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A photograph of studies emphasizing the use of digital technologies: the production of ANPEd's GT-19 as a focus

Una fotografía de estudios que enfatizan el uso de tecnologías digitales: la producción del GT-19 de ANPEd como foco

Une photographie d'études mettant l'accent sur l'utilisation des technologies numériques : la production du GT-19 de l'ANPEd comme point de mire

Uma fotografia de estudos enfatizando o uso de tecnologias digitais: a produção do GT-19 da ANPEd como foco

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Abstract

This article presents reflections on the use of digital technologies in the field of Mathematics Education. It particularly problematizes how these technologies intertwine with mathematics teaching and learning processes, as well as with research. The empirical material consists of the publications presented in WG 19 – Mathematics Education of ANPEd (National Association for Graduate Studies and Research in Education), from 2000 to 2023, which mentioned the use of technologies in their titles or abstracts. The analysis of the material involved the following dimensions: a) mapping the technologies and mathematical knowledge explored in investigations; b) sharing results about the use of technologies in Mathematics classes; c) explaining the adopted approach to technology (as a means, tool or artifact) in the studies. We highlight the diversity of technologies referred to by studies and the shift from offline computers to online devices. We suggest further investigations into the characterization of technology as a means of expression or of revelation.

Keywords: Technology in research, Characterization, Tool, Artifact, Means.

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Resumen

Este artículo reflexiona sobre el uso de las tecnologías digitales en la educación matemática. En particular, problematiza las formas en que estas tecnologías se entrelazan con los procesos de enseñanza y aprendizaje de las matemáticas, así como en la investigación. El material empírico consiste en trabajos presentados en GT 19 – Educación Matemática de la Anped (Asociación Nacional de Estudios de Posgrado e Investigación en Educación), de 2000 a 2023, que mencionaron el uso de tecnologías en el título o resumen. El análisis semántico del material involucró las siguientes dimensiones: a) mapeo de tecnologías y conocimiento matemático explorado en la investigación; b) presentación de algunos resultados sobre la inclusión de tecnologías en clases de matemáticas; c) elucidación del enfoque adoptado para la tecnología (medios, herramientas, artefactos) en los estudios. Se destaca una diversidad de tecnologías en los estudios y la transición del computador desconectado al dispositivo en red. Se sugiere un análisis futuro sobre la caracterización de la tecnología como un modo de expresión o de revelación.

Palabras clave: Tecnología en la investigación, Caracterización, Herramienta, Artefacto, Significados.

Résumé

Cet article propose une réflexion sur l'utilisation des technologies numériques dans le domaine de l'enseignement des mathématiques. Il soulève notamment la question de l'imbrication de ces technologies avec les processus d'enseignement et d'apprentissage des mathématiques, ainsi qu'avec la recherche. Le corpus empirique se compose des publications présentées dans le groupe de travail 19 – Éducation mathématique de l'ANPEd (Association nationale pour les études supérieures et la recherche en éducation), de 2000 à 2023, qui mentionnent l'utilisation des technologies dans leur titre ou leur résumé. L'analyse de ce corpus a porté sur les dimensions suivantes: a) cartographier les technologies et les connaissances mathématiques explorées dans les recherches; b) partager les résultats concernant l'utilisation des technologies dans les cours de mathématiques; c) expliquer l'approche adoptée vis-à-vis de la technologie (en tant que moyen, outil ou artefact) dans les études. Nous soulignons la diversité des technologies mentionnées dans les études et le passage des ordinateurs hors ligne aux appareils en ligne. Nous suggérons de poursuivre les recherches sur la caractérisation de la technologie en tant que moyen d'expression ou de révélation.

Mots-clés : Technologie en la recherche, Caractérisation, Outil, Artefact, Signifiés.

Resumo

O artigo apresenta reflexões sobre o uso das tecnologias digitais no campo da Educação Matemática. Em especial, problematiza as formas pelas quais essas tecnologias se entrelaçam com os processos de ensino e de aprendizagem da matemática, e na pesquisa. O material empírico é constituído pelos trabalhos apresentados no GT 19 – Educação Matemática da Anped (Associação Nacional de Pós-Graduação e Pesquisa em Educação), no período de 2000 a 2023, que mencionaram, no título ou no resumo, o uso de tecnologias. A análise semântica do material envolveu as seguintes dimensões: a) mapear tecnologias e conhecimentos matemáticos explorados nas investigações; b) trazer alguns resultados sobre a inserção das tecnologias nas aulas de Matemática; c) elucidar a abordagem adotada da tecnologia (meio, ferramenta, artefato) nos estudos. Evidencia-se uma diversidade de tecnologias nos estudos e o movimento do computador desconectado ao dispositivo em rede. Sugere-se análise futura sobre a caracterização da tecnologia como modo de expressão ou de revelação.

Palavras-chave: Tecnologia na pesquisa, Caracterização, Ferramenta, Artefato, Significados.

