was statistically significant ($Z = 4.28$; $p < 0.001$; $r = 0.91$), which supports the hypothesis of positive evolution associated with the frequency of the curricular unit. In substantive terms, the results show a shift of the group, at the initial time point, to levels concentrated between medium, low and very low, and, at the end, to predominantly medium, high and very high levels.

Table 2 — Comparison between retrospective self-assessment of the previous moment and exit level.

Indicator	Average	DP	Median	Min.-Max.
Before the module	2.42	0.72	3	1-3
After the module	3.67	0.56	4	3-5
Perceived gain	1.25	0.68	1	0-3

Wilcoxon test for paired samples: $Z = 4.28$; $p < 0.001$; $r = 0.91$. Source: research data, 2026.

4.3 Performance by analytical dimensions

In order to refine the interpretation of the results, the 32 learning items from the final questionnaire were grouped into four analytical dimensions. The first, pedagogical understanding of technologies, included items related to the educational role of ICT, the understanding of its potential and limitations, and the distinction between instrumental use and

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pedagogically enriched integration. The second, didactic planning and integration , focused on items related to the selection of resources, their suitability to the teaching level, and the articulation between mathematical content, teaching strategies, and technology. The third, applied and operational use, focused on the use of software, platforms, and digital resources in concrete tasks. The fourth, critical evaluation and adaptation, included items related to the pedagogical evaluation of resources, the production of materials, and adaptation to real-world contexts.

As shown in Table 3, the highest averages were concentrated in pedagogical understanding of technologies (M = 4.77; SD = 0.26) and didactic planning and integration (M = 4.68; SD = 0.31). These were followed, with equally high values, by applied and operational use (M = 4.51; SD = 0.46) and critical evaluation and adaptation (M = 4.51; SD = 0.54). Cronbach 's alpha coefficients ranged from 0.71 to 0.90, revealing acceptable to very good internal consistency across the constructed dimensions.

These figures indicate that the strongest gains were not limited to simple technical training. The most significant progress occurred in the area of pedagogical understanding and didactic organization of teaching with technology, suggesting that the curricular unit acted on the educational meaning of the use of ICT and not just on the mastery of tools.

Table 3 — Means, standard deviations, and internal consistency of the analytical dimensions

Dimension	Items	Average	DP	Alpha
Pedagogical understanding	8	4.77	0.26	0.71
Planning and didactic integration	8	4.68	0.31	0.81
Applied and operational use	9	4.51	0.46	0.89
Critical evaluation and adaptation	7	4.51	0.54	0.90

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Satisfaction with the module	8	4.89	0.23	0.79

Source: research data, 2026.

4.4 Items with the highest and lowest average

In the item-by-item analysis, the highest values were observed in statements related to understanding the pedagogical role of technologies and the ability to distinguish between a lesson merely supported by technology and a lesson effectively enriched by it. Items associated with identifying appropriate technological resources and choosing technologies based on content, teaching level, and student profile also stood out.

On the other hand, the items with relatively lower averages, although still high, focused on the design of mathematical tasks in which students use technology to explore and validate results, on the proposal of digital resources that promote active learning , on adapting the use of technologies to the real limitations of schools, and on the use of specific software such as GeoGebra , Desmos , and spreadsheets. Taken together, these data suggest that the most demanding aspects remain linked to fine-tuned operationalization and the transfer to more complex practical scenarios.

Table 4 — Items with the highest and lowest average scores in the final questionnaire.

Position	Summary of the item	Average	DP
Higher	The importance of integrating technology into education.	4.96	0.20
Higher	Difference between technical support and educational enrichment.	4.92	0.28
Higher	Understanding the role of technologies in teaching and learning.	4.83	0.38
Lower	Designing tasks with exploration and validation through technology.	4.33	0.76
Lower	Promoting active learning with digital resources	4.38	0.88
Lower	Adapting the use of ICT to the real conditions of the school.	4.42	0.83

Source: research data, 2026.

4.5 Perceived gains, remaining difficulties and satisfaction

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The frequency data from the final questionnaire essentially converged with the pattern already suggested by the open-ended responses of the initial diagnosis. When asked to indicate the main gain obtained from the module, 15 participants (62.5%) mentioned a better understanding of the pedagogical integration of technologies. This was followed by a better understanding of the challenges and limitations of technologies (16.7%), greater confidence in applying them in mathematics classes (8.3%), a greater ability to plan lessons with digital resources (8.3%), and a better ability to produce digital resources (4.2%).

