

Mathematics education laboratories in higher education in Portugal: what does a bibliographic study reveal?

Laboratorios de enseñanza de matemáticas en la educación superior en Portugal: ¿qué revela un estudio bibliográfico?

Laboratoires d'enseignement des mathématiques dans l'enseignement supérieur au Portugal : que révèle une étude bibliographique ?

Laboratórios de educação matemática no ensino superior em Portugal: o que revela um estudo bibliográfico?

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Abstract

Mathematics Education Laboratories (MEL) can play a relevant role in the training of teachers who will teach Mathematics in Portugal, functioning as privileged spaces for articulating theory, practice, and research. In this study, we seek to understand what Portuguese scientific productions focused on MEL within public higher education reveal about the conceptions attributed to these environments and the repercussions of the work carried out in them for teacher education and professional development. Accordingly, the aim was to systematically map and analyse the existing academic productions, identifying the conceptions associated with MEL, the formative practices they promote, and the contributions they generate towards strengthening professional identity and teaching practice. To this end, a systematic literature review was conducted, guided by the POT strategy (Population, Outcome, Type of study), adapted from the PICOT structure, and by the principles of the PRISMA 2020 protocol. The

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research was carried out in the repositories of Portuguese public higher education institutions, following the phases of identification, screening, eligibility, and inclusion, and considering only productions that explicitly addressed MEL in the university context. The analysis revealed varied conceptions of MEL, formative practices that value experimentation, reflection, and the integration between theory and practice, as well as significant repercussions for teacher education. The results highlight the importance of rethinking, strengthening, and expanding these formative environments, recognising their multifaceted nature, which transcends the physical dimension of space, and reinforce the need to broaden the dialogue between university, community, and pedagogical practice, contributing to the ongoing debate on mathematics teacher education.

Keywords: Mathematics education laboratory, Teacher training, Professional development.

Resumen

Los laboratorios de educación matemática (LEM) pueden desempeñar un papel relevante en la formación de los profesores que enseñarán Matemáticas en Portugal, constituyéndose como espacios privilegiados para articular teoría, práctica e investigación. En este estudio, buscamos comprender lo que revelan las producciones científicas portuguesas centradas en los LEM de la enseñanza superior pública acerca de las concepciones atribuidas a estos entornos y de las repercusiones del trabajo allí desarrollado para la formación y el desarrollo profesional. Así, el objetivo fue mapear y analizar sistemáticamente las producciones académicas existentes, identificando las concepciones asociadas a los LEM, las prácticas formativas que estos promueven y las contribuciones que generan para el fortalecimiento de la identidad y de la práctica docente. Para ello, se llevó a cabo una revisión sistemática de la literatura, orientada por la estrategia POT (Población, Outcome, Tipo de estudio), adaptada de la estructura PICOT, y por los principios del protocolo PRISMA 2020. La investigación se realizó en los repositorios de las instituciones públicas de educación superior portuguesas, siguiendo las fases de identificación, cribado, elegibilidad e inclusión, y contemplando únicamente producciones que abordaban explícitamente los LEM en el contexto universitario. El análisis reveló diversas concepciones sobre los LEM, prácticas formativas que valorizan la experimentación, la reflexión y la integración entre teoría y práctica, así como repercusiones significativas para la formación docente. Los resultados destacan la importancia de repensar, fortalecer y ampliar estos entornos

formativos, reconociendo su naturaleza multifacética, que trasciende la dimensión física del espacio, y refuerzan la necesidad de ampliar el diálogo entre universidad, comunidad y práctica pedagógica, contribuyendo al debate permanente sobre la formación de profesores de Matemáticas.

Palabras clave: Laboratorio de educación matemática, Formación de profesores, Desarrollo profesional.

Résumé

Les laboratoires d'éducation mathématique (LEM) peuvent jouer un rôle pertinent dans la formation des enseignants qui enseigneront les Mathématiques au Portugal, en se constituant comme des espaces privilégiés pour articuler théorie, pratique et recherche. Dans cette étude, nous cherchons à comprendre ce que révèlent les productions scientifiques portugaises centrées sur les LEM de l'enseignement supérieur public quant aux conceptions attribuées à ces environnements et aux répercussions du travail qui y est réalisé sur la formation et le développement professionnel. Ainsi, l'objectif a été de cartographier et d'analyser systématiquement les productions académiques existantes, en identifiant les conceptions associées aux LEM, les pratiques formatives qu'ils promeuvent et les contributions qu'ils apportent au renforcement de l'identité et de la pratique enseignante. Pour cela, une revue systématique de la littérature a été réalisée, guidée par la stratégie POT (Population, Outcome, Type d'étude), adaptée de la structure PICOT, et par les principes du protocole PRISMA 2020. La recherche a été menée dans les dépôts institutionnels des établissements publics d'enseignement supérieur portugais, suivant les phases d'identification, de sélection, d'éligibilité et d'inclusion, et ne retenant que les productions abordant explicitement les LEM dans le contexte universitaire. L'analyse a révélé diverses conceptions des LEM, des pratiques formatives valorisant l'expérimentation, la réflexion et l'articulation entre théorie et pratique, ainsi que des répercussions significatives pour la formation des enseignants. Les résultats soulignent l'importance de repenser, de renforcer et d'élargir ces environnements formatifs, en reconnaissant leur nature multifacette, qui dépasse la dimension physique de l'espace, et renforcent la nécessité d'amplifier le dialogue entre université, communauté et pratique pédagogique, contribuant au débat permanent sur la formation des enseignants de mathématiques.