A photograph of studies emphasizing the use of digital technologies: the production of ANPEd's GT-19 as a focus

Analyzing knowledge production within a particular field is both a challenge and a stimulating scientific activity. It allows us to observe and navigate across different dimensions – writing and analysis. This was precisely the challenge that motivated the writing of this article: the possibility of being authors engaged in analyzing and reflecting on research studies conducted by other researchers and peers at different moments in time.

The review conducted by Rosa, Bairral, Gitirana and Borba (2018) deserves to be highlighted. It articulated research studies on Digital Technologies (DT) and Distance Mathematics Education within the scope of Working Group 6 (WG 6) of the Sociedade Brasileira de Educação Matemática (SBEM – Brazilian Society of Mathematics Education) based on publications presented in the Seminário Internacional de Pesquisa em Educação Matemática (SIPEM - International Seminar of Research in Mathematics Education, in free translation), particularly in its sixth edition (VI SIPEM). The study indicated four non-mutually exclusive domains of the production of WG 6: the role of media in terms of mathematical knowledge production; the collaboration among participants in educational spaces related to mathematics based on the use of technological resources; the development of digital resources focused on Mathematics Education; the consideration of the body alongside the resources used; and mathematics teacher training focused on using Digital Technologies (Rosa et al., 2018).

Although the analysis conducted by Rosa et al. (2018) also highlighted the contribution from WG 6's production in the national and international contexts, it is important to mention the review carried out by Drijvers and Sinclair (2024), which emphasizes the evidence of benefits of using DT in mathematical learning, such as: investigations in DT lead to new theoretical developments; it enables the development of new paradigms; it fosters changes to the curriculum, teaching and assessment practices. The authors stressed that even though aspects related to equity in terms of access and use of DT are important, they have been underexplored so far (Drijvers & Sinclair, 2024).

The two aforementioned reviews are pivotal to our analysis, especially for enabling us to access and engage in dialogue with results provided by various studies published in another space focused on discussing Brazilian Mathematics Education: WG19 of ANPEd. In order to do so, we will: a) map technologies and mathematical knowledge explored in investigations; b) discuss some results about the use of technologies in Mathematics classrooms; c) explain the adopted approach to technology (as means, tool or artifact) in the studies.

Theoretical aspects

We are aware that the field of digital technologies is broad and heterogeneous. However, we still consider it relevant to include this section and present some of the discussions that mark the field and that have been used by us as theoretical lenses. According to Rosa and Souto (2023), research in Mathematics Education commonly views "Digital Technologies (DT)" as "media", "artifacts", "instruments", "tools" or "means". Understanding this difference and clarifying it in an investigation is important because it allows subjects to be situated in the place of knowledge production – in some cases, as recipients, and in others, as producers or authors. In our analysis, based on Rosa and Souto (2023), we will solely focus on the terms *tool* (instrument), *artifact* and *means*.

The notion of *tool* is commonly used in studies on technologies. In some productions, it is possible to notice that *tool* is treated as a synonym for instrument, resource, device, etc., so it is important for us to better situate this construct in the field of educational technology. The idea presupposes a path, a determined use. The subject makes use of a tool to do something whose product is previously known. For example, using a computer keyboard to write these lines.

In contrast to the tool, which usually evokes a physical element, there is the artifact – a concept that views a DT in its physical or symbolic dimension, as anything that mediates the human relationship with the world. Nevertheless, Souto and Borba (2018) reinterpret the role of artifacts beyond the concept of mediation in activity theory, considering them as part of a collective that possesses agency in a dialectic relationship of transforming itself and transforming the way of producing mathematics. The identification of artifacts is a dynamic process, and we considered studies in this scope that aim to expand possibilities of learning, creating, belonging, and do on, to all parties involved[3].

While the tool presupposes use aimed at achieving a universally expected goal, the artifact involves an appropriation process, which is individual and temporally situated. We consider within the scope of tools those studies that employ DT to consolidate previously taught content, or those that make use of informatic laboratories as a means of materializing what has been covered in class, for instance. This use of technologies as tools was identified in studies presented within ANPEd's WG19, particularly those conducted between 2000 and 2006.

Any particular technology can be a tool, an artifact and/or a means. For example, let us consider the possibility of using Microsoft Excel to perform calculations and build graphs, or

[3] See in Assis (2020) an enrichment of the notion of *artifact* with the advent of touchscreen-based devices.

employing it to analyze and compare graphs. From the perspective presented by Heidegger, Rosa and Souto (2023) understand that finding purposes and producing or using means to achieve them is a human activity. The authors add that:

> According to the understanding of technology in which it is conceived as a means and a human activity, the instrumental and anthropological definition of technology is accepted and made evident. Hardly anyone would disagree that this is correct. Furthermore, the idea of media as the means responsible for mediating the relationship between human beings and the world is equally intertwined with this perspective, as well as the conception of the tool as a utensil for carrying out a human activity (Rosa and Souto, 2023, p. 3, our translation).

