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The Teaching Laboratory as a formative space for teachers who teach Mathematics

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ABSTRACT

This bibliographical article discusses the emerging aspects of Brazilian research that relate the Teaching Laboratory to the formation of Mathematics teachers. To this end, we considered the articles published in online Brazilian scientific journals published on the Brazilian Society of Mathematical Education (SBEM) website addressing the role of the laboratories in the training of Mathematics teachers, which resulted in seven selected works based on the application of the criterion that they should contain the word "laboratory" in the title. In addition, a search was also performed on the website of the Brazilian Digital Library of Theses and Dissertations (BDTD) with the words "laboratory," "training" and "mathematics," so that the title of the texts contained the three words simultaneously. With these criteria, the searches found five thesis and two dissertations. The Content Analysis guided the analysis of the texts, based on the definition of the following analysis units*: (i) The role of the laboratories in teacher training according to the Brazilian research; (ii) The Laboratory as a tool for the development of teaching practices; (iii) The use of the Laboratory for students' development and learning*. The results point out that the environment provided by the Mathematics

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Teaching Laboratory can develop new methodological alternatives, as well as opportunities to reflect and discuss about teaching practice, capable of contributing to the improvement of the teachers' formative process and the teaching of mathematics.

KEYWORDS: Initial training. Teaching Laboratory. Mathematical Education.

O Laboratório de Ensino como espaço formativo para docentes que ensinam Matemática

RESUMO

No presente artigo, de cunho bibliográfico, discutem-se os aspectos emergentes em pesquisas brasileiras que relacionam o Laboratório de Ensino com a formação dos docentes de Matemática. Para este fim, foram considerados os artigos publicados em periódicos científicos brasileiros *online* divulgados no site da Sociedade Brasileira de Educação Matemática (SBEM), que abordassem o papel dos laboratórios na formação de professores de Matemática, resultando em sete trabalhos selecionados, a partir da aplicação do critério de que contivessem a palavra "laboratório" no título. Em complemento, também foi realizada uma busca no site da Biblioteca Digital Brasileira de Teses e Dissertações (BDTD) com as palavras "laboratório", "formação" e "matemática", de modo que o título dos textos contivesse as três palavras, simultaneamente. Com tais critérios foram obtidas como resultado das buscas cinco dissertações e duas teses. A análise dos textos foi orientada pela Análise de Conteúdo, a partir da definição das seguintes unidades de análise*: i) O papel dos laboratórios na formação de professores de acordo com as pesquisas brasileiras; ii) O Laboratório enquanto instrumento de desenvolvimento das práticas docentes; iii) A utilização do Laboratório para o desenvolvimento e aprendizagem dos estudantes.* Os resultados apontam que o ambiente proporcionado pelo Laboratório de Ensino de Matemática possui potencialidades que permitem o desenvolvimento de novas alternativas metodológicas, além de oportunidades de reflexão e discussão acerca da prática docente, capazes de contribuir para a melhoria do processo formativo do professor e do ensino de Matemática.

PALAVRAS-CHAVE: Formação inicial. Laboratório de Ensino. Educação Matemática.

El Laboratorio de Enseñanza como espacio formativo para los profesores de Matemáticas

RESUMEN

Este es un artículo bibliográfico que discute los aspectos emergentes de las investigaciones brasileñas que relacionan el Laboratorio de Enseñanza con la formación de profesores de Matemáticas. Para ello, se consideraron los artículos publicados en revistas científicas brasileñas en línea publicadas en el sitio web de la Sociedad Brasileña de Educación Matemática (SBEM), que abordaban el papel de los laboratorios en la formación de profesores de matemáticas, resultando siete trabajos seleccionados, a partir de la aplicación del criterio de que contenían la palabra "laboratorio" en el título. Además, también se realizó una búsqueda en la Biblioteca Digital Brasileña de Tesis y Disertaciones (BDTD) con las palabras "laboratorio", "formación" y "matemáticas", para que el título de los textos contuviera las tres palabras simultáneamente. Con estos criterios se obtuvieron como resultado de las búsquedas cinco disertaciones y dos tesis. El análisis de los textos fue guiado por el Análisis de Contenido, a partir de la definición de las siguientes unidades de análisis: i) El papel de los laboratorios en la formación de profesores según la investigación brasileña; ii) El Laboratorio como herramienta para el desarrollo de las prácticas de enseñanza; iii) El uso del Laboratorio para el desarrollo y aprendizaje de los estudiantes. Los resultados indican que el ambiente proporcionado por el Laboratorio de Enseñanza de Matemáticas tiene potencialidades que permiten el desarrollo de nuevas alternativas metodológicas, así como oportunidades de reflexión y discusión sobre la práctica docente, capaces de contribuir a la mejora del proceso de formación del profesor y de la enseñanza de las Matemáticas.

