ORIGINAL PAPER

Experiences of preservice mathematics teachers during their education in times of pandemic

Mónica E. Villarreal[1] · Jhony Alexander Villa-Ochoa[2] · Jeannette Galleguillos[3]

Abstract

Due to the COVID-19 pandemic, educational institutions at all levels closed their doors and began to operate remotely. In this paper, we analyze the educational experiences of preservice mathematics teachers (PMTs) enrolled in mathematics teacher education programs from three South American universities, as the pandemic was unfolding. An exploratory study was conducted, based on an inductive and thematic qualitative text analysis of narratives written by 24 PMTs. Based on the study, we report on the following aspects: (1) experiences of PMTs in the passage to remote education (RE) mode (considering characteristics of remote classes—interactions, the rhythm of the class, teaching work—time management, home–classroom fusion, and physical and psychological discomfort), and (2) opportunities and limitation experienced by PMTs in relation to the use of technologies. The results of the study suggest the need to rethink teacher education programs regarding the integration of technologies in mathematics classes, the opportunities offered by hybrid education, and teacher education for distance teaching.

Keywords Preservice mathematics teachers · Experience · Technology · Remote education · COVID-19

1 Introduction

Since January 2020, the COVID-19 pandemic has caused a crisis in social systems, requiring immediate and systematic answers on the part of governments, health care areas, and economic, educational, scientific, social, and cultural institutions. This crisis has changed human attitudes and behaviors, as well as human interaction. In the educational field, the crisis triggered epistemological, ontological, and pragmatic concerns about how education could handle a health emergency. The roles of education in response to the emergency, its goals and purposes, teaching methodologies, resources, learning environments, and family participation, among other issues, are under review (Morgan et al., 2022; Ozdamli & Karagozlu, 2022).

In the literature reviews conducted by Abu Talib et al. (2021) and Morgan et al. (2022) to study the impact of the digital transformation in higher education during the pandemic, opportunities and limitations were noted. Opportunities include the following: flexibility in time and location offered by online distance education; increased exposure to the use of technologies that contribute to the closure of the technological literacy gap and foster the use of online and digital media; and the impetus to carry out necessary reforms in curriculum and teaching approaches. Limitations include the following: inequality of access to technology for the attendance to online classes; the inadequacy of online teaching for areas in which face-to-face practices are necessary; poor quality of communication among students themselves and with their teachers; technical difficulties; increased workload and stress; low technological literacy; difficulties in evaluating student performance; lack of work-life balance; and concerns regarding breaches of privacy.

In May 2020, the International Institute for Higher Education in Latin American and The Caribbean (IESALC) published a report (UNESCO-IESALC, 2020) analyzing the impacts of the pandemic on the different actors in

✉ Mónica E. Villarreal
monica.ester.villarreal@unc.edu.ar

1 Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Facultad de Matemática, Astronomía, Física y Computación - Universidad Nacional de Córdoba, Córdoba, Argentina

2 Facultad de Educación, Universidad de Antioquia, Medellín, Colombia

3 Instituto de Matemática, Facultad de Ciencias, Universidad de Valparaíso, Valparaíso, Chile

higher education systems, and the political measures aimed at guaranteeing the right to higher education during the pandemic. The report also dealt with the main difficulties of Latin American students, namely, internet connectivity, financial issues, and regular study schedules. Besides these difficulties, the report also noticed a lack of technological equipment, pandemic-related anxiety, social isolation, and poor communication with peers and teachers. Research is required to understand the nature of these difficulties and, equally importantly, their consequences for the students' experiences. In this context of crisis and in our role as mathematics teacher educators from three Latin American universities (Argentina, Chile, and Colombia), we were particularly concerned to investigate the experiences of PMTs to better understand the nature of the difficulties experienced by them in the transition to compulsive remote education (RE) that we had to go through during the pandemic.

In mathematics education, Bakker and Wagner (2020) pointed out that the crisis resulting from the pandemic causes challenges, but also offers hope. Challenges lead to rethinking the usual teaching methodology, forms of evaluation, or the use of technologies in mathematics education. And hope because, among other things, there has been an increase in the use of digital tools and finding creative solutions to practical problems. But on his part, Borba (2021), warned, with a concerned tone, how the COVID-19 pandemic has exposed dramatic social inequalities and the urgent need to study how students learn online when the home environment and inequalities in access to digital technologies play such important roles in RE.

Although the use of technologies in general and the Internet, in particular, have already been the focus of numerous studies in mathematics education, the compulsive and unplanned shift to RE has generated numerous problems that expand the research agenda towards new issues. This result was reported in both Castro et al.'s (2020) regional survey and Bakker et al.'s (2021) international survey, regarding future themes of mathematics education research. Among the various topics mentioned, 'Technology' is a lead topic listed by the authors, the study of which gained momentum since the pandemic due to the main role that technologies play in emergency RE. Meanwhile, the already limited access to technologies on behalf of students at different levels of the Latin American educational systems translates to limited access to education (Castro et al., 2020). According to Bakker et al. (2021), researchers agree on the idea that "the pandemic functions as a magnifying glass on issues that were already considered important" (p. 1).

Engelbrecht et al. (2020b) brought to the forefront the fact that the Internet is transforming the mathematics classroom and teacher education. Because of the pandemic and the consequent shift to RE, technologies such as mobile phones, digital learning objects, social networks, and the Internet have become central players in education, as long as access and connectivity are possible. One might wonder what transformations took place in classrooms during this obligatory transition to RE. Our study allows us to 'enter' some classrooms inhabited by PMTs.

As mathematics education researchers, we recognize the research opportunities that this unexpected educational context offers for research on any of the themes mentioned in the surveys conducted by Bakker et al. (2021) or Castro et al. (2020), more specifically, those that combine the education of PMTs and technology. As Latin American teacher educators involved in the education of PMTs, we have been subject, along with our students, to challenges and uncertainties, but we hardly knew about their personal experiences regarding RE during the pandemic, in general, and about their experiences with the use of technologies, in particular. Therefore, in the research on which we report in this paper, we proposed to answer the following question:

How did PMTs experience the passage to RE mode during the pandemic, both in general terms and specifically in relation to the use of technologies?