Rosa (2023), as cited by Rosa and Souto (2023), provides an interesting characterization of "means of revelation". According to the author, they are means of creating ideas, environments, and loci – that is, they become a "resource connected to the 'being' in order to constitute itself as a body (cyborg) that manifests itself and suggests cognitive flows, which reveal and highlight new thoughts, new ways of acting, creating, imagining, and shaping images" (Rosa, 2023, p. 10, our translation).

In line with Rosa and Souto (2023), in this article, we understand that distinct perspectives of Digital Technologies in Mathematics Education often overlap, collide, intersect and are mistaken for one another. Regardless of the scope of your research, we invite you not to place the essence in the DT themselves, but to consider that there are other factors at play, such as yourself, the environment, the subjects who will act alongside you in this environment, and the ways in which you will share experiences and knowledge.

Based on the reflections shared up to this point, we will now begin to analyze and classify the studies from ANPEd's WG 19 that address the use of technologies. We searched for different meanings mobilized by the use of DT in the field of Mathematics Education, while paying attention to the creative environments they design, to dialogue and the sharing of ideas as means to foster DT-based learning, without creating hierarchies. In the next section, we will present the methodological paths adopted for selecting and working with WG 19's studies.

Research methodology

In order to conduct a study on the publications presented within ANPEd's WG 19 that addressed the relationships between Digital Technologies and Mathematics Education, we adopted some of the reflections shared by Paraíso (2012) as our methodological basis. According to the author, more than searching for pre-established methods that guide a specific way to generate and analyze the empirical material to be examined, it is important to consider

that our concerns, questions and the way we formulate our research problems will enrich the paths that will be followed in empiricism. The author emphasizes that: "we know that the way we conduct our research depends on the questions we ask, the concerns that move us and the problems that we formulate" (PARAÍSO, 2012, p. 23-24, our translation).

We opted for a methodology that goes beyond a single method, as we do not believe in the possibility of having something ready, *a priori,* which could be considered and adjusted based on pre-established models. Our path was marked by a constant reading of the material, guided by questions that emerged as we read – we extracted fragments from the texts, wrote this text and repeated the process. There were several questions and very few certainties, such as the impossibility of finding totalizing explanations or absolute truths about the theme: the relationship between Digital Technologies and Mathematics Education within Anped's WG 19.

Thus, in order to find some clues about the aforementioned theme, some actions were necessary. The first one was selecting the material to be examined. We visited the official website of ANPEd, which holds all National Meetings[4], to obtain the publications presented in WG 19. According to the information on the website, within a defined time frame, we decided to analyze the national meetings held from 2000 onward. It is important to highlight that we did not find studies on digital technologies in 2007, 2009 and 2012. Moreover, we could not find the annals of the 2019 National Meeting.

We identified the articles based on their titles and abstracts by looking for the word *technology* or correlated terms such as *digital, software, Cabri, GeoGebra, computer, internet, multimedia, virtual, computational* and *touchscreen*. Our inclusion criterion relied on the presence of words or expressions related to digital technologies in the title or abstract. Studies on Distance Education without a direct reference to technology in their titles or abstracts – such as the publication by Resende and Vieira (2010) – were not considered.

After selecting the articles, we read them. We adopted a semantic perspective on the studies, neither evaluative nor classificatory in nature. Each text has its relevance and particularities, which can be theoretical or related to context and historical moment. As technology progresses, theoretical foundations evolve, as we are subjects undergoing constant change. We did not assess the studies; we merely interpreted them through our lenses, which do not share the same point in time as those at which the studies were conducted and published. The textual markers we used are not exclusive, that is, they cannot be seen exclusively in the approach in which we situated them. Although there is an explicit conceptualization of

[4] https://anped.org.br/reunioes-nacionais Accessed: January 10, 2025.

technology by the authors in some articles (Bolite Frant, 2002; Frota and Borges, 2004), our "classification" was inspired by Rosa and Souto (2023), but we were not limited to their study.

Furthermore, it is important to highlight that based on the aforementioned criteria, we selected 21 studies for analysis in this article, encompassing the period between 2000 and 2023. In each text, the reading process was carried out in the same way: access, reading and annotation. Then, we built tables with the data we considered necessary: article title, authors, year, objectives, data production stages, technologies involved and the relationships between the technologies and Mathematics teaching and learning processes.

The empirical material in this study is composed of studies presented in the yearly meetings of ANPEd's WG 19 between 2000 and 2023 that were digitally accessible. These publications were considered documents, as proposed by Pimentel (2001). According to the author, "if analysis categories depend on documents, they need to be found, 'taken off' shelves and receive a treatment that, guided by the problem proposed by the researcher, enables pieces to be put together, as in a puzzle" (Pimentel, 2001, p. 180, our translation). Along the same lines, Lüdke and André (1986) stress that documents constitute a "stable and rich source" of information that can be consulted multiple times and used to support a plethora of studies. For the authors, documents "are a form of contextualized information that emerges from a particular context and provides information about this context" (LÜDKE; ANDRÉ, 1986, p. 39, our translation).