PALABRAS CLAVE: Educación inicial. Laboratorio de enseñanza. Educación matemática.

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Introduction

In Brazil, the training of teachers who teach mathematics is a theme that has been increasingly discussed in the field of research. Proof of this is the existence of several research groups spread throughout the country, bringing together teachers from Higher Education, undergraduate students of education, and teachers from Basic Education. Moreover, we have, among the working groups that make up the Brazilian Society of Mathematics Education, a specific work group for this theme, entitled Teacher Training. On the other hand, we believe that the discussion on training also needs to go through other debates, involving different aspects, such as the teacher's professional development, teaching practices, the school/community partnership, among others. In this text, we aim to link teacher training to the role of teaching laboratories, regarding the specificities related to teaching mathematics.

To Lagar (2011, p. 1), "[...] teacher training refers to the movement to form (shape), to make up the teacher, to make them a professional, endowed with inherent knowledge in the development of their profession" (free translation). Different perspectives allow for developing a model of teacher training, which must be intricately linked to the type of professional we aim for in each context. This is an issue of high relevance and complexity, as its implications influence schools, universities and, consequently, the quality of education.

Training can and must occur in different contexts, some of which are more promising to talk about teaching practice, in addition to theory, as it is the case with the Mathematics Teaching Laboratories. They have been established as an opportune environment in renewing and developing new methodologies and, therefore, their presence has become increasingly necessary in the institutions that wish to promote higher quality teacher education to future teachers (LORENZATO, 2012). These factors were also attested in research with undergraduate students in mathematics conducted by Pinto and Conte (2020).

Thus, considering current approaches in teaching mathematics, we emphasize the importance of understanding the Mathematics Teaching Laboratory (LEM) as a teaching training space and reflecting on how its use can help the initial and continuing training of mathematics teachers. Therefore, it is necessary to understand the context of the methodological practices made possible by the LEM environment, as its use provides students with a mathematical learning based on exploration, research, hypothesis testing and approximation with the future teaching professional practice through the experimentation of teaching activities (OLIVEIRA, 1983).

Among the most widespread conceptions about the LEM possibilities is that presented by Lorenzato (2012, p.7): "[...] structuring, organizing, planning, and making mathematical thinking happen [...]" (free translation). The author also points out that this can be an orderly place to develop mathematical experiments and practical activities.

In view of this, this study is justified as it intends to discuss, based on the studies of different researchers, what emerging aspects are found in Brazilian research that relate LEM to the training of mathematics teachers, as well as the development of their practices. Bibliographical searches allow us to promote interpretations that will serve as a starting point for other research, especially by expanding scenarios that can contribute both qualitatively and quantitatively to certain themes. More than that, such research, with the definition of a field of research, such as Mathematical Education, serves to present to the reader, albeit in a partial way, how a particular theme has been addressed.

Since this is a bibliographical-type research, we decided not to bring a theoretical basis item, as this discussion will be given simultaneously to the analysis of the texts, avoiding repetition of ideas. In the sequence, we present the methodological course that guided the research.

Methodological course

This is a bibliographic research about the aspects of teaching laboratories in the initial training of mathematics teachers. Thus, this work is organized and based on bibliographic sources, according to Gil (2002)'s assumptions.

Scientific journals, master's theses, and doctoral dissertations were considered to make part of the corpus of the research, by means of specific criteria for each type of material. For scientific journals, Brazilian online publications published on the Brazilian Society of Mathematics Education (SBEM) website were considered as initial criteria[4]. This choice was because SBEM discloses most journals that bring contributions to the field of Mathematical Education. Considering our interest in papers that addressed the most varied aspects of the laboratories in the initial training of mathematics teachers, we selected the texts in these journals that brought the word "laboratory" into the title. As not all the texts that bring this term in the title would have the Mathematics Teaching Laboratory as a focus, we set out for a first reading to filter those that, in fact, were related to our research objective. After reading the abstracts of the articles, we got to the total of seven publications.