Mots-clés : Laboratoire d'éducation mathématique, Formation des enseignants, Développement professionnel.

Resumo

Os laboratórios de educação matemática (LEM) podem desempenhar um papel relevante na formação de professores que ensinarão Matemática em Portugal, constituindo-se como espaços privilegiados para articular teoria, prática e investigação. Neste estudo, procuramos compreender o que revelam as produções científicas portuguesas centradas nos LEM do ensino superior público acerca das conceções atribuídas a estes ambientes e das repercussões do trabalho neles desenvolvido para a formação e o desenvolvimento profissional. Assim, o objetivo foi mapear e analisar sistematicamente as produções académicas existentes, identificando as conceções associadas aos LEM, as práticas formativas que estes promovem e os contributos que geram para o fortalecimento da identidade e da prática docente. Para tal, realizou-se uma revisão sistemática da literatura, orientada pela estratégia POT (População, Outcome, Tipo de estudo), adaptada da estrutura PICOT, e pelos princípios do protocolo PRISMA 2020. A pesquisa foi conduzida nos repositórios das instituições de ensino superior públicas portuguesas, seguindo as fases de identificação, triagem, elegibilidade e inclusão, e contemplando apenas produções que abordavam explicitamente LEM em contexto universitário. A análise revelou conceções variadas sobre os LEM, práticas formativas que valorizam a experimentação, a reflexão e a integração entre teoria e prática, bem como repercussões significativas para a formação docente. Os resultados destacam a importância de repensar, fortalecer e expandir estes ambientes formativos, reconhecendo a sua natureza multifacetada, que transcende a dimensão física do espaço, e reforçam a necessidade de ampliar o diálogo entre universidade, comunidade e prática pedagógica, contribuindo para o debate permanente sobre a formação de professores de Matemática.

Palavras-chave: Laboratório de educação matemática, Formação de professores, Desenvolvimento profissional.

Mathematics education laboratories in higher education in Portugal: what does a bibliographic study reveal?

Introduction

Educational environments play a very important role in teaching and learning processes. Among these 'noospheres', mathematics education laboratories (MEL) stand out as privileged spaces for doing mathematics and reflecting upon this field, which is as relevant as it is problematic.

Considering the pressing educational issues we currently face, especially within the scope of teacher training and Mathematics teaching in Portugal, a deeper knowledge of MELs may have a significant influence on the (re)formulation of teacher training policies and on the (re)definition of curricula, with clear effects on students' learning (Meurer, Borges & Hermann, 2023). More specifically, it could contribute to the development of specific and transversal mathematics competencies, which are important for human sustainability (Pereira et al., 2022; Kaushik Das, 2020).

In this context, our research question is: *What do Portuguese productions focused on public higher education mathematics education laboratories reveal about the conceptions related to these environments and the repercussions of the work performed in them for the training and professional development of educators who teach Mathematics in Portugal?*

Thus, this study seeks to map and analyze Portuguese academic productions on Mathematics Education Laboratories within public higher education, identifying the conceptions associated with these formative spaces and the repercussions of the work conducted in them for the training and professional development of educators who teach Mathematics in Portugal.

Given the need to ensure rigor and systematization in the study, we conducted a systematic review guided by the principles of the PRISMA 2020 statement, which required the prior definition of the population, analytical focus and eligible types of studies, operationalized through the POT strategy.

In the scope of this investigation, we focused on Portuguese scientific publications on mathematics education laboratories located within public universities or Escolas Superiores de Educação (ESE) in Portugal.

Regarding the collection of documents to be investigated, we were interested in every scientific publication, including full articles published in journals or conference proceedings, doctoral theses and master's dissertations. These productions, which

discussed work performed in mathematics education laboratories in Portugal, were found at repositories of public higher education institutions offering teacher training degree programs in the country.

A brief theoretical foundation

In this section, we will provide the theoretical foundation for some of the points approached in this investigation. First, we discuss teacher training and professional development while highlighting the importance of this theme for this study. Next, we focus on mathematics education laboratories, exploring not only their conception as a physical space, but mainly as a training agent for (future) mathematics teachers.

Teacher training and professional development

It is relevant to explore the concepts of teacher training and teacher professional development, considering the importance they have in this study.

Teacher training is often understood as a formalization stage of teacher professionalization, which differentiates it from complementary, postgraduate or continuing education. It is based on a set of principles that support the construction of educational fundamentals, *lato sensu*. Initial training is the first part of the stage in which individuals are prepared to start their profession.

The initial formative stage was clearly different from the teacher education process itself, and the later stage was associated with professional development (Marcelo García, 1999).

Ponte (2005) highlights another difference. Professional training (also considered initial training) generally refers to a fragmented structure, organized into separate themes or specific disciplines, whereas professional development involves the teacher as a whole, encompassing their cognitive, affective and relational aspects. Therefore, initial training was predominantly theoretical and often remained within this scope, while professional development considered theory and practice interconnectedly.

It is evident that when Ponte (2005) established this relationship, the author constructed the criticism based on how professional training was usually viewed by higher education institutions and revealed in their curricula and formative paths. The distance between theory and practice weakened training and it could largely influence the way professional development was viewed by future teachers. Moreover, this initial training "may be conceived in a way that fosters teacher professional development, but

it might also contribute to a reduction in creativity, self-confidence, autonomy and sense of professional responsibility” (Ponte, 2005, p. 06, our translation).