2 Theoretical background

2.1 Experience

In the educational field the notion of experience has been approached from various philosophical and pedagogical perspectives. For example, Dewey (1938) assigned to experience a central place in education. According to him, for an experience to be educative two principles must be followed: the *continuity* of experiences that guarantee the growth of the student (physically, intellectually and morally) and the social *interaction* of the student with the environment and the other actors in education. Based on empiricism, Dewey pointed out that experiences constitute the core around which school work should be organized, and proposed the experimental method in the natural sciences as the model that should guide the student's way of learning.

Larrosa's (2006) notion of experience departs from pragmatic or empirical views such as Dewey's, and is rather linked to philosophical positions close to phenomenology. In his writings, references to philosophers such as Benjamin, Agamben, or Heidegger allow us to differentiate him from Dewey's vision. Larrosa (2006, p. 88) claimed that experience is "*that which happens to me*" (in Spanish "*eso que me pasa*"). The author warned that although many events happen daily, few of these happen to me or touch me. If we want something to happen to us, it is necessary to stop and think, look, listen, and feel.

Larrosa ([2006](#)) disassembled the expression "*that which happens to me*" into three parts, namely, *that* (*eso*), *happens* (*pasa*), and *me*. "*That*" refers to an external event, something strange and alien to the subject,[1] something different from the subject, an event that does not depend on the subject, "something that does not depend on my knowledge, nor on my power, nor on my will" (p. 88, our translation).

When Larrosa refers to the word "*happens*" (pasa), he asserts that an experience is a passage or path, a journey, a departure towards something different from the subject, towards the "*that*" of "*that which happens to me*". This journey is also an adventure and, consequently, entails uncertainty, risk, and danger. Given that the subject is the place where experience occurs, it leaves marks, traces, and even scars.

Finally, "*me*" refers to the fact that although an event external to me happens, at the same time, something happens *inside* me, not in front of me or around me. It is in the subject that the experience takes place—in their words, ideas, representations, feelings, projects, intentions, knowledge, power, and will—and, as a consequence, experience is subjective. The experience is a *bidirectional* movement of the subject, coming out to meet the event, and coming back transformed since the experience presupposes that the event affects the subject in what they are, think, feel, and want, among other things. The subject who is capable of letting something happen to them is sensitive, vulnerable, exposed to and open to transformation. Therefore, when a subject lives an experience, they become transformed. The educational process also produces a transformation of the subject, which is why for this author, there is a constitutive relationship between education and experience (Larrosa, [2003](#)).

Larrosa ([2006](#)) proposed thinking about education by taking into account the relationship between experience and sense-making. Experience includes not only what is lived by the subject, but also the reflection upon it; such reflection leads to the production of meaning or sense for what was experienced. We make sense of an experience, of 'that which happens to us' through written or even spoken words.

For the purpose of our study, Larrosa's ideas offer a perspective to analyze the peculiar experiences lived by PMTs in the transition to emergency RE mode, because it enables us to emphasize the exceptional, unrepeatable, touching, unplanned, and existential character of their experiences during the pandemic.

Each subject creates and endures their own experience in a unique and singular way, but experience also involves interaction with 'others'. In RE scenarios, those 'others' may be humans, but they can also be technologies. Technology took a central role in RE during the pandemic, and we devote the next section to presenting the epistemological perspective regarding the use of technology that we assumed for our study.

2.2 Humans-with-media (h-w-m)

We adopted the perspective that assumes that, in any educational context, knowledge is produced by collectives of h-w-m (Borba & Villarreal, [2005](#)), that is, the epistemic subject is an inseparable unit made up of human beings and media of different natures. When speaking of media, the authors include any type of tool, device, equipment, instrument, artifact, or object (material or symbolic) produced as a result of technological developments. In the h-w-m system, the notion of use is key to recognizing different types of technology. For the purposes of this paper, technologies refer specifically to digital technologies, including those used for communication, information and collaboration purposes (Internet, applications for online communication, etc.) and any kind of software used for educational purposes, including mathematical software.

The notion of h-w-m is associated with the following two central postulates: firstly, that cognition is not an individual but a social enterprise, and, secondly, that cognition includes tools, media with which knowledge is produced; and this component is not auxiliary or complementary, but essential, so that the presence of different media conditions the production of different knowledge. More recently, in a paper referring to the future of mathematics education since COVID-19, Borba ([2021](#)) stated that "The pandemic foregrounds the role of home and the role of different parents and different social conditions in collectives that construct knowledge" (pp. 393–394). Thus, although of a different nature, good access to the Internet, as well as the conditions of the family environment or the characteristics of each home influence the construction of knowledge, particularly in situations of RE. Collectives of h-w-m as a basic unit of knowledge production are extended to collectives of h-w-m-things (Borba, [2021](#)). Although in this study we do not dwell on the production of mathematical knowledge, this epistemological perspective offers us a theoretical lens through which to evidence the active role of technology in the emergency RE.

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[1] When we say 'subject', we refer to the individual/person/human being who lives the experience. Larrosa speaks of the 'subject of experience' and that is why we decided to use the word subject.

3 Preservice teacher (PT) education and technologies during the pandemic: a literature review

In this brief review of the literature, we have selected publications that focus on the education of PTs or PMTs during the pandemic and the use of technology in this scenario. In a situation of lockdown, technology became a key factor for the continuity of PTs' education, especially network technology (platforms, multimedia, videoconferences, etc.). We identified studies regarding two topics. On one hand, researchers have been preoccupied with understanding visions, perceptions, attitudes, learning, and factors that have an impact on the use of technologies, on behalf of PTs during the transition from face-to-face classes to RE mode (Dilling & Vogler, 2022; Long et al., 2022; Mulenga & Marbán, 2020a, 2020b; Naidoo, 2020; Nketsia et al., 2021). On the other hand, the researchers have documented actions taken in order to reorganize curriculum and give continuity to important processes in the PTs' education, such as teaching practices in schools (Adams et al., 2021; Kim, 2020; Rodrigues & Garcia, 2022).