To choose dissertations and theses, a search was performed on the Brazilian Digital Library of Theses and Dissertations (BDTD)[5] website with the words "laboratory," "training" and "mathematics," so that the titles of the texts contained the three words simultaneously. As in the journals, the dissertations and theses found should be related to the mathematics teacher training involving the use of laboratories. We had five theses and two dissertations as a result.

The texts were classified according to the type of publication, and the code "A" was established for articles, "D" for dissertations and "T" for theses.

[4] http://www.sbembrasil.org.br/sbembrasil/index.php/95-periodicos/117-periodicos. Search on April 27, 2020.
[5] http://bdtd.ibict.br/vufind/Search/Advanced. Search on April 27, 2020.

In Table 1, we show the identification code of the texts obtained, the title, the authors, and the year of publication and, finally, the results highlighted in the abstract. This latter field, of results, is justified by our choice of defining Analysis Units from these extracts, as we will explain below.

TABLE 1 – List of texts in chronological order of publication

ID	TITLE	AUTHORS/YEAR	RESULTS HIGHLIGHTED IN THE SUMMARY
A1	The mathematics teaching laboratory: Implications for teacher training	Lopes and Araujo (2007)	The project provided the undergraduate students with the analysis of their own practice and the observation of the process of (re)construction of algebraic concepts and procedures. Many students not only overcame their difficulties, but changed their attitude toward mathematics; the project allowed the teacher to visualize new methodological possibilities, paths to a new praxis. The partnership highlighted the potential of the Teaching Laboratory as a crucial environment in the initial and continuing training of teachers.
A2	The different types of approach of a laboratory in mathematics and your contributions for teacher training,	Rodrigues and Gazire (2015)	As a result of this paper, we highlight the creation of seven categories to classify the mathematics laboratories currently used in teacher training. Among all the typing proposals and based on the description of each one, the study suggests that the laboratory called "Training Agent" offers greater contributions to the training of teachers in mathematics.
A3	Mathematical training spaces: Laboratories, Fairs and Shows	*Kindel and Oliveira (2016)*	Within this perspective, we understand that laboratories, fairs and shows in mathematical education contribute to the mathematical training of future teachers in Basic Education. Also, they are intrinsically linked to the way in which the production of mathematical knowledge is understood.
A4	The Presence of Rousseau, Pestalozzi and Piaget's ideas in the Brazilian researches on the laboratory of mathematics teaching	Cury (2017)	We found that most of the researches analyzed, even if they do not directly discuss the studies of those three names of education, point to arguments that converge to their teaching proposals based on observation, experimentation and manipulation of concrete materials preceding activities with abstract individuals.
A5	Laboratory of Teaching of Mathematics in Teacher Training: Perspectives and Experiences of UFT and UFCA	Khidir, Gonçalves and Rodrigues (2018)	The challenge of the Mathematics Teaching Laboratory in the field of teacher training is to promote and make innovations from research undertaken by Mathematical Education accessible to future teachers, so that they can permeate the practice of these professionals and contribute to a change in the current paradigm in relation to teaching and learning mathematics.
A6	The State School Padre Tiago's Laboratory to Learn Mathematics	Gomes and Cevallos (2018)	Data point out that the laboratory is underused by the teachers; however, they emphasize its relevance to the students' involvement and learning. There is clearly a gap in discussions and reflections on the practice among the professionals participating in the research and also a lack of continued training that reflects the actual training needs of the teacher.