From this perspective, it is important to emphasize the need for a connection between scientific, pedagogical and practical aspects in teacher professional training (Ponte, 2005; Ribeiro and Ponte, 2020). Throughout a training process that has these characteristics, future teachers ideally start to view themselves as professionals, identify needs and potentials to be discovered and developed, act accordingly and start the construction of their teaching identity (Nascimento et al., 2017). Thus, training is conceived as a *continuum*, in which (future) teachers should play a central and active role in their own professional development (Nóvoa, 1991; Flores, 2014; Nascimento et al., 2017).

Based on the aforementioned discussion, teacher training and professional development are deeply interconnected concepts, involving the harnessing of knowledge from theoretical and practical scopes in order to understand and fulfill the needs of the profession (Nascimento et al., 2017). Therefore, they are understood as complex, intricate, idiosyncratic and multidimensional fields of study, where numerous elements, individuals and spaces should be considered (Flores & Day, 2006). This is primarily due to the challenges that have been constantly posed by social, political and educational contexts over time.

As we understand the importance of reflecting, systematically and fundamentally, upon multifaceted experiences related to the integration between theory and practice in training, we advocate mathematics education laboratories as one of the structures able to effect this integration creatively in initial professional training, thus contributing significantly to the construction of professional identity and to professional development (Kaushik Das, 2020; Pereira et al., 2022; Silva, Silva & Ribas, 2024).

Mathematics Education Laboratories

According to Rodrigues & Gazire (2015, p. 117-118), seven categories of laboratories can be considered: laboratory/storage-archive, laboratory/classroom; laboratory/discipline; laboratory/technology laboratory; laboratory/traditional – mathematics laboratory; laboratory/learning environment – mathematics teaching laboratory and laboratory/training agent – mathematics education laboratory.

For this study, we chose to focus our analysis on the conception of this space not only as a learning environment, but especially as a training agent for (future) mathematics teachers.

From this perspective, the mathematics education laboratory should be a space that guides the development of multiple competencies indispensable for renewed and transformative (future) teaching, through the plural activities performed by its participants. However, merely labeling it as a place to perform practical activities, as it is often thought, or to apply knowledge constructed in other places or at other times would mean perpetuating the same mistake seen in several propositions to create laboratories and even degree programs.

It is vital to highlight that, according to Mota (2021), Kaushik Das (2020), Pereira *et al.*, (2022) and Silva, Silva & Ribas, (2024), a mathematics education laboratory should be constituted as an encouraging environment for the development of formative paths that acknowledge and integrate theory and practice as interdependent elements.

Besides interconnecting these two dimensions fundamentally, MELs should promote a sustained and continuous rethinking of the school curriculum and of various methodological perspectives that they are capable of materializing (Oliveira & Kikuchi, 2018; Kaushik Das, 2020; Mota, 2021; Pereira *et al.*, 2022; Meurer, Borges & Hermann, 2023; Silva, Silva & Ribas, 2024). In particular, it should support the critical reflective planning of different didactic experiences by adopting creative and appropriate approaches while focusing on society, school, students and the mathematics learning process. This interrelationship among academic mathematics, school mathematics and the mathematics 'of life' acknowledges different approaches and importances, without establishing any hierarchy (Oliveira & Kikuchi, 2018; Pereira *et al.*, 2022; Meurer, Borges & Hermann, 2023; Silva, 2023).

In order to foster these experiences for its participants, the MEL should not be a self-contained space. On the contrary, it should be open to the community, establishing a dynamic relationship with it. This opening could occur through *indoor* or *outdoor* movements; that is, by bringing the community into the MEL or by taking propositions developed within the laboratory out to the community. Thus, the definition of a space confined within four walls will be transcended.

These movements may favor, for instance, the desired early insertion of future teachers into school environments, whether formal or non-formal, encourage dialogue with in-service teachers and promote renewed critical reflections on different school realities, contributing to strengthening bonds with the school community (Cabrita, 2018; Oliveira & Kikuchi, 2018; Kaushik Das, 2020; Pereira *et al.*, 2022; Meurer, Borges & Hermann, 2023; Silva, Silva & Ribas, 2024).

Another crucial aspect to be considered is fostering a close relationship with research. Future teachers should not limit themselves to 'drawing from' investigations developed and published by others. Instead, they should participate actively in ongoing projects within their field, especially those involving professors who have an affinity for the laboratory. It will contribute to the constitution of investigative teachers, who systematically (re)think their own practice, aiming at their students' learning.

In conclusion, a fundamental characteristic of the mathematics education laboratory is the ability to interconnect training, investigation and expansion into the community. By intertwining these three elements, which provide a basis for higher education, as highlighted by Silva (2023) and Silva *et al.* (2023), it is possible to acknowledge that investigation and expansion into the community are not complements, but indispensable elements that are essential to solid and appropriate professional teacher training (Pereira *et al.*, 2022; Silva, 2020a, 2023; Silva *et al.*, 2023).

Methodological approach

This investigation makes use of a qualitative approach, supported by the ontological perspectives proposed by John Creswell (1994), which conceive reality as multiple and subjective. In the epistemological dimension, the author emphasizes the interaction between the researcher and the object of study, while they methodologically follow a logical-inductive approach. In this context, the aim is not to assemble the pieces of a pre-defined puzzle, but to construct a figure that takes shape as pieces are collected and examined, as highlighted by Wiley & Hatch (2002).