Considering the methodological pathways described in this section and the theoretical reflections shared up to this point, we analyzed the studies presented in ANPEd's WG 19 to detect relationships between digital technologies and Mathematics Education. The results of this analysis are presented in the following sections.

Methodological procedures

We begin this section by presenting a summary of the studies analyzed in this article. Of the 21 selected papers, technologies were not used empirically[5] in only four of them.

Table 1.

Objects of study and technologies (Created by the authors)

Author(s)	Object of study	DT used

[5] In Table 2 (Appendix), you will find other studies that have not been listed here. They are theoretical studies that analyze conceptions (Costa, 2006), career moments (Carneiro; Passos, 2010), profiles (Frota; Borges, 2004) or documents (Gonçalves; de Marco, 2021). Different technologies are mentioned by the subjects or appear in the analyzed documents. Although these studies did not make use of technologies, they enabled us to collect textual excerpts related to approaches to technology.

Laudares; Lachini (2000)	Calculus in an engineering program	Computer
Gitirana (2000)	Symmetry with 6th grade students	Computer, Cabri Géomètre
Araújo, Bairral, Giménez (2001)	Geometry concepts using Cabri Géomètre with in-service teachers	Cabri Géomètre, Virtual learning environment (VLE)
Coutinho (2002)	Modeling and simulation of random geometric probability situations using Cabri Géomètre II	Internet, Cabri-Géomètre II
Bolite Frant (2002)	Reading and constructing Cartesian plane graphs that represent motion situations to discuss the role of the body and technology in mathematical cognition	CBR software and sensor connected to the TI-83 graphing calculator
Bairral (2003)	Professional development of mathematics teachers in geometry through online interactions (extension course)	VLE, Internet
Bairral (2005)	Learning of spatial geometry topics (course) by future mathematics teachers in virtual environments	VLE
Fusco (2005)	Research and multimedia resources in an Electrical Engineering degree program, specifically in the course Analytics Geometry and Vector Calculus	Multimedia resources, website (http://rsapuc.cjb.net)
Garcia; Penteado (2006)	Future teachers organizing didactic-pedagogical activities related to a Mathematics topic using online resources within a project-based context	Internet
Scherer (2006)	Communication and learning in an online message board in the course Applied Statistics in Education	Online message boards
Mendes; Grando (2006)	Sim City 4 (computer game) for the appropriation/mobilization of mathematical concepts in high school	SimCity 4 (video game)
Jahn; Healy (2008)	Argumentation and proof in the mathematics classroom: collaborative design of learning scenarios	VLE
Silva (2011)	Narrating and analyzing the constitution of teacher identity in Mathematics through distance education – when knowledge related to teaching practice and higher education intersect.	Moodle3, Internet, GeoGebra

Bairral (2013)[6]	Analysis of touchscreen interaction singularities in the geometric thinking of high school students using the Geometric Constructer software	Geometric Constructer
Bairral (2015)	Mathematics teaching undergraduate students analyzing the behavior of notable points of a triangle in a virtual environment with GeoGebra (VMTcG)	VLE integrated with GeoGebra (VMTcG)
Henrique (2017)	Elementary school students learning parallel lines intersected by a transversal on Geogebra through touchscreen interactions on smartphones	GeoGebra App, audio and video recordings; device screenshots
Bairral, Oliveira, Henrique (2023)	A literature review on eye-tracking methodology in mathematics education research	Eye-tracking

In Table 1, we can observe the presence of studies that use or discuss technologies in productions by ANPEd's WG 19. They show a variety of technologies used in empirical studies. In addition to this abundance, we can also notice a chronological shift in WG 19's technology-based productions, which, to some extent, reflects a chronology of the development of educational technologies in contexts that go beyond WG 19. Research studies began with the use of computers; then, in the 2000s, dynamic construction environments emerged – such as Cabri –, and virtual settings began to be designed and used, initially, in continuing teacher education.

The integration of GeoGebra into synchronous virtual environments was discussed in 2015. Embodied cognition appeared in 2002. This perspective was enhanced with touchscreen devices (2015 and 2017) and the capture of on-screen gaze (2023). In general, there was a shift from desktops – offline computers and physically situated subjects – to the overcoming of physical and spatial barriers through VLEs and mobile devices. The latter did not exclude the former, but reconfigured it (Lemos, 2009).

It is curious that, although Cabri Géomètre – the first and most popular dynamic geometry environment – is still being enhanced, its use in Brazil is largely absent from research studies. GeoGebra is the most widely used tool in investigations because it is a free platform, a repository of diverse activities, an environment that integrates geometry, algebra, functions and so on, and serves as a space for constant collaboration among users. Moreover, we highlight the prevalence of studies – 9 out of 17 – within the scope of geometry education, which we considered interesting, since geometry often tends to be treated as secondary.