A7	Survey of students and teachers' perceptions about the math lab teaching: Contributions for the training of teachers.	Campos and Ferreira (2019)	The analysis of the collected data converged to results revealed by other research on this theme by revealing the knowledge degree and opinions of teachers and students about LEM. Based on these results, it discusses the need for training actions for future mathematics teachers.
T1	The laboratory of mathematical education in the initial training of teachers	Turrioni (2004)	The results obtained showed that the Laboratory under study was initially used for professionally developing undergraduate students and then for developing some research activities, which could characterize the beginning of the training of the teacher-researcher.
T2	The laboratory of mathematical education in the continuing training of the mathematics teacher	Costa (2014)	The data analysis led us to observe, in the process of developing this study, three categories: From naive curiosity to epistemological curiosity; the development amid transformative practices; the meaning of experience for the teacher and students. The analysis of these data signalizes a change in this teacher's practice, including in relation to their position before the class.
T3	Playful training of the future mathematics teacher through the teaching laboratory	Silva (2014)	In conclusion, we believe it is necessary to rethink the undergraduate courses in Mathematics in order to perceive the playful element as an important element in the process of shaping the teacher's identity.
T4	Laboratory at school: Possibilities for teaching mathematics and teacher education	Oliveira (2017)	The importance of LEM to be an institutionalized space was realized and, as such, recognized in the school's pedagogical project. It analyzed that the space represents possibilities for enhancing teaching practices in mathematics and other areas, as it invites to research and sharing. This encourages students to participate with enthusiasm and willingness, thus facilitating teaching for the teacher. With the planning and the very differentiated way of treating mathematical content, the teachers extend their formation.
T5	Mathematical education laboratory "Zaira da Cunha Melo Varizo": A mosaic about teacher education in IME/UFG	Santos (2018)	This narrative shows that the laboratory has been undergoing changes in both its setup and role in teacher training.
D1	Contributions of the laboratory of mathematics education to the initial formation of teachers: Practical knowledge and professional formation	Cabral (2010)	In short, results showed four significant points of learning in the practical knowledge of the future teacher, which are: The rupture with the egocentric discourse; the adoption of the conceptual decentralized discourse; the appreciation of pedagogical-disciplinary knowledge; and the autonomy (moral and intellectual) mediated by collaboration.
D2	Operation and effectiveness of the virtual laboratory for teaching mathematics in initial teacher training in mathematics through distance education	Cavalcanti (2014)	The approach of Estar Junto Virtual promoted by the interactions in LEM highly contributed for the students to take ownership of these technological tools to produce mathematical knowledge in a collaborative manner. Furthermore, it has provided subsidies and reflections that contribute to encouraging the use of these technological resources to make changes in the process of teacher vocational training.

Source: Research data

For data analysis, we chose to work with Analysis Units, following the assumptions of Moraes (1999), which were organized based on the results highlighted in the abstract of each of the texts defined in our search. We understand that the results presented in the abstract provide us with a range of possibilities of aspects for discussion. They also represent the highlights of the research in its main conclusions. As Moraes (1999) points out, "the units can be either words, phrases, themes or even documents in their complete form" (MORAES, 1999, p. 5) (free translation). In this sense, in the phase of preparing and organizing information, the Analysis Units were created from the convergence between the aspects highlighted in the results, always considering our research issue.

We listed the results shown in the abstracts of each of the 14 studies searching for convergence of themes, and the following Analysis Units were defined: *(i)* The role of the laboratories in teacher training according to Brazilian research; *(ii)* The laboratory as an environment for the development of teaching practices; *(iii)* The use of the laboratory for students' development and learning.

Afterwards, we present our discussions on the role of the Mathematics Teaching Laboratories in the teaching training of the mathematics teacher, starting from the three defined analysis units.

I - The role of laboratories in teacher training according to Brazilian research

In this Analysis Unit, we discussed what would be the role of the Mathematics Teaching Laboratories in teacher training based on the studies of the following authors, who constitute the corpus of research: Lopes and Araujo (2007), Rodrigues and Gazire (2015), Kindel and Oliveira (2016), Gomes and Cevallos (2018), Campos and Ferreira (2019), Turrioni (2004),

Oliveira (2017), Santos (2018), Cavalcanti (2014). For Lorenzato (2012), as in any profession, the environment and available resources directly influence good professional performance. With this, the author understands the Mathematics Teaching Laboratory as a crucial item to the school, as it is a promising methodological alternative in teaching and learning mathematics. And if this space is relevant for the school, it is totally appropriate to also think of its role in the initial trainings of the teachers who will act in these establishments.

Cavalcanti (2014) shows the importance that the training courses for teachers of mathematics reflect on the teaching of mathematics, both in terms of the use of diversified teaching methodologies and resources and in the understanding of the phenomena that involve the educational practice and the subjects involved. For the author, the "constitution of teaching knowledge to exercise teaching activities needs knowledge far beyond the specific knowledge of the area in which one intends to act" (CAVALCANTI, 2014, p. 19) (free translation). Therefore, there must be a greater combination of the specific knowledge and the pedagogical knowledge that involve the praxis of the mathematics teacher, and that must be taken into account in the training courses. This conception is in line with the conceptualization brought by Lorenzato (2012), who assures the importance of planning the contents and teaching education in an integrated way, and also that the Mathematics Teaching Laboratory is an important space to explore the realization of pedagogical practices.