Furthermore, this investigation has a bibliographical nature, employing methods focusing on quantifying written communication processes and the use of indicators to measure scientific production, as proposed by Ciríaco & Arantes (2020). This type of study serves as a device that enables mapping, offering a specific reference to analyze a predetermined theme. As noted by Kitchenham and Charters (2007), systematic reviews are rigorous and structured procedures designed to minimize bias and ensure reliability through clear criteria for identifying, selecting, assessing and synthesizing relevant studies. The methodological approach was developed in order to meet these requirements, thus enabling the identification, selection, organization and critical analysis of scientific production on MEL in public higher education in Portugal.

The prisma statement and the POT strategy

The systematic review is grounded in the principles established by the PRISMA 2020 statement (Preferred Reporting Items for Systematic Reviews and Meta-Analyses), internationally recognized as one of the main methodological frameworks for ensuring rigor, transparency and reproducibility in literature reviews (Page *et al.*, 2021; Mendes & Pereira, 2021).

The search process was organized around the POT strategy (Population, Outcome, Type of Study), adapted from the PICOT structure (Population, Intervention, Comparison, Outcome, Type of Study), which is widely employed, particularly in review processes and search for evidence (Santos, Pimenta & Nobre, 2007).

In the context of this study, the following elements were considered:

- Population (P): academic productions related to Mathematics Education Laboratories in public higher education institutions in Portugal;
- Outcome (O): conceptions of MEL, the formative practices proposed and repercussions for teacher training and professional development;
- Type of Study (T): qualitative, quantitative or mixed-methods studies.

Based on this organization, the descriptors used in the document search – *laboratory*, *education* and *mathematics* – were employed in the repositories of Portuguese public higher education institutions that offer teacher education programs. No specific time window was established; therefore, all productions available in open-access format at the time of the search (April 2024) were included.

The search procedure followed the four stages defined by the PRISMA 2020 statement:

1. Identification – a search was conducted in academic databases and repositories, using combinations (in Portuguese and English) of the keywords *laboratory(ies)*, *education* and *mathematics*. When possible, the following filters were applied: *Portugal*, *public higher education* and *type of document* (scientific articles, texts published in conference proceedings, master's dissertations and doctoral theses). All records were exported to a reference manager, and duplicate documents were removed;
2. Screening – conducted by two independent reviewers, who reached a final decision by consensus. This stage involved reading titles and abstracts/descriptions, and the following texts were excluded: those that explicitly presented other meanings of *laboratory*, those that did not refer to the

Portuguese context or to public higher education, and studies for which the full text was not available.

3. Eligibility – potentially eligible records were assessed through reading the full text according to the criteria established by the POT strategy, as previously described, ensuring the traceability and rigor characteristic of PRISMA systematic reviews. This more in-depth reading employed the same exclusion criteria mentioned earlier in this text.
4. Inclusion – the productions that fully met the established criteria were included:
 - (i) academic productions that explicitly and directly addressed Mathematics Education Laboratories in Portuguese public higher education institutions;
 - (ii) studies published in open-access format fully available in institutional repositories;
 - (iii) texts corresponding to the typologies defined by the POT strategy - scientific articles, full texts published in conference proceedings, master's dissertations and doctoral theses. These criteria ensured transparency and consistency in the selection of the identified productions, reinforcing the rigor required in systematic reviews (Kitchenham & Charters, 2007; Page *et al.*, 2021, our translation).

The data analysis was conducted from an interpretive perspective grounded in the qualitative approach proposed by Wiley and Hatch (2002), valuing the construction of meanings emerging from the document corpus. The analytical categories were defined *a priori*, in line with the research question and the POT strategy: i) conceptions of Mathematics Education Laboratories; (ii) formative practices proposed by the MEL; (iii) repercussions for teacher education and professional development.

The adoption of this methodological approach enabled a rigorous and systematic mapping, ensuring a comprehensive, well-founded and critically informed view of Portuguese academic literature on MEL in a field marked by recent expansion and theoretical-methodological diversity (Moreno-Esteva *et al.*, 2018).

First, we identified public higher education institutions offering teacher training degree programs in Portugal. Figure 1 shows the distribution of these institutions:

Figure 1

Public higher education institutions offering teacher training degree programs in Portugal