[6] From 2013, the meetings began to be held every two years, and in 2011, they became itinerant.

In the research studies presented within WG 19, particularly from 2000 to 2006, we observed that the investigations aimed to encourage the integration of technologies into Mathematics classes, a practice that was likely not common in schools at the time. This was mentioned in the conclusions drawn by some researchers, as shown in the excerpts below:

> We saw that our virtual environment favored and fostered a communicative process among all teachers who participated in it and contributed to their valuing of this new form of distance learning. **However, merely using the internet will not generate improvements in the formative process; it must be properly integrated into the curriculum and educational setting, which will require a deep didactic and epistemological reassessment and reorientation** (Bairral, 2003, our emphasis and translation).
>
> **The shifts experienced by the analyzed teachers in terms of developing a proactive attitude toward technology incorporation still seem rather tenuous**. This adoption must represent a move away from the comfort of a heteronomous position, which places sole blame on the educational system for the slow pace in the incorporation of technology use in basic education (Frota and Borges, 2003, our translation).

This first shift, attempting to integrate technologies into Mathematics classes by positioning them as tools or means to teach specific content, began to make room for other discussions in 2013. For instance, studies by Bairral (2025, 2013) and Henrique (2017) show the integration of other technologies into Mathematics classes, such as touchscreen devices. The authors highlight that these mobile devices have become increasingly present in students' lives.

In our analysis, we observed not only a change in the type of technology used in research studies, but also in pedagogical discussions during the periods between 2000 and 2006, and from 2013 to 2021. Without searching for a fixed reflection within these periods – as if there were linear marks that appear at one point in time and disappear at another –, we only identified some different emphases in researchers' reflections on the use of Digital Technologies in Mathematics Education.

Initially, in research studies conducted between 2000 and 2006, it is possible to identify a concern with using technologies as a way to teach specific content. The reflections presented in the publications focus on the content itself and on the positions adopted by teachers and students, who occupied different roles: students who learn mathematics through technologies, and teachers who must appropriate these technologies in order to organize a teaching setting.

In the later period, the importance of technology is no longer questioned. Authors' considerations are more centered on interaction strategies between teachers and students when pedagogical actions involve technologies, based on collaborative and argumentative debates that constantly take place among the subjects involved (Bairral, 2013).

Regarding the identification of approaches in the studies

In this section of the article, we aim to present a small summary of the analyzed studies in order to complement the reflections shared in the previous section. Table 2 (Appendix) synthesizes how we situated the studies on Digital Technologies[7] as tools, artifacts or means. We did not classify the investigations; rather, we collected and interpreted text fragments (with boldface markings) that enable us to mobilize approaches to technologies in the studies, which do not necessarily adopt an exclusive perspective, but that may shift. The excerpts are either literal reproductions or summaries provided by us, and the boldface markings serve as mere semantic markers (van Dijk, 2000), since our classification was guided by a global understanding of each study.

Laudares and Lachini (2000) warn us about using computers to consolidate content without attention to the subjects involved. The authors noted that teachers used computers to operationalize didactics with an emphasis on didactic materials, while overlooking subjects' actions. They stressed that, in the hands of agents, the means – technological tools – become instruments to obtain results. Finally, they stated that the tool – the computer – does not possess intelligence, sensitivity, emotion or intuition; it only becomes an instrument that can make the qualities of those who handle it explicit when used by a subject. While the study by Laudares and Lachini (2000) moves between aspects related to the tool and the means, the research by Gitirana (2000) – who considers the tool to be decisive for students' comprehension of the notion of rotational symmetry and decision-making in order to reflect on the validity of their production –, enables us to situate this Cabri-based study as both a tool and an artifact.

[7] In some studies, the terminology adopted was Information and Communications Technology (ICT). Within the theoretical scope of the study under analysis, this characterization aligns with the more recent terminology, Digital Technologies (DT). For this reason, we opted to use the latter term in order to enhance readability. In summary, DTs presuppose internet-connected devices used in face-to-face or online situations.

Decision-making, metacognitive reflections and the observation of changes in learning allow us to interpret the use of technology beyond the scope of tools. In this sense, the study conducted by Araújo, Bairral and Giménez (2001) – about pedagogical practices that clarify teachers' mathematical beliefs and the pedagogical implications that may result from them, from a multimodal perspective – enables us to situate this study within the dimensions of artifact and means. Coutinho (2002) highlights that game modeling is an element of a particular didactics engineering in which students accept the use of a pseudo-concrete model. Direct actions on the parameters of game simulation and decision-making grounded in theoretical knowledge – not derived from the perceptual apprehension of an image – situate this study within the scope of tool and artifact.

When we view a technology from the perspective of a tool, the path is explicit and known. It is important to consider that using technology adds an element that situates the production of meaning within a semantic field different from the one in which students are used to operating (Bolite Frant, 2002). New technologies in mathematics education, seen as prostheses – not reparative ones –, enable action and discourse about mathematical objects. According to the author, this action refers to considering technology as a mode of expression, with diverse and complex connections.