Ponte (2014) points out that, for teaching better-quality mathematics, the teacher must have had a more appropriate training, in addition to having educational competence, since its main assignment is to provide the teacher with the relevant resources for continuous evaluation of their teaching and of the student learning. From this perspective, Lopes and Araujo (2007) consider it essential that, when working in the environments provided by the laboratories, the teacher is willing to research new methodologies and ways of teaching mathematics.

Although the use of LEM is strongly encouraged, Passos (2012) warn that the use of manipulative materials may not always lead to the expected results, since students may not understand the mathematical relationships they represent when selected by the teacher. Thus, he argues that moments of discussion and reflections on the theme should be carried out during the initial training of the mathematics teacher, in view of its crucial role in the students' process of understanding the mathematical content.

Passos (2012) further highlights the importance of discussing more appropriate ways of using the teaching materials during the initial training courses, because depending on how the teacher chooses to present it, whether or not there is manipulation by the students, it can influence in such a way as to lead to completely different teaching situations in terms of internalizing the proposed concepts and properties. Thus, the author, influenced by Ewbank's conceptions (1977), recommends that teachers should base on curricular guides to select the contents that can be worked on in LEM, aiming to provide an environment of exploration, research, and innovation.

On the role of LEM, the authors Gomes and Cevallos (2018) highlight the possibility that future teachers develop interdisciplinary projects, encompassing cross-sectional themes that contribute to the reflection on teaching theories, contributing gradually to their professional experience. Similarly, Rodrigues and Gazire (2015) point out that, with LEM, students in training are encouraged to develop research and projects aimed at identifying the educational issues faced by the school community, seeking alternatives to minimize them.

Turrioni (2004)'s research reflects on the importance of articulating the teacher's academic training with the school reality with which they will have to deal daily. The author points out the little integration between the University and the Middle and High Schools, which reflects on the separation between theory and practice in training courses. As an

alternative for organizing this association between the teaching and knowledge-specific training disciplines, Turrioni (2004) points out LEM as potentially promising, since it establishes itself as a space for realizing projects and exchanging experiences that allow the renewal of methods, techniques and research that can promote significant changes to Mathematical Education.

Campos and Ferreira (2019) point out that LEM can be a space that comprises the preparation of challenging situations and a facilitator to solve the students' questions, which arise during the classes, emphasizing how important it is to have access to different types of teaching materials for teaching mathematics. For the authors, developing pedagogical works involving activities in LEM during the undergraduate course allows the formation of better prepared and more confident teachers, with expertise in mathematical concepts and with a range of options to offer students in their practice.

LEM is a versatile environment in which content can be worked for the initial and continuing training of mathematics teachers, as well as various teaching, research, and extension activities. For Campos and Ferreira (2019, p. 10), the main role of LEM is the organization of a "center for discussion and development of new knowledge," contributing not only to initial training, but also to training actions for future teachers. This idea is legitimized by Cury (2017), who also recognizes teaching laboratories as catalysts for research in the educational field.

Therefore, it is important to highlight the relevance of LEM as an environment of scientific research, production, and dissemination, especially with research and extension projects that foster the debate on the initial and continuing training of teachers who act in the degree in mathematics. Furthermore, by strengthening the bond with the external community with extension activities such as lectures, workshops, fairs, etc., it can contribute to the awakening of interest in mathematical knowledge in other people. The actions that can be carried out with LEM

allow us to reaffirm not only its role as a research space for students and teachers, but also its role of sharing mathematical knowledge, that is, a productive space to overthrow the belief that mathematics is difficult and destined for few (KINDEL; OLIVEIRA, 2016).

We highlight, by the studies presented in this unit, that, although different conceptions and objectives are attributed to LEM, its notoriety is undeniable in the process of teacher training. Undergraduate courses in Mathematics can find in LEM an environment to support the most diverse disciplines, be they specific to Mathematics or didactic, as well as to enable the performance of activities related to the professional exercise of teaching. Furthermore, LEM is a favorable space to make up knowledge for future teachers in a collaborative manner and to implement a culture of scientific base, by promoting and encouraging research projects. Finally, LEM enables a closer and more interactive relationship between teachers and students, and the practices performed should provide a more effective engagement in teaching and learning processes.