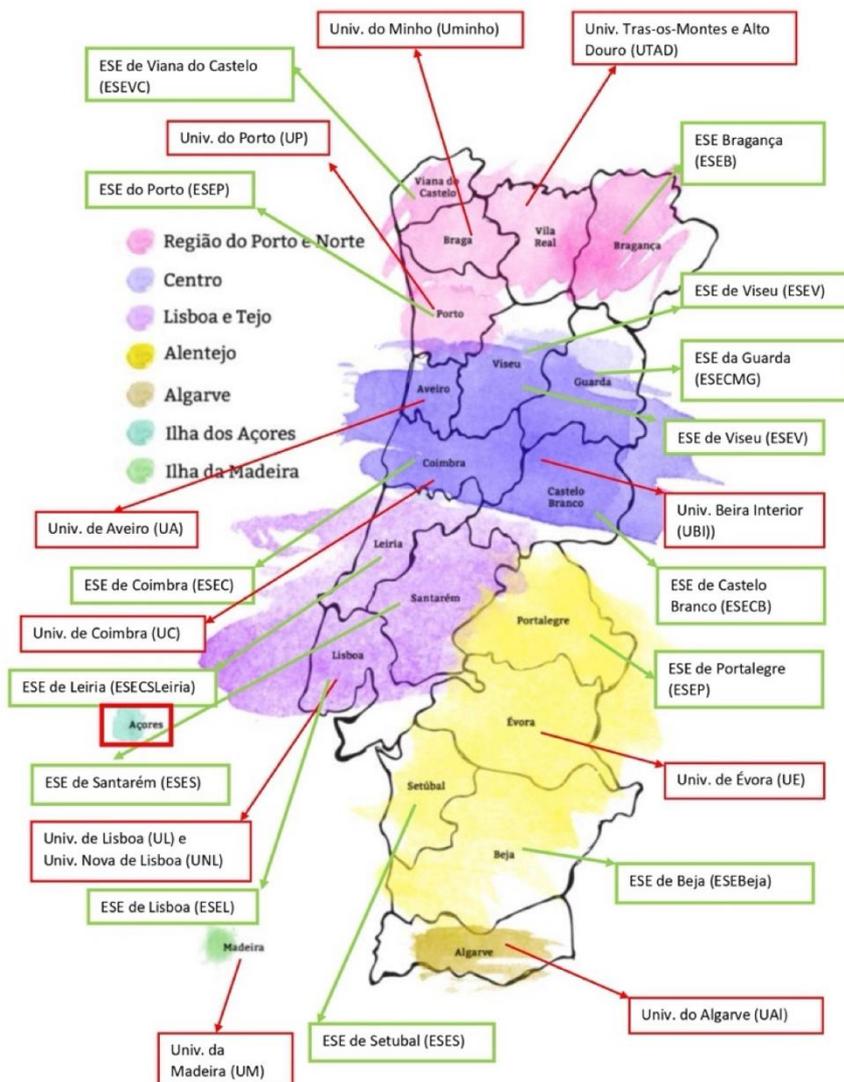


Figure 1 (translation):

- **Porto and Northern Region**

Braga – University of Minho (UMinho)

Bragança – School of Education of Bragança (ESEB)

Porto – School of Education of Porto (ESEP), University of Porto (UP)

Viana do Castelo – School of Education of Viana do Castelo (ESEVC)

Vila Real – University of Trás-os-Montes and Alto Douro (UTAD)

- **Central Region**

Aveiro – University of Aveiro (UA)

Castelo Branco – School of Education of Castelo Branco (ESECB)

Coimbra – School of Education of Coimbra (ESEC), University of Coimbra (UC)

Guarda – School of Education of Guarda (ESECMG)

Leiria – School of Education of Leiria (ESECSLeiria)

Viseu – School of Education of Viseu (ESEV)

- **Lisbon and Tagus Region**

Lisbon – School of Education of Lisbon (ESEL), University of Lisbon (UL), NOVA University of Lisbon (UNL)

Santarém – School of Education of Santarém (ESES)

Setúbal – School of Education of Setúbal (ESES)

- **Alentejo**

Beja – School of Education of Beja (ESEBeja)

Évora – University of Évora (UE)

Portalegre – School of Education of Portalegre (ESEP)

- **Algarve**

University of Algarve (UAlg)

- **Madeira Island**

University of Madeira (UM)

Note. Adapted from <https://encurtador.com.br/aOSX8>

Next, we visited their institutional websites to search for productions on mathematics education laboratories in their repositories. According to the chosen methodology, we identified the following publications, as shown in Table 1:

Table 1

Productions identified in the repositories of public higher education institutions offering teacher training degree programs in Portugal

Title	Type	Year	Institution	Region	Author(s)
Mathematics Education Laboratory	Article in conference proceedings	2001	University of Aveiro	Central Region	Isabel Cabrita Eugénia Correia
Lem@tic: and the construction of a new mathematical culture	Article in conference proceedings	2002	University of Aveiro	Central Region	Isabel Cabrita
Laboratory spaces: unity in diversity	Article in conference proceedings	2002	University of Aveiro	Central Region	Isabel Cabrita Maria Helena Araújo e Sá Isabel Martins
Opening lem@tic to the community and the professional development of (future) childhood educators	Article in a journal	2004	University of Aveiro	Central Region	Isabel Cabrita

Note. Produced by the authors.

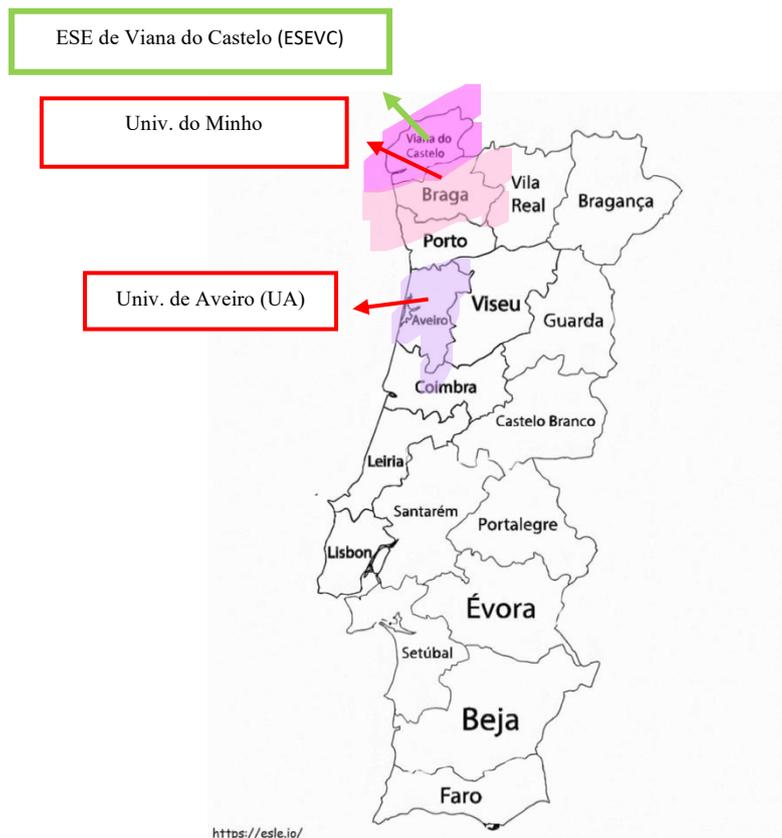
Considering the limited number of productions found, the absence of master's and doctoral studies, and the concentration of investigations in a single region, we ask the following question: *what public higher education institutions in Portugal offering teacher training degree programs have a mathematics education laboratory?*