Within the framework of the first topic, Long et al. (2022) explored changes in PTs' perception of learning environments in the transition to RE. The study included PTs from a university teacher education program in the USA. The results showed that there was a significant deterioration of student cohesiveness, "students felt that they had lost the feeling of being part of the class" (p. 349). Meanwhile, the deterioration was less noticeable in the following realms: teacher support (for students), involvement (with inquiry and problem solving tasks), task orientation, and equity (regarding the teacher's attitude towards the students).

Mulenga and Marbán (2020a, 2020b) analyzed the online mathematics learning activities of PMTs from a university in Zambia during the first months of the COVID-19 pandemic. The study identified students with excellent online learning skills for mathematics in technology-rich environments, as well as students with low levels of skills in the use of mobile technology and the implementation of social media to learn mathematics. Despite the contrast between results from these groups, the authors showed that digital learning was a feasible response to the closure of educational institutions due to the pandemic. This conclusion converges with the results of Alabdulaziz (2021), who argued that the compulsory use of technology during the pandemic influenced teachers to broaden their point of view regarding the easiness and usefulness of technology. The author explained that teachers experienced a transformation in the ways of teaching and learning to which technologies contributed. It is expected that, in the future, technology will continue to be incorporated into the school routine.

Nketsia et al. (2021) and Dilling and Vogler (2022) reported that the pandemic revealed factors that affect the integration of technologies and reflections of the PTs regarding the use of digital platforms. Nketsia et al. (2021) evaluated the online learnings of PTs from Ghana and informed on the need for training on information and communication technology and development of confidence in their computer skills. For their part, Dilling and Vogler (2022) studied the reactions of German PMTs regarding the use of online mathematics learning platforms and their changes after participating in online training for using them. The results showed that the PMTs do not intend to use these online learning platforms as a substitute for face-to-face teaching, but mainly for differentiated and individualized support of mathematical issues. Naidoo (2020) researched South African postgraduate mathematics education students' experiences using digital platforms for learning mathematics. The author reported on the positive experiences in the use of mobile applications and the challenges that their use entails. Also, the digital platforms allowed students to be actively involved in a virtual community of practice.

Regarding the second topic, actions taken in order to reorganize curriculum, we analyzed the following works. Adams et al. (2021) reported on the implementation of strategies that implicated the intensive use of visual technologies and online communication during the pandemic so that Australian PTs could complete their supervised professional practice. The PTs worked online with teachers and designers to develop lesson plans and teaching resources, in order later to deliver the content remotely. Visual technologies were used for the PTs to analyze and develop learning programs for little children. For his part, Kim (2020) described the online learning experiences of PTs from an early childhood education program in the USA. According to the author, such experiences provided these PTs opportunities to interact with children, as well as encouragement for them to reflect on the best way to promote children's development and learning through online communication. Rodrigues and Garcia (2022) studied the teaching methods used in education programs of PTs in Portugal and Spain, and analyzed the development of their pedagogical practices in the classroom post-lockdown; their results showed that technologies can motivate, facilitate learning and have a positive impact on such practices. Furthermore, the authors pointed out the potential of technology to create learning experiences, the need to develop technological skills of teachers and students, and the need to adapt the teaching methods to the new modality.

Overall, the literature reviewed contributes knowledge on teaching, learning environments, opportunities, and limitations that technology offers in the PTs' or PMTs' education. These authors documented that the events that occurred during the pandemic assigned technologies a central role in the

Table 1 Participants in the study

University/Country	No. of students	Pseudonyms
University of Córdoba (UNC) Argentina	9	Nik, Bia, Caty, Celu, Fer, Flo, Gi, Lula, Sil
University of Valparaíso (UV) Chile	8	Kim, Cecy, Dan, Feli, Fran, Jo, Leo, Rob
University of Antioquia (UdeA) Colombia	7	Alex, Jair, Joe, July, Yen, Andy, Walt

Table 2 The invitation

Write a text in which you develop and think about your experience as a student during the pandemic. How was your educational process? Could you adapt yourself to remote learning? Have you faced any difficulties? Was it easy/hard to do? Have you noticed favorable opportunities for your learning process? How did technology contribute to/impede your learning process? What feelings have you experienced? Do you think that your experiences in this context have influenced in some way your idea of becoming a teacher? What have you learned from this experience? (text originally written in Spanish)

continuity of education and implicated a reorganization in ways of teaching, learning, and relating to one another. Our study joins the body of research that seeks to comprehend the experiences of PMTs in the transition to RE during the pandemic, for the purpose of highlighting the unique and unrepeatable character of what they lived.

4 Methodology

Our study was conducted using a qualitative approach based on an inductive analysis of narratives written by PMTs. Narratives give authors the chance to objectify their own experience, create or recreate meanings, and comprise knowledge in the process of writing or communicating their own experiences to others. Narratives give researchers the possibility of scrutinizing the sense that those who wrote them attributed to 'that which happened to them' in relation to RE imposed by the pandemic. Freitas and Fiorentini (2007) acknowledged written narratives as a way of considering, reporting, and representing experience, attributing meaning to what we are, do, think, feel and say. Likewise, Chapman (2008) stated, "since the stories we tell reflect who we are and what we may become, they can provide a basis for meaning recovery and meaning construction or reconstruction of our experiences" (p. 17).

4.1 Study participants and educational contexts

Participants in our study were 24 PMTs in three South American universities, enrolled in the mathematics teacher education programs of their respective universities. Students attending the courses in which the authors were teaching in the year 2020 were invited to write a narrative about their educational experience during the pandemic. Thus, a convenience sample was constituted (Given, 2008). They were all students in advanced courses. Table 1 shows the number

of students from each university and the pseudonyms used to identify them in the analysis.