II - The laboratory as an environment to develop teaching practices

In this analysis unit, we discuss the role of LEM on the development of teaching practices, based on the texts of the following authors: Lopes and Araujo (2007), Khidir, Gonçalves and Rodrigues (2018), Costa (2014), Oliveira (2017), and Cabral (2010). Based on the studies shown, one can understand the relevance of the mathematics teaching laboratories in the discussion of teaching practices, as well as in the professional development of teachers.

According to Franco (2016), pedagogical practices should be structured around intentions that can be performed based on timely routes, therefore, "[...] include from planning and systematizing the dynamics of learning processes to walking in the midst of processes that

occur beyond learning [...]" (FRANCO, 2016, p. 14) (free translation). Thus, pedagogical practices should be based on a conscious action by the teacher, which guarantees that the students will learn the contents they need for a certain stage of their training. Also part of this educational process is the stimulation of the student's participation using the association with their previous knowledge.

The implementation of the Mathematics Teaching Laboratories brought many advances in the teaching institutions that offer undergraduate courses in Mathematics. This has benefited not only teachers, but also the students, in their most varied proposals for use. Lorenzato (2012) states that, regardless of the direction to which LEM is directed, whether to approach a more theoretical concept or a practical concept, it is essential that it allows reflection on teaching practices, aiming at improving teaching and learning.

Costa (2014) understands that it is essential to look at the teacher's practice, considering that their knowledge is built along their professional path, which means a process of continuous development. In their daily pedagogical practice, this professional needs to deal with an expressive number of students, and they all have their particularities, their life histories, ways of learning and distinct learning times. Thus, the author evaluates that LEM can be an enabling space for the teacher to diversify their methodological strategies and reorganize their classes to meet their students' expectations and needs.

In a training conceived purely through the traditional teaching model, in which knowledge is transmitted through expository classes and centered on the teachers, they often become a mere applicator of techniques and transmitter of finished knowledge. This makes it difficult to the exercise of the teaching practice because they carry with themselves insecurities that make decision-making and the constant development of their work impossible. In this context, Lopes and Araujo (2007) highlight the importance of training actions for teachers, aiming at

knowing alternative methodologies that can contribute to the learning of the most diverse mathematical content. For the authors, study in the Mathematics Teaching Laboratories should have clear objectives regarding the role of teachers in learning assumptions. This would be a necessary condition for them to live experiences, research new methods and renew the ways of approaching concepts to be worked in class. The experience at LEM must allow the future teacher to broaden their methodological horizons, as well as to develop as a habit the continuous reflection regarding their practice, the purposes of teaching and learning and the various methodological trends of teaching mathematics.

Khidir, Gonçalves and Rodrigues (2018) state that, among the main objectives of LEM, it is to power the knowledge that relates to the teacher's training and its influence in the teaching process, above all, starting from the practical experiences legitimized in this space that allow for didactically structuring the methodologies to be used in the future by the education students. Thus, LEM can be understood as an environment that represents the connection between the teacher training base, regarding the previously-established theoretical knowledge, necessary to build the skills that are essential to the teacher's profile, and the professional practice, provided by creating problem situations, preparing workshops, developing research projects, validating didactic proposals, which allow the experience of their work during their training.

One of the great challenges of LEM is to promote innovations in teaching methodologies while making them accessible to the undergraduate students, so that they start permeating professional practice (KHIDIR; GONÇALVES; RODRIGUES, 2018). In this respect, Rêgo and Rêgo (2012) state that implementing LEM in higher education institutions and schools allows the teachers to increase their training critically, by applying and evaluating in practice new materials and methodologies and, by evaluating how the education system employed in the school is organized, to subsidize decision-making on changes that are indispensable to improve the training process.

Turrioni and Perez (2012) highlight the role of LEM in the educational environment in the perspective of initiation in research activities for future teachers, as well as exercises that mobilize their professional development and practices. The engagement in projects makes it possible for the pedagogic and theoretical training to occur concurrently with the application in real situations. This approximation between theory and practical use in a research environment is designed as a viable alternative to articulate substantial changes, either in undergraduate courses or in the curricula of Middle and High schools. This justifies the authors' understanding of the concept that LEM is an agent of change within training institutions. This change brought about by LEM also involves a behavioral change by the future teacher, who needs to develop a more active and committed conduct in the face of their own learning, acting towards continually exploring new teaching skills, aiming to overcome the existing educational issues by creating new strategies and continuously reflecting on their practice.