Next, we emailed professors in the field of mathematics education at the universities and Escolas Superiores de Educação (ESE) listed in Figure 1 asking the following questions: *does the institution where you work offer mathematics education laboratory facilities? Are you familiar with any MEL facilities at other Portuguese institutions? Are you aware of any publications addressing this theme?*

The answers we received corroborated the information obtained during our mapping of the repositories, confirming the small number of texts on mathematics education laboratories. This is reflected on the fact that the interviewed professors were not aware of this type of production. Figure 2 shows the mathematics education laboratories we identified in their respective regions and institutions:

Figure 2

Regions and institutions that have mathematics education laboratories



Note. Produced by the authors

Figure 2 (translation):

Aveiro – University of Aveiro (UA)

Braga – University of Minho (UMinho)

Viana do Castelo – School of Education of Viana do Castelo (ESEVC)

Note. Produced by the authors.

During data collection, we discovered the existence of laboratory facilities that provide support to training within various undergraduate and master's degree programs, encompassing several fields of knowledge, such as those related to Physics, Chemistry, Pharmacy and various digital technologies. Furthermore, we observed a considerable number of master's and doctoral investigations and articles focused on analyzing the formative practices developed within these laboratories. We perceived that the experiences fostered by these environments constitute research problems that spark researchers' interest.

We detected a significant number of studies investigating the use of games, software and manipulatives. We observed that in higher education institutions that have mathematics education laboratories, the number of productions of this nature is

sometimes larger than in those that do not have this type of facility. We understand that having a laboratory may generate reflections, influence the development of competencies specifically related to the use of available materials and stimulate training, investigations and community extension activities, which, in turn, may result in science popularization. These elements reinforce our initial assumption that the Mathematics Education Laboratory transcends its physical dimension and becomes a concept (Mota, 2021; Silva, 2020; Silva, 2023).

As shown in Figure 2, we identified three mathematics education laboratories at public higher education institutions that offer teacher training degree programs in Portugal: at the School of Education of the Polytechnic Institute of Viana do Castelo, at University of Minho and at University of Aveiro.

We do not consider it a coincidence that the three mathematics education laboratory facilities we identified are located in regions close to one another: Viana do Castelo, Braga and Aveiro. It is possible that the formative practices conducted by these universities and the School of Education, along with the institutional partnerships established among their researchers, have influenced proposals for structures, projects and other practices.

Another noteworthy aspect is that when we emailed the professors who work at the institutions shown in Figure 1, we learned that many of them were not aware of the mathematics education laboratory facilities existing in the country, especially in regions far from their workplaces. This highlights the need to increase the visibility of the work performed in these laboratories and discuss the impacts of these structures and their formative practices on the professional training and development of educators who teach mathematics in Portugal.

Among the three mathematics education laboratories identified, we highlight the Mathematics Education Laboratory at University of Aveiro (lem@tic), which houses all the productions we found during the mapping process. Created in 2001, this laboratory is a functional structure of Centro de Investigação em Didática e Tecnologia na Formação de Formadores (CIDTFF – Research Center in Teacher Training Didactics and Technology, in free translation). It is important to mention that this Center has several laboratories, which impacts the production of knowledge related to the formative practice within these spaces (Cabrita, Araújo and Sá & Martins, 2002). Lem@tic positions itself at the convergence of training, research and extension to the community.

In the following section, we will thoroughly examine the textual productions identified in our mapping, focusing specifically on the first four years after the establishment of lem@tic. Although the number of texts we found is small, we recognize their relevance within the Portuguese context, as they are the entirety of productions on this theme. This constitutes one of the reasons that justify the need for a more detailed analysis of this topic.

Presentation and Discussion of Results

At this stage, the evidence identified is systematized and characterized. Due to space limitations and in order to avoid discursive redundancies, these results are simultaneously interpreted in light of the literature.

Conceptions about lem@tic

Based on Cury (1999), we understand “conceptions” as a set of ideas shaped by people’s experiences, which emerge from the knowledge they have built, as well as the opinions and sociocultural influences that have marked their lives.

Therefore, the mathematics education laboratory at the CIDTFF of University of Aveiro is conceived as a living space for systematic reflection, involving deductive and inductive reasoning, doubt, demonstration, analysis, conjecture, refutation, argumentation and communication through rigorous and specialized language, not only about phenomena intrinsic to Mathematics itself, but also about those from other fields of knowledge and daily life (Cabrita & Correia, 2001).