Programs interested in teachers' professional development in mathematics, using resources available on the internet through online interactions, must operate according to principles of equity and foster professional actions committed to significantly changing the educational process and teachers' professional knowledge (Bairral, 2003).

Frota and Borges (2004) highlight that the movement each mathematics teacher must make toward their own technological training is a strategy for development – a means. In addition to playing the roles of teaching and learning resources, and of tools and instruments of thought, digital technologies can become sources of renewal of curricular approaches and generate new themes for the curriculum.

Moreover, the opportunity to become familiar with and use a range of technologies contributes to mathematical learning in a different way, as it enables singularities to emerge rather than a generalized behavior (Bairral, 2005). Therefore, designing environments –

whether face-to-face or remote – and their formative principles allows for the identification of the three dimensions of technology in studies by Bairral (2003, 2005) and Frota and Borges (2004). Technology-based classes can foster the development of critical thinking and the intersection of different types of knowledge (Fusco, 2005). One possible classroom strategy is the use of the computer laboratory. This kind of experience in higher education can be carried out through activities that integrate scientific knowledge from various disciplines and develop other competencies desired for the training of future professionals. This sole focus on the activities and the location (the laboratory) enables us to situate this type of study as a mediating use of technology.

Garcia and Penteado (2006) view prospective teachers as both users and authors of material published on the internet. According to the authors, through interaction with information technology (IT), future educators can develop new perspectives on the use of this technology, as well as on ways to teach and learn mathematics. This is what differentiates using technological resources as a technical activity from situations that enable prospective teachers to reflect on what it means to use technology for learning. The researchers argue that teacher training, in particular, should be a space for accessing, producing and disseminating information. To achieve this, it is necessary for technologies to be made available to future teachers and for conditions to be created so that they can be active participants, not mere spectators. In this formative approach, technology is viewed as an artifact.

The authors of the aforementioned study argue that subjects must become inhabitants of learning spaces, not mere visitors. To that end, Scherer (2006) presents learning and communication possibilities through virtual message boards. This type of space favors complex movements of individual and collective order and disorder, of cooperation and organization according to each group's specificities. In this sense, educational action in message boards should articulate the collective movement of learning by asking questions, presenting summaries, revisiting propositions, making proposals to the group and formalizing concepts, while aiming to especially foster each student's learning and keeping the debate open.

IT technologies that enhance teaching interactions are also highlighted by Costa (2006). The author emphasizes the need for teachers to change and establish more and better

interactions. Cybertraining emerges as a possibility for teachers to reflect upon a broader educational context, receive, contribute and exchange support to their pedagogical practices, and work on their professional development. According to the author, learning and teaching with technological support through reflective and collaborative practices – in the relationships established with the device and with others – can foster a new teaching culture.

By viewing subjects as inhabitants and the formative space as a context for enhancing possibilities, studies such as those by Scherer (2006) and Costa (2006) make technology an artifact in the process. Mendes and Grando (2006) understand that using computer games in classes must follow the constructionist approach. For instance, according to this approach, when subjects play while thinking aloud – describing what they are thinking and doing –, they highlight the procedures they use and make decisions about their own actions. Jahn and Healy (2008) focused on aspects of the collaborative design of learning settings related to argumentation and proof in school Mathematics. Activities related to recording and producing the text for a proof were analyzed and proposed. Games and the design of argumentative environments are means through which technology is used.

Although Carneiro and Passos (2010) did not implement DT in the classroom, they stressed that using these technologies at school is not a simple process, especially for novice teachers. Using DT in mathematics teaching is shaped by various factors such as unpredictability, insecurity, fear and the drive for continuous learning. The reorganization of thinking is highlighted by Silva (2011). According to the author, human beings' interactions with non-human collectives can enable this reorganization. In his study, the subjects demonstrated this when they cited their more intense use of the internet for researching, establishing contact and interacting with different people and spaces. In these two studies, perspectives of technology as an artifact and a means intersect.

Identifying various ways of touching a screen could generate new insights and foster the expansion of cognitive possibilities for mathematics education with this type of digital technology (Bairral, 2013). In this sense, it can be viewed as an artifact. The use of dynamic geometry environments emerges as a means of making future teachers more aware of the

importance of developing strategies for analyzing interactions and creating ways to promote a sustained argumentative and collaborative debate among participants (Bairral, 2015).

To integrate a mobile device into teaching contexts, it is necessary to identify the potentialities and limitations of the resource, aiming to assign appropriate meaning to its use and to foster a favorable environment in which learning can occur. The addition of different resources to a task contributes to the development of the cognitive capacity of all those involved (Henrique, 2017). Studies like this one move between the dimensions of the artifact and the tool.