The education programs for PMTs in our universities have historically been in face-to-face mode. In March 2020, each university took different measures to shift all its activities to a virtual environment in order to continue the educational process. To handle this situation, many electronic devices—PCs, notebooks, tablets, mobile phones—were lent, and Internet connection plans were given to teachers and students. In addition, platform licenses were acquired, guidelines for the use of digital resources (Moodle, Google Classroom, Meet, Zoom, Teams) were produced and made available, and support strategies on the organization of curricula and the use of technologies in teaching were created. The professors made adaptations to their syllabus and class schedules, as well as to the evaluation methods, following the guidelines established by the authorities at each one of the universities. Synchronous classes were held, and virtual classrooms were used.

4.2 Data

The data are comprised of 24 narratives written by the PMTs between November and December 2020. Table 2 shows the invitation made to the PMTs.

The research aim was explained to all the PMTs who voluntarily decided to participate in our study. PMTs sent their narratives by email (or through the virtual classroom) to the professors (authors of this paper) who had invited them.

4.3 Analytical procedures

We conducted a thematic qualitative text analysis (Kuckartz, 2014) based on the PMTs' narratives. To start the analysis, narratives were organized in online folders identified by country of origin, and each of the researchers had access to all of them. From a first reading of the narratives and
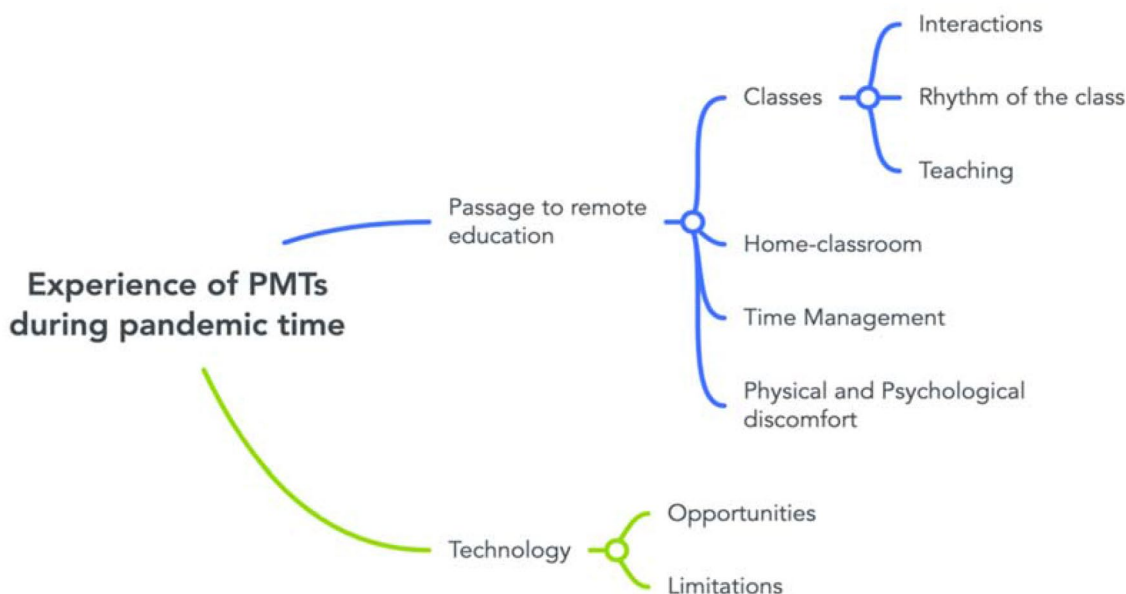
Fig. 1 Categories and subcategories of our study

considering the text in which PMTs were invited to write them, we selected three themes to begin coding the narratives: *adaptation to RE*, *difficulties and feelings*, and *technology*. Then, each researcher reviewed the narratives, independently, and coded text fragments related to these three themes. Subsequently, a *consensual coding* procedure was initiated: joint sessions were held to discuss the individual findings and find agreement. Next, we created a thematic matrix in a worksheet, in whose cells we recorded the text fragments of each PMT's narrative related to each theme. From the matrix analysis, we observed that the three themes were deeply linked; in particular, issues related to the technology theme also appeared in the other two themes. Therefore, for analytical purposes, and considering the research question, we decided that the three initial themes would converge into the following two main categories:

1. *Passage to remote education*: This category focuses on what happened to PMTs in the transition to RE and includes issues related to the themes *adaptation to RE*, *difficulties and feelings*.
2. *Technology*: This category focuses on PMTs' views about technologies used during the passage to RE.

In a second phase of analysis, for each category, the fragments from the PMTs' narratives were once again reviewed, reorganized, and re-coded in some emergent subcategories which not only made the main category more specific but also favored the development of a thorough analysis. These subcategories, which are presented in Fig. 1, regrouped the contents of the themes that initially formed the categories.

Within the category *Passage to remote education*, from the themes *adaptation to RE* and *difficulties and feelings*, the following subcategories were identified: *classes* (and three aspects associated with it: *interactions*, *rhythm of the class*, and *teaching*), *home-classroom*, *time management*, and *physical and psychological discomfort*. Finally, the theme *technology* (together with all the issues about technology that had appeared in the other two initial themes) resulted in the generation of the category *Technology* that was split into the subcategories *opportunities* and *limitations*.

5 Results and analysis

Transition to RE without previous preparation caused different reactions among PMTs that led us to describe and analyze '*that which happened to them*'. The narratives unfold multiple experiences. We organized the analysis in two categories concerning the research question: passage to remote education and technology.