When asked about the area in which they had improved the most, participants highlighted planning mathematics lessons with technology (33.3%), theoretical knowledge about educational technologies (20.8%), and critical reflection on the use of technologies (16.7%). The production of digital resources, the practical use of tools, and assessment with technological support were also mentioned, although less frequently. This distribution of responses essentially confirms the interpretation already suggested by the open-ended responses in the initial diagnosis (section 4.1): the most recognized gain was not isolated technical mastery, but the transition to a more confident, critical, and pedagogical understanding of the use of technologies.

It is important to note that, unlike the initial diagnostic questionnaire, the items in the final questionnaire relating to the main gain, the area of greatest improvement, and the remaining difficulty were designed as single-choice questions from a closed set of options, and not as open-ended questions with free responses. For this reason, the data supporting them are categorical in nature—duly quantified in Table 5—and it is not possible to illustrate them with individual textual excerpts without risking attributing formulations to the participants that they did not write. For methodological rigor, this section was kept exclusively anchored in the frequency data already reported.

Regarding remaining difficulties, three main categories stood out: technical proficiency in some digital tools (37.5%), material and technological limitations of the school context (25.0%), and difficulties related to assessment using technology or lesson planning with pedagogical integration (16.6% combined). In addition, four participants (16.7%) stated that they no longer experienced significant difficulties.

Satisfaction levels were very high. The satisfaction dimension with the module reached an average of 4.89 (SD = 0.23), with the best-rated item being the participatory nature of the methodology, followed by the usefulness of the examples and resources used, and the recommendation of the module to other teachers or students in the field. The overall rating of the module was distributed between excellent (79.2%), very good (12.5%), and good (8.3%).

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These data suggest that the perceived gains not only coexisted with satisfaction but also contributed decisively to it.

Table 5 — Summary of perceived gains, remaining difficulties, and satisfaction.

Category	Most frequent answer	n	%
Main gain	Better understanding of the pedagogical integration of technologies.	15	62.5
Major evolution	Planning math lessons with technology	8	33.3
Remaining difficulty	Technical proficiency in some digital tools	9	37.5
Aspect to emphasize	More time for exploring GeoGebra , Desmos, and spreadsheets.	11	45.8
Overall module classification	Excellent	19	79.2

Source: research data, 2026.

5. DISCUSSION

The results confirm, firstly, the relevance of the curricular unit within the formative architecture of the Master's Degree in Methodology of Mathematics Teaching. The Course's Pedagogical Project explicitly foresees the expansion of the professional pedagogical skills necessary for the use of information and communication technologies in the teaching and learning process of Mathematics and assigns the curricular unit a transversal role in strengthening the professional profile of the master (ISCED-BENGUELA, 2022). The evolution observed in the empirical data shows that this purpose did not remain only at the level of curricular prescription: it found correspondence in the formative experience actually lived by the participants.

Secondly, the results help to clarify the nature of the gains produced. The improvement hypothesis was confirmed statistically, but, more importantly, it was confirmed qualitatively. The dimensions that grew the most were precisely those associated with pedagogical understanding and didactic planning , and not just the operational use of tools. This finding converges with the TPACK theoretical framework, according to which the quality of technological integration depends on the articulation between technological, pedagogical, and content knowledge (MISHRA; KOEHLER, 2006). The curricular unit seems to have acted precisely on this point of articulation, shifting participants from a diffuse relationship with technology to a more pedagogically intentional one.

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This movement also confirms the argument of Harris, Mishra , and Koehler (2009) that planning should start from learning goals and types of activity , and not from tools taken in isolation. The fact that participants identified a better understanding of the pedagogical integration of technologies as the main gain, and lesson planning with technology as the greatest improvement, suggests that the training acted on the logic of teaching work, and not just on its instrumental dimension.

The results also align with the literature on teacher professional development. Nóvoa (2009) and Tardif (2014) argue that meaningful training is that which is rooted in the profession, in the concrete problems of practice, and in the teacher's ability to reconfigure their knowledge in light of experience. The sample for this study consisted predominantly of secondary school teachers, meaning that the observed gains tend to project onto real teaching contexts. In this sense, the curricular unit appears to have functioned as a space for professional reconstruction, rather than simply as a technological updating course.