Using digital technologies can generate changes in classroom dynamics and in the ways of teaching and learning mathematical concepts (Gonçalves and de Marco, 2021). One possibility for integrating digital technologies into mathematics teaching and learning processes could be the implementation of these technologies in teaching degree programs, which constitutes a formative strategy – a means.

Finally, a study by Bairral, Oliveira and Henrique (2023) that focuses on the eye-tracking method frames the importance of the device, which is a resource – a tool – that enables the tracking and quantification of eye movement based on a stimulus, such as image or text. It is a piece of specialized data analysis software used to examine a subject's eye movement and position.

Final reflections

This article offers a historical contribution by presenting a micro-trajectory within the scope of Anped's WG 19, but it also holds didactical value, as it provides beginning researchers in education with technology with a reflection on the approach they will adopt when integrating technologies into their investigations. It is always important to remember that our approach is not detached from our worldview and understanding of what is means to produce knowledge.

With the studies summarized in this text, we have highlighted some results, which may invite you to revisit the original publications. We observed a range of technologies in the studies, as well as how they are integrated into research and teaching design – aspects that should go hand in hand. Regarding the analyzed texts, we identified a path similar to those

described in studies published at other events; that is, a shift from offline computers to online devices, into cyberspace, with its different environments and inhabitants. With connectivity, virtual learning environments began to be increasingly designed and implemented, using and analyzing internet resources became more popular, and the utilization of mobile devices in the classroom and in other activities was facilitated (Henrique, 2017). The movement – from offline to fully connected – is not linear; that is, mobile devices can be used to access virtual environments.

Although we do not acknowledge a hierarchy among the three analyzed dimensions of Digital Technologies (tool, artifact and means), a study currently situated within the instrumental aspect of technology may appear out of step with how we engage with technology nowadays. During implementation, a more "technical/instrumental" approach may be present, with a more didactic orientation. Nevertheless, when producing data and, consequently, knowledge, we should proceed with caution. Instrumental use may be associated with the predominance of offline computers. Further investigations into this type of use in other events and publications are warranted.

In line with Rosa and Souto (2023), we understand that distinct perspectives on digital technologies in Mathematics Education – tool, artifact or means – often overlap, collide, intersect, or are mistaken for one another. Regardless of the scope of your research, we invite you not to place the essence in the DTs themselves, but to consider that there are other factors at play, such as yourself, the environment, the subjects who will act alongside you in this environment, and the ways in which you will share experiences and knowledge. For this reason, we focused on studies that design creative environments, that aim at dialogue and the sharing of ideas without hierarchy as means of learning with digital technologies.

An interesting set of discourse markers emerged during the organization and analysis of the material (Table 2, boldface). Within the scope of the **tool**, we identified the following markers: facilitating didactics, decisive tool, direct action, explicit path, a variety of information, continuous interest, knowing and using, instruments for thinking. In the dimension of the **artifact**, these elements emerged: decision-making, enhancing communicative skills, developing professional actions committed to significant changes in the educational process,

sources of renewal, contributing differently, interacting with the computer in diverse ways, expanding and articulating possibilities, inhabiting, bringing about modifications in classroom dynamics. From the perspective of digital technologies as a **means**, we identified: design, means, reassessing and feeling motivated, thinking and doing mathematics, composing and enhancing, through activities, mediation, the way in which, experimentation, incorporation, driving changes. Although these markers are not sufficient to classify the studies, they invite us to reflect on their appropriateness – or not – for the purposes of the investigation and the production of data.

As highlighted by Bolite Frant and Castro (2009), a suggestion for future analyses is to verify if the production environment is in sync with the design and implementation ones. We believe this is not a simple task, as our lenses are distinct, but it could be stimulating and necessary. Furthermore, studies that problematize digital technology as a means of expression (Bolite Frant, 2022) or revelation (Rosa, 2023) could provide new perspectives on formative environments and on the production of mathematical knowledge.

We hope the discussions and summaries presented in this text can inspire and guide new research studies in the field of digital technologies in Mathematics Education. We know that we have presented only a brief excerpt of the vast body of research conducted within ANPEd's WG 19. Finally, we invite other researchers to engage with this theme with the same empirical material. New perspectives will certainly be produced, thus enhancing the debate we have started in this text.

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Table 2: Some selected passages from the studies