5.1 Passage to remote education: that which happened to the PMTs

The beginning of the lockdown in March 2020 in Latin America due to the COVID-19 pandemic, and the consequent compulsive shift to a RE mode provoked new, strange, and external situations in relation to PMTs' daily life. Work and educational spaces started to coexist with 'home spaces', generating a strange situation. The pandemic and the passage to RE can be recognized as an external, surprising, and

unexpected event that, in Larrosa (2002)'s terms, we identify as "that" in his definition of experience. The passage to RE was characterized by the PMTs as something new, hard, causing strangeness, and that brought on changes:

> In the beginning, I found it very hard, everything was new […] It seemed strange having to give an oral presentation or do assignments in front of a computer without knowing the reaction of teachers nor the reaction of my classmates. (Celu)

As explained in the methodology section, four emergent subcategories disaggregate this category, namely, *classes, home-classroom, time management,* and *physical and psychological discomfort*. They highlight the changes that occurred in the learning environments and enabled us to describe and analyze what happened to the PMTs in relation to emergency RE.

5.1.1 Classes

The PMTs involved in our study attended remote classes through videoconference. In their narratives, we identified three aspects of the classes that enabled us to understand what happened to them in this new learning environment. These aspects are *interactions, rhythm of the class*, and *teaching*.

Interactions. In these types of classes, interactions are mediated by computer screens or other devices. This new way of interaction, which lacks physical contact, caused PMTs to miss the face-to-face way of relating to each other in the classroom:

> I miss the classroom, the chalk and the blackboard, having the professor physically present […] You don't have the possibility of solving doubts by talking directly to the professor […] we cannot address doubts among classmates. (Leo)
> Encountering professors and classmates through a screen was odd, […] as time went by, classes were farther and farther from reality. I missed all the interactions with my classmates and professors. (Flo)

The narratives show that some classes during this period did not encourage the PMTs' participation. It was difficult to pose questions to professors and classmates: "I needed the classroom dynamics in which I can ask everything of the professor until I understand the subject without feeling that I am interrupting the class" (Jo). In contrast, there was one student who claimed that "the methodology of remote education allows students to participate more during classes and not to stress when delivering an oral presentation" (Joe). However, this was a unique manifestation. In certain situations, the number of students was reduced in each class, losing the possibility to exchange opinions and ideas (Caty).

Some students wrote that virtual classes without interaction become tortuous and overwhelming (Yen). Lack of interaction was one of the reasons for students to drop some courses (Jo, Yen).

Rhythm of the class. Some PMTs wrote that theoretical classes (online) progressed at a very fast pace and that it was necessary, in this mode, for the classes to develop at a slower pace for the content to be better understood. This situation is depicted in the following text fragments:

> The professor explained the topics very fast and she established the rhythm of the class […] I would have liked that the theoretical classes would have had a slower pace. (Gi)
> Professors delivered classes faster than normal. This happened because they had the presentations done beforehand and they did not need to write on the blackboard. (Bia)

Other PMTs highlighted difficulties in following the rhythm of the classes or getting involved in classes: "it was hard to follow the rhythm because it was difficult to separate classes from everyday life" (Fran); "I could not follow the subject" (Jo). Some students even dropped courses. Bia states that RE overwhelmed her and that she "had to drop the computer science course". In the case of Yen, the situation made him decide that in the next semester, he would take only one course.

Teaching. PMTs highlighted professors' patience, willingness, and empathy, who provided them with equal access to classes and study material, taking into account the heterogeneous situation in which their students could be immersed. This contributed positively to the acceptance of the new modality. Nik emphasizes that professors "made an effort to balance work in a way that would enable every student to be under the same conditions".

Regarding assignments' deadlines, some professors were flexible, which allowed PMTs to devote time to completing the assignments carefully. Nevertheless, situations of tension emerged, mainly in online synchronic tests caused by the lack of flexibility of other professors ("in some final exams, the professor did not have any consideration as regards the connectivity problems of students", Gi). Students failed because they got disconnected involuntarily during an examination, without being aware of it.

5.1.2 Home-classroom

The lockdown caused the transformation of the home into a classroom and, in some cases, also into an office. The physical space available for PMTs to attend online classes conditioned their experiences with emergency RE. Among those who share that space with their families, one said that the situation strengthened her study habits ("the fact that I

was at home with my family encouraged my commitment to study", Kim) while for other students (Cecy or Jair) it meant discomfort. Lack of a suitable space, having to share devices with other members of the family, invasion of privacy, family issues, or any other distraction contributed to the student's discomfort. Cecy claimed,

…initially, in each class, I turned the camera on but I felt uncomfortable because my family appeared behind me on the screen […] this is the reason why I stopped turning the camera on. I had problems with my family because I did not have a suitable space to study.

The transformation of home to classroom, in many cases, created an uncomfortable situation. But for students who had to take care of their children, lived in a house with satisfactory conditions for study, lived far from the university, or preferred to stay at home, this situation was experienced as favorable. Nik, who is a blind student, shared his reaction when he found out that the classes would be online:

"Great! Virtual classes, I won't have to take the bus". I perceived it as a small favor since I don't like to leave my house much…every time I go out I am confronted with the fact that I live in a world that is not designed for blind people.

As Borba (2021) points out, "Housing matters in knowledge construction" (p. 394). The PMTs' narratives provide evidence that the home was incorporated into the PMTs-with-media collectives and became an important actor in knowledge production during remote classes, as the home may or may not offer the necessary conditions for allowing students to develop the academic tasks.

5.1.3 Time management

Issues related to *time* appeared in the narratives in two ways. On one hand, the majority of students indicated that the virtual classes mode and remote working took more time than they were accustomed to take. On the other hand, in some cases, not having to commute to university implied more time to devote to study.

The impossibility of getting together to do assignments brought on problems in regard to time ("what was solved in five minutes during in-person classes, turned out to be many messages when working with a team virtually and in that way, we wasted more time", Sil). Juli retold in a vivid way a routine in which time management was only based on the study:

I was in front of the screen the whole day, from 6 a.m. to midnight, to meet my obligations: having breakfast in the middle of the class, preparing lunch while listening to the class, and eating in front of the computer.