Although the researchers discussed here agree on the potential of LEM for teacher education, it is important to emphasize that its use alone does not guarantee success, as it must always be contextualized, with well-designed objectives, according to the characteristics of the institution and its possibilities, so that it can contribute to the learning of both teachers and especially, students. Passos (2012) warns that manipulative materials must play the role of mediators in the construction of knowledge; therefore, they cannot be used with self-purpose, as there is a chance of obtaining an outcome contrary to that which was initially intended. Often, under-use of mathematics teaching laboratories is linked to the lack of adequate training actions that could guarantee to the future teacher the development of the knowledge necessary to improve their professional practice.

We agree with the premise that the teacher constantly needs to review their actions in order to meet the students' needs and the

educational trends in teaching. The studies presented in this unit showed us that the initial and continuing training of these professionals must contemplate the need to seek new methodologies, with the appropriate adaptations in the curricula of the undergraduate courses regarding the use of LEM as a space of experimentation, preparation of didactic materials and reflection on pedagogical practice. After all, if we do not discuss and use LEMs and all their potential in the initial training, it becomes more difficult for future teachers to do so in their professional activities.

III - The use of the laboratory for students' development and learning

In this unit, we considered the texts of Khidir, Gonçalves and Rodrigues (2018), Gomes and Cevallos (2018), Oliveira (2017), and Cavalcanti (2014), whose approaches involve discussions on students' development and learning in mathematics teaching using the Mathematics Teaching Laboratories.

Considering the issues raised over the past decades about the quality of teaching mathematics, especially as regards insufficient learning by students, researchers have addressed the importance of using different educational resources, based on the construction of meanings and that it instigates greater participation and interaction of students. Gomes and Cevallos (2018) point out that, in view of this scenario, one of the alternatives lays on the restructuring of what is conceived about teaching and learning in mathematics, focusing more on experimentation by students, encouraging them to participate actively in the construction of their knowledge. From this point of view, implementing the Mathematics Teaching Laboratory in schools shows up as an alternative, by proposing a promising multifunction environment for varying/expanding didactic-pedagogical resources, capable of favoring learning based on interactive experiences for greater involvement, participation and understanding by students in mathematics classes.

Gomes and Cevallos (2018) also point out that the resources made available in LEM can provide the opportunity to develop learning in a more satisfactory way, since it is an environment that provides collaboration and the exchange of information, favoring the generation of knowledge both individually and collectively. Furthermore, the teaching materials provided by LEM allow new ways of working on reflection and creativity, minimizing the transmission of content alone, which is the main problem of the molds of traditional teaching.

The research by Khidir, Gonçalves and Rodrigues (2018) points out the importance of LEM for the education of better-prepared teachers to direct students to a higher level of development of mathematical knowledge. This is because in their professional practice, the teacher will often encounter challenging situations, especially in relation to specific difficulties that students may have to understand certain concepts. In these cases, the resources provided by LEM can have expressive results, highlighting that any kind of material that can contribute to the teacher's performance is considered as a didactic resource (books, software, manipulative materials, magazines, etc.).

The possibility of building and making use of manipulative materials and technological resources to develop activities aimed at teaching and learning mathematics provide students with a relationship between the theories studied and their daily life, as it helps and encourages them to test, apply and analyze the concepts discussed in order to build knowledge to understand the world around them (CAVALCANTI, 2014). In this sense, Lorenzato (2012) argues that schools need to rely on tools that favor learning, and that laboratories, with their variety of educational materials, can contribute to the process of building new knowledge. The author, however, makes a point about the use of these materials, making it clear that only their manipulation does not mean learning, because mental activity is fundamental on the student's part, that is, they must be able to assimilate the concepts proposed by the teacher based on the use of the material, giving meaning to the information received.

Reinforcing this idea, Passos (2012) reflects on the creation of expectations, often exaggerated, that many teachers carry when they choose to work with manipulative materials. Such materials should not be used solely based on the increased motivation of the students or their playful character, as no material is justified on its own. They should be considered only as means of achieving a teaching and learning purpose. Educational materials can be used to show various mathematical situations and contents; however, concepts are not extracted from them in a synthetic way, the student must be able to make an interiorized action, which gives meaning to the experiences of manipulation, formulations, and verification.