Supported by the aforementioned authors and in line with the perspectives proposed by Kaushik Das (2020), Pereira *et al.* (2022), Meurer, Borges & Hermann (2023) and Silva, Silva and Ribas (2024), the mathematics education laboratory is an optimal environment for the development of mathematical thinking. As pointed out by Cabrita (2004), in this space and based on the work done within it, (future) educators have the opportunity to transform situations provided by daily life and/or intentionally organized into meaningful moments of mathematics learning. In order to achieve this goal, the author highlights the importance of emphasizing not only the use of rigorous language and calculation skills, but also advanced problem-solving activities, preferably in ludic contexts and settings related to daily life, while mediated by various didactic tools.

Aiming to provide meaningful situations and moments of mathematics learning, as highlighted by Cabrita & Correia (2001, p. 1896) and Cabrita (2002, p. 01, our

translation), the mathematics education laboratory is responsible for “conceiving, developing and evaluating innovative strategies and methodologies for initial teacher training, [...] recognized as a way to achieve meaningful mathematics learning, facilitating the construction of a new mathematical culture”. This understanding is in line with conclusions published by Oliveira & Kikuchi (2018), Silva (2020a, 2020b), Mota (2021), Pereira *et al.* (2022) and Meurer, Borges & Hermann (2023).

According to Cabrita (2004), environments like mathematics education laboratories should be able to stimulate the adoption of new cognitive strategies; cultivate the spirit of initiative, persistence, curiosity, creativity, innovation and flexibility; encourage the development of self-confidence; foster a higher level of responsibility for one’s own work; incentivize equal opportunities and the reduction of social exclusion; promote the establishment of new relationships among the participants; intensify the development of ties of cooperation and mutual assistance; and nurture respect for diversity.

Formative practices proposed by lem@tic

Analyzing the selected productions revealed that the formative practices provided by the mathematics education laboratory are situated at the convergence of the triptych: investigation, training and innovation (Cabrita & Correia, 2001; Cabrita, 2002).

Guided by this principle, lem@tic is organized into stations, themes or transversals, encompassing the main fields included in the Portuguese Mathematics curriculum (Cabrita & Correia, 2001), while maintaining the social purpose assigned to Mathematics teaching, an aspect that grants it transversality. For each station, a collection of materials should be selected and (re)created, encompassing four main fields: history of mathematics, curiosities, bibliography and tasks.

Since its genesis, lem@tic has aggregated a wide range of didactic materials “in several forms, acquired, selected or constructed by professors and students, namely: unstructured materials, books, journals, ‘physical models’, games, mass-media, overhead transparencies, slide presentations, videos, software, graphing calculators, CBLs and CBRs” (Cabrita, 2002, p. 03, our translation).

For the sustainability of didactic materials, we should highlight the importance of having engaged “students from undergraduate, vocational and postgraduate degree programs” (Cabrita & Correia, 2001, p. 1899, our translation), as well as supporting teachers’ continuous development throughout their careers (Cabrita, 2002). In fact,

the creation of materials by professors and students, as exemplified in the experiences shared by Silva (2020a), is one of the formative practices offered by MELs and, as evidenced by the selected productions, it is also an activity carried out at lem@tic.

Based on the ideas proposed by Cabrita (2002) and in line with Silva (2020a) and Silva, Silva and Ribas (2024), the materials provided or produced by the mathematics education laboratory must be contextualized within the educational reality, considering “the educational stages that will be or are taught” by the (future) teachers (Cabrita, 2002, p. 05, our translation). This means that it is fundamental to establish “connections with daily life, with other mathematical topics and/or with fields of study [and consider them] through various forms of documents/materials, structured or not” (Cabrita, 2002, p. 05, our translation).

Within the context of lem@tic, some disciplines that were offered at that time, such as Seminar, Didactics of Mathematics, Assessment in Mathematics, Mathematics at Kindergarten and Educational Technology held classes in this space. The respective formative practices at lem@tic encompassed concrete proposals for didactic actions, embodied in the tasks. These proposals should be properly implemented among students from different educational stages and appropriately assessed (Cabrita, 2002).

According to Cabrita & Correia (2001, p. 1899, our translation), the laboratory is organized in a sober manner, “but it is quite welcoming, animated by various structured or unstructured two- or three-dimensional images/objects, highlighting aspects related to mathematics and nature. Thus, it is possible to admire rotation and symmetry in an apple, a cauliflower and its fractals, the Fibonacci sequence and a celery root”. The exploration of these materials occurs in a fluid manner every time the context of a class requires it or when it is part of the professor’s plan.

Based on the aforementioned considerations, there is a clear need to open the mathematics education laboratory to the community. Since the facility is also visited “by children from the earliest educational stages, an optimal space was created to support the development of diverse activities” (Cabrita & Correia, 2001, p. 1905, our translation).

Another aspect to be highlighted is the engagement of (future) teachers in investigative practices “as a means of contributing to the construction of a (new) mathematical and technological culture that is more in line with the demands of society [...]” (Cabrita, 2004, p. 77, our translation).

Silva (2023) and Silva *et al.* (2023) corroborated this view, emphasizing the

fundamental importance of the relationship between the two dimensions – extension to the community and investigation – for the formative practice proposed by/at the laboratory, especially in order to change not only teachers’ perspectives, but also those of society in general (Cabrita, 2004). This contributes to strengthening the connection between spaces for initial training and schools, which are sites for professional practice, and to the development of a teacher-researcher profile (Silva, 2023; Silva *et al.*, 2023).