Likewise, Feli describes an overwhelming daily routine devoted entirely to attending classes and doing assignments. Meanwhile, as has been stated previously, some PMTs recognized that by attending classes from their homes, they could devote more time to study. Gi's words were convincing in this sense:

I devoted 4 hours a day commuting to university and now, virtual classes allowed me to devote that time to studying. This also allowed me to attend classes while taking care of my child.

5.1.4 Physical and psychological discomfort

Some PMTs reported physical discomfort. Cecy indicates that apart from the technological problems, she suffered from "back pain and eyesight problems." Likewise, Gi stated that: "I spent a lot of time in front of the computer, causing me eyestrain and tiredness". Some PMTs mentioned that they suffered from *sleeping disorders*. Fran stated "It was difficult to fall asleep", while Dan indicated that sleeping disorders were due to changes in study habits. Flo stated that she started to stay awake until very late at night.

PMTs mentioned multiple negative situations related to the lockdown during the pandemic in convergence with family, home, study, and work-related problems. As a consequence, this brought about *psychological discomfort*. Problems such as anxiety in virtual exams because of Internet connection failure (Sil), loneliness (Feli, Sil), depression (Jo, Andy), and a sense of despondency (Fran), among others. Some of the students were encouraged at the beginning but, as the semester went by, they were discouraged (Rob, Leo). Two PMTs stated that they had to follow treatment using medication to face adversities and changes throughout this process (Cecy, Jo). Leo narrated how he coped with difficulties despite rejecting the RE mode:

… at the end of the tunnel, I always found my own light. I told myself "you cannot give up" […] At the beginning of the second semester, I was in a neutral mood because I didn't allow all things to greatly affect me.

This brief description of the different physical and psychological conditions that the students went through during the pandemic is evidence of the vulnerability of the students and the way in which "that" affected them in their educational processes.

The reported evidence depicts that the process of dealing with emergency RE was complex for all the PMTs. The passage to RE was a dynamic process, conditioned by multiple factors. Despite difficulties, the majority expressed their capacity for resilience and acceptance of

the modality. Meanwhile, some students clearly adopted a resistant attitude:

> I was by myself during the entire first semester. I felt weird. I was carrying a heavy burden all the time. It was like carrying a heavy backpack that got heavier and heavier. (Feli)
>
> I believe that the model of [remote] education is inconvenient. I have never considered the possibility of studying remotely. I don't like any of these alternatives because I like having my own physical space and meeting people face-to-face. (Andy)

So far we have referred to what happened to the PMTs with the passage to RE, how they felt, how they lived this journey towards something strange, unforeseen, and uncertain. This journey also implied, for each PMT, a shift and a return to themselves transformed. In the narratives, it is possible to identify evidence of the PMTs' transformation when they narrate how their experiences in the RE context influenced their visions of being a teacher. Some PMTs agreed that their thoughts on the teaching profession have changed. Such changes are understood as traces of what they experienced. We recognized that these changes were nurtured from the following two main sources: the appreciation of the teachers' role and the social responsibility of the profession during the lockdown; and the recognition that the health emergency could last longer. As future teachers, it is necessary for them to be prepared to plan and deliver classes in remote mode. The following narrative excerpts exemplify changes reported by PMTs that are related, respectively, to each of the mentioned sources.

> I could realize that there were other realities and that there are students who appreciate all the work done by teachers when creating entertaining and interesting classes. Also, it showed me how much responsibility it implies to be a professor, and that motivates me to be better and learn more so that in the future, I can be a better person and teacher. (Cecy)
>
> I can't forget when Professor Moni told us that we have to get used to this situation because, in the future, classes would probably be remote. Ever since then my point of view has been changing and I believe the most important thing is the vocation. No matter what the modality would be, teaching will be an act of love. (Celu)

Despite that the factors described could have hindered the acceptance of RE, PMTs continued to be motivated to become teachers. Most showed that their desire to be a teacher remained, but their view of the teaching profession changed due to what happened to them in the RE mode. It is possible to assert that there were some transformations

that led them to understand clearly the responsibility of being a teacher.

5.2 Technology: opportunities and limitations

When we inquired about what happened to the PMTs with regard to the use of technologies during RE, we observed that PMTs recognized that technology gave them *opportunities* for continuing their studies, but at the same time implied some *limitations*.

5.2.1 Opportunities created by technology

Technology offers multiple possibilities regarding education. The pandemic generated conditions to explore its uses and to create new developments. In their narratives, PMTs acknowledged how technology had contributed to their education. Caty pointed out that "technology was essential for my remote learning experience. If during this time we hadn't used these tools, I think that the classes wouldn't have been so fruitful."

Like Caty, the rest of the PMTs valued the opportunities offered by the Internet through educational platforms, social media, instant messaging, online educational resources, information repositories, and mathematical digital technologies such as GeoGebra. According to PMTs, these technologies allowed them to continue attending classes, communicate, have access to information and support each other both academically and emotionally during the lockdown. Regarding this situation, Kim stated: "…technology is useful for learning. We now realize that it is essential; nowadays, it helps us to connect and to better understand certain topics using games and videos." Celu asserted that "technology highly contributed to this learning process since, without it, we could not finish this course." Also, the RE encouraged PMTs to continue learning about the use of technologies since, as Jo said, "it is paramount to understand this technological world for me to use it in the future, instead of hindering my work."

The conditions imposed by the lockdown on face-to-face communication and interaction processes led PMTs to turn to social networks and instant messaging platforms to complement these processes. Regarding this aspect, Lula wrote:

> In mid-May [2020], I was more or less used to technology. Due to my connectivity problems, my group partners had to adapt their schedules to meet mine. Also, we had to take into account the working hours of Eve [classmate] so most of the time we used WhatsApp to solve the activities.