Oliveira (2017) points out that LEM is a space of action, as well as it favors the exchange of experiences by living together and interacting. It is also an environment that allows a cycle of renovation and continuous reflection by both teachers and students, providing an opportunity for teaching with greater understanding. The author also highlights the essential role of the teacher in this process because it is up to them to guide the student in the search for developing their knowledge. For the teaching to be more contextualized, the student must be encouraged to reflect on what is done, how it is done and why it is done.

Rêgo and Rêgo (2012) reflect on the role of school and the formation of citizens in the face of a society that is undergoing constant transformation. This movement creates new social and educational demands, which leads to a requirement that education be able to promote intellectual autonomy, creativity, and a critical vision on the student. Thus, they recognize that new methodologies should be applied to achieve this purpose, so that the student is considered the center of teaching and learning processes, considering their previous experiences. This conception considers that the activities proposed with the use of LEM should be prepared deciding at what educational objectives to aim, considering that each student has their own way of thinking and assimilating information, with the influence of the

environment in which they live and the previous experiences they carry. Thus, the activities carried out in LEM can be, depending on the type of use, a favorable artifact for the students to broaden their point of view on the importance of learning mathematics and its functionalities, enabling a construction of knowledge based on the structuring of ideas, templates, and information organization.

The discussions on this unit show that an environment prepared exclusively for teaching mathematics favors the learning and development of more self-confident students who have an independent and investigative conduct and search solutions and can work collaboratively. Finally, it is necessary to highlight the relevance of LEM in overcoming the remaining distancing between theory and practice, as a greater connection of mathematical concepts with everyday applications contributes to the development of more creative citizens, endowed with critical sense and capacity for reflection and therefore better prepared for life in society.

Final considerations

This bibliographic study aimed to discuss the emerging aspects in Brazilian research that relate the Mathematics Teaching Laboratory to the teaching training. It is important to emphasize that the results achieved by this research do not exhaust the theme and, therefore, cannot be considered conclusive, as other related researches have not been contemplated. The highlights here are part of our focus and take into account the research selected from our data production criteria.

Based on the initial question that guided the study, it is clear the need for more research addressing this subject, aiming at a better theoretical deepening on the matter. The existence of a common space in most universities and schools, that is, the teaching laboratories, is quite pertinent.

The texts analyzed are unanimous in the conclusion that the environment provided by the Mathematics Teaching Laboratories can contribute to the professional training of teachers, because, with this space, research can be carried out and several experiences can be lived and converge to improve the teaching of mathematics. Consequently, they provide better and different learning.

Our analysis units showed us that the use of various resources, such as manipulative materials, digital environments with software, games, books, journals, research and extension projects, etc., made possible by LEM, when used linked to the teaching and learning objectives of mathematics and adapted to individual/contextual needs, mostly favors the understanding of the proposed concepts.

The reality of teaching mathematics shows that the activities developed in the Mathematics Teaching Laboratory advanced, that is, they helped to raise the students' skill levels regarding mathematical knowledge. The practices carried out in this space enable students to understand mathematical relations, with a view to the collaborative environment of information exchange, possibilities of research, and the pedagogical and technological resources applied.

The lack of knowledge about the Mathematics Teaching Laboratory and its possibilities of exploration by future graduates is still predominant. For an expressive result with the use of LEM in teacher training, students in training must recognize the importance of LEM in this process. This will only happen if the teachers also assume the importance of this space, taking it pedagogically. To do this, it is essential that actions be promoted to allow greater awareness of their relevance and that teacher-student interactions be fostered.

Moreover, teachers that are trained to deal with the conduct of work in this space are essential, they must have a uniform understanding of the supporting role that LEM can offer in initial training. A gap in the training of teachers who work in undergraduate courses is clear, which often makes

it difficult to develop significant activities for the learning and practice of future teachers. And laboratories can be explored by most of the curriculum components of initial training courses, in a cross-sectional approach that do not depend on a few more interested teachers responsible for these spaces. Thus, we point out the need for initial or continuing teacher education to include in their discussions methodological strategies for teaching mathematics in a perspective that includes LEM.

Finally, we hope that our process of reading and understanding the research that are related to LEM to teacher training will contribute to further research and discussion on the subject, especially regarding the assumption of the great potential of this space for teaching in mathematics.

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