The difference between the initial diagnosis and the retrospective reassessment of the starting point also deserves to be highlighted. Participants tended to rate their previous level lower in the final questionnaire than in the initial diagnosis. Instead of interpreting this as inconsistency, the discussion suggests that it is a phenomenon of recalibration of self-perception . As teachers gained a better understanding of the complexity of the pedagogical integration of technologies, they became more demanding in their assessment of what they knew before. This reading is consistent with the notion of reflective practice discussed by Schön (2000).

The remaining weaknesses, in turn, contribute to complicating the results. The technical proficiency in certain tools, the material limitations of schools, and assessment using technology remained significant challenges. This corroborates Bingimlas 's (2009) warning that the integration of ICT continues to be conditioned by factors... infrastructural , formative and contextual.

The same pattern explains why the operational use and critical adaptation dimensions, although high, were below the averages observed in pedagogical understanding and planning. In other words, training seems to have changed the way of thinking about and planning technology first, while the full consolidation of the technical-operational dimension requires more time, more practice, and better implementation conditions.

The relationship between perceived gains and satisfaction also deserves highlighting. The literature on the evaluation of training programs indicates that satisfaction, by itself, does not prove learning; however, when linked to consistent indicators of progress, it can be interpreted as complementary evidence of the program's effectiveness (GUSKEY, 2002;

DESIMONE, 2009). This is what was observed in this study. Satisfaction was very high, but it did not appear in isolation or disconnected from the results; on the contrary, it was associated with clear gains in several dimensions and a robust perception of usefulness for teaching practice.

Taken together, the findings suggest that the curricular unit studied contributed to the professional development of master's students who were teaching mathematics, not simply because it introduced them to new tools, but because it helped them to pedagogically reorganize their way of looking at technologies, lesson planning, and the possibilities of mathematical learning mediated by digital resources. This seems to be, ultimately, the most relevant contribution of the training analyzed.

6. CONCLUSION

6.1 Answering the research questions

Regarding question PI1, the results allow us to affirm that the curricular unit contributed consistently to strengthening the pedagogical-technological skills perceived by the master's students-teachers, with emphasis on the dimensions of pedagogical understanding of technologies (M = 4.77) and didactic planning and integration (M = 4.68). As for PI2, a statistically significant change was observed between the initial diagnosis and the exit level ($Z = 4.28$; $p < 0.001$), with an average gain of 1.25 points and progression in 22 of the 24 participants, without any case of regression. Regarding PI3, the data show that the perceived gains and the degree of satisfaction (M = 4.89) did not appear as independent phenomena: satisfaction was associated with clear gains and a robust perception of usefulness for teaching practice, which reinforces the interpretation of satisfaction as a complementary, and not a substitute, indicator of formative effectiveness.

6.2 Contribution of the study

Beyond answering the three research questions, the study contributes to the discussion on teacher professional development and the pedagogical integration of technologies by showing, in a postgraduate training context in Angola, a pattern consistent with the TPACK framework (MISHRA; KOEHLER, 2006): the most significant gains were concentrated in the articulation between pedagogical and technological knowledge, and not in the isolated technical mastery of tools. The study also empirically demonstrates the usefulness of interpreting

differences between initial self-assessment and retrospective reassessment not as methodological inconsistency, but as a possible recalibration effect of self-perception associated with the development of reflective practice (SCHÖN, 2000), opening a relevant avenue for further pre-post studies based on self-report .

6.3 Limitations and future research agenda

The study presents limitations that recommend caution in generalizing the results: the small and convenience size of the sample; the absence of a control group, which prevents attributing the gains exclusively to the curricular unit with certainty; the predominant reliance on self-assessment measures, without triangulation with objectively observed performance; the risk of social desirability in satisfaction responses; and the partial asymmetry between the two instruments used. Even so, the harmonization of the sample, the combined use of quantitative and qualitative analysis, the use of appropriate statistical tests, and the articulated reading with the literature and regulatory documentation of the course provide interpretative solidity to the conclusions presented.

As a future research agenda, it is suggested that the study be replicated with larger samples and, whenever possible, with a comparison group; that self-assessment be triangulated with objectively observed performance measures, such as the analysis of lesson plans produced by participants or direct observation of classes taught; and that participants be followed longitudinally to verify the extent to which perceived gains actually translate into sustained changes in teaching practice in real school contexts.

In summary, the study argues that the analyzed curricular unit constituted a relevant formative device for the professional development of mathematics teachers in postgraduate training. Its most significant contribution lay less in simple instrumental training and more in building a pedagogical intelligence in the use of technologies. In contexts where educational innovation is frequently confused with superficial adherence to tools, this result seems particularly relevant both for formative practice and for future research in the area.

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