The PMTs also highlighted new learning related to technologies that existed previous to the pandemic; for them, the conditions imposed by the lockdown promoted a more

intense use of those technologies in mathematics classes. For example, there was increased use of GeoGebra in geometry which, according to Bia, helped her to understand more about 3D Space Geometry. Joe also pointed out that thanks to the virtual tools,

> I learned to use some educational tools such as Educaplay, Cuadernia, dynamical presentations, etc. […] Through this period I have been encouraged to study other things that I previously viewed as complicated due to commuting issues…

We can say that PMTs used technologies to produce and understand mathematics (GeoGebra, spreadsheets, etc.) and to communicate and interact with peers and teachers (social networks, video calls, virtual classrooms, etc.). The PMTs recognized these uses as opportunities to continue their education and as a response to the constraints imposed by the pandemic. Thus, given the impossibility of face-to-face interactions, virtual classrooms, and video conferencing platforms generated opportunities to continue classes; social and messaging networks offered opportunities to interact and collaborate, and software for mathematical work implied both opportunities to learn about the use of these tools, as well as opportunities to learn mathematics.

Also, technology provided PMTs with unseen opportunities in face-to-face mode. The need to communicate topics more dynamically led Joe, Jair, and Andy to *explore the web* and to *integrate new and different resources* into their classes, for instance, *Cuadernia*, an electronic notebook. *Videotaped classes* and the possibility of accessing them at any moment were highly valued by Flo, Lula, July, and Jair. Furthermore, the Internet gave Nik, Gi, and July, the possibility of *carrying out their academic and work activities from home*; they could save time, do their assignments efficiently, and be more flexible in personal situations.

The pandemic imposed conditions on school systems that allowed the creation of new opportunities for the use of new or already known technologies. PMTs combined all available technologies to account for RE; according to Borba and Villarreal (2005), they sought to transcend the status quo of mathematics classes before the pandemic.

5.2.2 Technology-related limitations

Despite the opportunities, PMTs also acknowledged certain limitations in which technology *conditioned* their educational processes during the lockdown. Caty mentioned the impossibility of recreating face-to-face environments, despite their efforts:

> We cannot deny that there were classmates who found it hard to participate in class since they didn't have a stable Internet connection nor tools. Also, they didn't

attend because of their workload. This situation also affects the rest of the classmates since it is not the same to be in a 15-student class as attending one in which only 5 students are present.

This fragment emphasizes some of the causes that conditioned the participation of students in the RE courses.

In the narratives, PMTs pointed out that RE brought about some changes in how they related to one another and how they carried out their daily activities. Sil and Bia insisted on the idea that they had to undertake an increase in their responsibilities and their hourly load. According to PMTs, technology also affected their educational experiences in different ways. Caty, Lula, Dan, and Rob stated that there were some required technologies that they needed to learn how to use, which, consequently, affected their performance, creating distress, and an additional hourly load. Lula, Feli, and Jair highlighted *poor connectivity* and having *obsolete devices.* Leo, Alex, Jair, Any, and Walt claimed that in RE environments, the *relationships* with professors, between students, and with the topics were different and less dynamic.

So far, we analyzed PMTs' experiences with regard to the opportunities and limitations of technology, during the pandemic. PMTs viewed technology as 'two sides of the same coin' which required them to *make decisions.* Flo, for example, stated that one of the opportunities granted by technology was that the videotaped classes were available "at any time", but simultaneously she recognized that she didn't have enough time to watch the videos. This implied a necessary decision: reviewing the way she was managing her time and organizing her daily life so that she could take advantage of the opportunity that technology offered her.

Although technologies offer opportunities for the continuity of education, they do not solve the challenges of RE by themselves. Teachers, students, available technology, connectivity, the learning environments, and the homes formed collectives of h-w-m-things (Borba, 2021; Borba & Villarreal, 2005), which transformed PMTs' views and ways of knowing and acting in the context of RE. Thus, there are many factors and actors that must be combined to consolidate educational proposals in accordance with the needs of these new h-w-m collectives. The opportunities as well as the limitations associated with technologies condition the functioning of these collectives, and therefore, how knowledge can be produced in RE contexts.

5.3 A word about the experience

The notion of experience adopted in this paper enabled us to recognize the passage to RE as a result of the pandemic as an event outside and alien to all the PMTs of this study, which acted as a catalyst of their experiences. However, for

an experience to happen in each subject, for something to happen to them, it is required to stop. Narrative writing was a moment in which PMTs stopped to look back, think, and write about what had happened or was happening to them concerning their educational processes during the pandemic. They were able to say what they thought and how they felt regarding the online classes, having their homes transformed into classrooms, the difficulties faced, the opportunities and limitations associated with technology, and their reflections on becoming teachers, making sense of what they experienced from their projections as future teachers. Although the fragments were brief, they showed vividly the richness of their experiences. As Larrosa (2006) claims, for each subject, the experience was subjective, unique, and peculiar. For this reason, our study shows a confluence of multiple singularities, considering Latin American voices, which allowed us to approach the experiences lived by PMTs from three different universities.

Finally, considering Dewey (1938)'s principles of *continuity* and *interaction* that guarantee the educative character of an experience, we can ask whether the experiences lived by the PMTs in the passage to RE mode were educative in the sense of Dewey. We believe that this question could guide further research.

6 Discussion and conclusions

In this section, we compare and relate the results of our study with the literature reviewed, establish links between the categories analyzed, refer to the limitations of the study, and make some final remarks and suggestions for future research.

In Sect. 5, we approached the events, thoughts and feelings lived by PMTs from three Latin American universities in the passage to RE. Likewise, given the central role that technologies played in RE, we recognized opportunities and limitations that technologies implied for the PMTs.