Author(s)	Approach		
	Tool	**Artifact**	**Means**
Laudares; Lachini (2000)	teachers use it to **facilitate didactics** with an emphasis on didactic materials, and the agency of students and teachers is downplayed		**mediation** between knowledge and study methods
Gitirana (2000)	Cabri was a **decisive tool** for students' understanding of rotational symmetry	these resources foster students' **decision-making** and reflections on the validity of production	
Araujo, Bairral, Giménez (2001)		the use of CABRI serves to recognize more complex contents in order to formulate conjectures, identify necessary and sufficient properties, **enhance** communicative skills	it is necessary to conduct research that deepens and analyzes **the role of design**, of assessment and tutoring techniques and instruments, aiming to understand and improve teaching
Coutinho (2002)	Using Cabri enables students to **take direct action upon the parameters** of game simulation (…) depending on the level of knowledge of the software, the elements of validation of their conjectures and solution increase	subjects can **make decisions** regarding appropriate strategies to solve the proposed problem; such decisions are **grounded in theoretical knowledge**, not in a perceptual apprehension of an image	
Bolite Frant (2002)	when I use a tool, **this path is explicit**; the example I like to give is a hammer being used to drive a nail into a wall	we also wish to defend the use of technology as **a means of expression**. There are no bridges or simple **paths** for expression.	
Bairral (2003)	the availability of **a range of information contained on the web** (activities, websites, events, articles and other publications, resources, software etc.), without a doubt, had considerable impact on teachers' **continuous interest** in personal improvement and studies	formative programs **that develop professional actions** committed to significant changes in the educational process	interactions in the environment were important so that teachers **reassessed** their work in geometry and **felt motivated** and challenged to invest in their own professional development
Frota; Borges (2004)	**in addition to** playing a role as learning and teaching resources, ICT are also tools and **instruments for thinking**	they can become **sources of renewal** of curricular approaches to consolidated themes in mathematics education	as educators, teachers will not be able to undertake the effort to **integrate technologies** into mathematics education if they haven't advanced in their own learning of how to use technology to **think and do mathematics**
Bairral (2005)	future teachers had the opportunity to **know and use** a range of technologies	understand how such resources could **contribute differently** to mathematics learning	ICT **compose and enhance** the constitution of one more formative setting, but they do not replace face-to-face programs

Fusco (2005)			the teaching-learning process in higher education can be enhanced **through activities** that articulate the scientific knowledge of various disciplines. **Visiting the** computer **laboratory** brought mathematical concepts to the virtual world
Garcia; Penteado (2006)		accessing IT with possibilities to **interact with the computer in diverse ways** and to critically discuss matters related to the transformations shaped by IT, especially in knowledge styles and interactions patterns	we highlight the importance of the trainer's agency and their **mediation in the development of formative activities**, especially when they involved information technology
Scherer (2006)		teachers and students must **be inhabitants** of learning spaces, not mere visitors or passers-by. Communicative actions are complementary, competing and antagonistic, contributing to the learning of all subjects who inhabit the virtual environment.	
Costa (2006)		with a collective computer, collaboration and reflection on matters that concern professionals are **expanded**, impacting teacher training, which gains new dimensions.	cybertraining engenders a teaching cyberculture, adding new characteristics to teaching culture. **The way in which** teachers establish relationships with their peers gains new dimensions
Mendes; Grando (2006)			computer games can be used in problem-solving from a constructionist perspective. To do so, the teacher's role **as a mediator** of the process is fundamental
2007, no papers within the theme			
Jahn; Healy (2008)			we focused on aspects of collaborative design of learning scenarios related to argumentation and proof in school Mathematics
2009, no papers within the theme			
Carneiro; Passos (2010)		using ICT in teaching practice, particularly in mathematics teaching, can bring about **modifications in class dynamics**, learning and teaching processes, teachers' mediation and in the relationship between the teacher and the student. This practice introduces **new aspects**, such as unpredictability, insecurity, fear and the drive for continuous learning	with the use of technologies, for instance, **teachers can** experiment, test, discover, fail and succeed. **This experimentation** leads them to continuously replan their classes because successes and failures place them in a process of (re)creation, (re)elaboration and (re)adaptation, which enables them to learn constantly

Silva (2011)		mathematics teaching through Distance Education can **bring about changes** in processes of knowing and generating different teaching and learning connections, thus giving rise to other languages, signs and other forms of interaction that need to be investigated further.	Distance Education enables an even larger **incorporation** of ICT, creating spaces for a likely **(re)organization of thinking**.
2012, no papers within the theme			
Bairral (2013)[8]		touch interactions on the screen are important because learners **expand** their abilities to explore, argue and justify a particular geometric property.	
Bairral (2015)			using DGEs can **raise** future teachers' **awareness** of the importance of developing strategies for analyzing interactions and creating ways to foster a continuous collaborative and argumentative debate among participants.
Henrique (2017)		the intervention provided students with a **broader and more articulated view** on geometric properties and relationships.	GeoGebra on smartphones enabled students to observe a **set of elements** (angles, position of lines etc.) associated with the exploration and manipulation of constructed lines.
2019, Annals not found			
Gonçalves and de Marco (2021)[9]	establishing relationships between the mathematical content and **when and how** to address it by using digital resources		the use of DT **can drive changes** in classroom dynamics and in ways of thinking and learning mathematical concepts
Bairral, Oliveira, Henrique (2023)	a device **that enables** the tracking and quantification of eye movement based on a stimulus, such as an image or text		

[8] In 2013, meetings began to be held every two years.
[9] In 2021, ANPEd's texts began to be presented in the form of extended abstracts.