Impacts of lem@tic on teacher professional training and development

After analyzing the mapped productions, we were convinced that the mathematics education laboratory “provides teacher training supported by professional competencies of a high taxonomy level – especially intellectual means that enable the analysis and assessment of mathematics teaching contexts and the development of tailored didactic and pedagogical alternatives and solutions” (Cabrita, 2004, p. 87, our translation). As pointed by the author, spaces like lem@tic may contribute to teacher training, allowing them to develop a continuous learning attitude throughout their lives, which is in line with the ideas published by Marcelo Garcia (1999), Nóvoa (1991), Ponte (2005), Nascimento *et al.* (2017) and Flores (2004).

In an effort to materialize the ideas shared in the previous paragraph, the mathematics education laboratory aims to establish an inseparable bond between theory and practice throughout initial training, in contrast to the situation described by Ponte (2005), where training often failed to transcend theory.

When the MEL is interpreted this way, it may enable this integration to occur from the beginning of the degree program, impacting teachers’ continuous development by viewing reflection and their own training as a *continuum* (Cabrita, 2004; Silva, 2020a; Silva, 2020b).

In order for that structure to have an effect on teachers’ initial training and on their professional development, according to Oliveira & Kikuchi (2018), Mota (2021) and Pereira *et al.* (2022), it is important to consider the relationship that there must be between future teachers and in-service teachers within initial training degree programs, which boosts training and the professional development of the individuals involved, and influences the construction of “a solid Mathematics Education, enhancing the development of structured thinking, the understanding of the world and participation in social life” (Cabrita, 2004, p. 78, our translation). These elements articulate theory and practice in initial training, resonate and play a fundamental role in the development of a self-learning attitude that occurs permanently throughout one’s

life (Nóvoa, 1991; Ponte, 2005; Cabrita, 2018).

Initial training and the need to support it through diverse pathways and spaces, such as the mathematics education laboratory – lem@tic, focus on the development of new practices to resignify the view of Mathematics and constitute a new mathematical culture (Cabrita & Correia, 2001; Cabrita, 2002; Cabrita, 2004). These practices offered by lem@tic may promote “students’ active and effective engagement in the knowledge construction process through laboratory activities that are as diversified and meaningful as possible, supported by several different materials [...]” (Cabrita & Correia, 2001, p. 1896, our translation).

By promoting the use of various didactic materials in consonance with educational reality, lem@tic enables meaningful activities for Initial and Continuous Training and contributes to a solid appropriation of concepts and the promotion of a new Mathematics teaching culture. Thus, “teachers, equipped with a new Mathematics teaching culture, will be more capable of conceiving teaching materials that stimulate experimentation and will be more available to manage laboratory work, which, in turn, will necessarily contribute to the development of a new mathematical and technological culture aligned with the latest results of research in these fields” (Cabrita & Correia, 2001, p. 1907, our translation).

Conclusion

This article enabled us to synthesize a perspective on Portuguese productions focused on studying the mathematics education laboratory. It provides significant insights into this formative environment and the implications of the work conducted within it for the training and professional development of educators who teach Mathematics in Portugal.

Through mapping and examining the productions, we perceived the importance of the mathematics education laboratory – lem@tic – and its conception as a multifaceted space capable of integrating theory and practice throughout teacher education. It is evident that the laboratory transcends its physical boundaries, emerging as a concept that encompasses the dynamic interactions among students, professors and innovative pedagogical practices, thus facilitating the development of essential competencies for teaching practice. Therefore, we verified that the laboratory does not only contribute to the improvement of mathematics learning, but also plays a crucial role in promoting a critical and reflective attitude in the processes of teacher training and practice, which resonates with professional development.

Within the specific context of the twenty-four Portuguese public higher education institutions offering teacher training degree programs, we identified three mathematics education laboratories, all located in regions close to one another. This raises questions about the visibility of these facilities and underscores the pressing need to expand the recognition of the work conducted within them, especially in more distant regions. From this perspective, we understand that expanding their visibility may foster the creation of other MELs in other higher education institutions all over the country.

Another significant aspect revealed by our analysis of the texts is the strong need to enhance the interaction between laboratories and the community through research and extension activities, aiming to foster a mathematical culture that is more aligned with social demands. The transformative role played by the laboratory transcends the academic context, extending specifically into schools and promote changes in perceptions regarding mathematics, which reduces the barriers faced in teaching and learning processes. This focus is directed not only towards school environments and society in general, but it also significantly impacts educators' training and professional development.

Through mapping the selected productions, this study aimed to stimulate reflections and debates that may boost advances related to the training of educators who teach Mathematics in Portugal, consequently resonating with the teaching and learning process. This approach acknowledges the essential role of the mathematics education laboratory as a fundamental component in initial training degree programs, facilitating the integration between theory and practice. The objective is to promote a dynamic and interconnected approach to Mathematics, establishing meaningful connections with educational realities.

We conclude by saying that the analysis of Portuguese productions on lem@tic generated valuable contributions to the discussion on teacher training and the professional development of educators who teach Mathematics. These studies highlight the importance of rethinking, strengthening and increasing the number of these type of formative environment in Portugal.

In concluding this study, we aim to broaden the perspective on the activities performed by the Portuguese MELs in the past two decades, from 2004 to 2024. This theme will be explored in future investigations.

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