In relation to remote classes, PMTs expressed the need for greater interaction and exchange with professors and peers, but at the same time acknowledged a decrease in their participation in classes. Videoconference classes did not seem to encourage active student involvement. Similar results were documented by Morgan et al. (2022). Study participants reported significant changes in their pedagogical experiences that were primarily attributed to the shift to distance learning. These results are also compatible with those reported by Long et al. (2022) who found that during the remote class period there was a decrease in student cohesiveness. A possible explanation for these findings may be the fact already pointed out by Abu Talib et al. (2021), that the poor communication quality among the students and with their teachers was a limitation of digital transformation in higher education

during the pandemic. Other causes have also been reported by Engelbrecht et al., (2020a) and Ozdamli and Karagozlu (2022) who noted that the pandemic exposed technological deficiencies such as poor Internet connections, and lack of ability to handle technological devices and to manage time appropriately to account for academic, domestic and family activities simultaneously.

The PMTs also showed criticism toward expository modes of teaching with faster rhythms than those found in face-to-face classes. We identified that, in some courses, the use of transmissive practices, based on the mere reproduction of knowledge, was intensified. Some classes were so rigidly structured that the PMTs considered interaction as a disruption to the class; participation was reduced to the mere fact of being online. It seems that the communicative potential of digital platforms was not exploited by some teachers, so that there was no transformation in the presentation of the classes. These concerns were shared by Bakker and Wagner (2020), Ozdamli and Karagozlu (2022) and Engelbrecht et al. (2020a), who drew attention to the risk of falling into a pedagogy of knowledge transmission as a consequence of the irruption and hasty adoption of new technologies. The continuity of online expository classes with little participation of the PMTs shows what Borba and Villarreal (2005) call a domesticated use of new technologies.

The benefits or disadvantages resulting from the *home-classroom* transformation were strongly present in PMTs' narratives. Borba (2021) affirmed that COVID-19 "has pushed homes into the center of a collective that produces knowledge" (p. 394). Our study provides evidence on how this home-classroom condition became critical in the experiences of some PMTs in particular, in accepting RE. This evidence contributes to thinking about the role of homes in the way we know and learn mathematics, which was previously discussed by Borba (2021), Castro et al. (2020), and Bakker et al. (2021). We believe that bringing forward the discussion on the home-classroom transformation allows us to realize how a collective of h-w-m (Borba & Villarreal, 2005) becomes more complex as a knowledge-generating collective when other actors, such as homes, families, or the coronavirus, become part of this collective.

Our results concerning the difficulties stated in the PMTs' narratives are consistent with the ones mentioned in the UNESCO-IESALC (2020) report, for example, pandemic-related anxiety, social isolation, and poor communication with peers and teachers. However, in our study, we detected other difficulties which were not mentioned in that report, namely, the ones related to *time management* or the *home-classroom* transformation.

Regarding technology, our study highlights that the perceptions and uses of technology manifested by the PMTs did not remain static during their experience; on the contrary, they were transformed as time went by. New conditions were

imposed by the pandemic and new technologies became available. Our study shows that PMTs employed the technology as a *tool to cope with RE*, as a *means to learn,* or as an *object to be learned*. Technology offered opportunities for PMTs to continue studying. They recognized these opportunities, but they also highlighted limitations in technology appropriation and access that conditioned the acceptance of RE by some of them. PMTs had the opportunity to use, more frequently than in face-to-face classes, software and other digital resources for learning mathematics. Furthermore, they had to develop skills to manipulate technology and learn about their technical affordances and limitations in order to use it properly. The identification of these roles for technology allows us to understand how in a h-w-m collective (Borba & Villarreal, 2005), both humans and media are not neutral actors but play roles according to the conditions of the educational scenario in which this collective is constituted.

The literature reviewed reports on affective, contextual, political, and curricular factors that influenced the integration of technology in PTs education during the pandemic. As in our study, the opportunities offered by the technologies to provide continuity of education during the quarantine were also recognized by Mulenga and Marbán (2020b), who considered COVID-19 as a gateway for digital learning in mathematics education, and by Alabdulaziz (2021), who observed that teachers positively valued technology as a means to overcome difficulties and promote mathematics learning in distance education. As in the studies conducted by Nketsia, et al. (2021), Dilling and Vogler (2022), and Naidoo (2020), the PMTs participating in our study used digital platforms to receive their classes. We agree with these authors when they argue that the use of technologies favored the generation of positive perceptions for the PTs regarding their usefulness in RE and emphasize the need to build their confidence in the use of technologies.

Our study allows us to conclude that PMTs considered two main aspects regarding technology. On the one hand, technology was seen as the 'last hope' to continue studying during the pandemic. On the other hand, the technology access gap was a driving force for inequalities and exclusion. As observed in the literature, the quarantine showed and exacerbated the gaps in access to technology (Borba, 2021; Morgan et al., 2022), but it also highlighted the creativity of teachers and students to cope with the contingencies that arose. Our study showed that PMTs decided to overcome limitations and take advantage of opportunities and were willing to learn and integrate new technological actors in their RE experiences, such as instant messaging, social networks, or videotaped classes.

The results and analysis in our study show a complex web of factors of different natures (material, housing, educational, personal) that conditioned the experiences lived by the PMTs and influenced the acceptance of the RE. For analytical purposes, these factors—which are related to the categories and subcategories of the study—were addressed and illustrated separately, although there were close links between them. Figure 2 schematically depicts relationships among factors, categories, and subcategories of the study.

For example, having a positive attitude towards RE, an adequate study space at home, access to appropriate technological devices, and good Internet connectivity allowed PMTs to attend classes regularly and, depending on the teaching model, to participate and interact in a more sustained manner with colleagues and teachers. As we mentioned before, the factors that form the web that conditions the experience and that supports the educational process, sometimes can also hinder it. Examples are, when PMTs had limited access to technology, poor connectivity, could not adequately manage study time, or experienced physical or psychological discomfort as a result of isolation. These material and personal factors have also been recognized in other studies and their educational implications are of different nature. On the one hand, there are studies reporting increased confidence in the effectiveness of e-learning and the ease of communication between students and teachers (Ozdamli & Karagozlu, 2022), but, on the other hand, face-to-face education is missed and the limitations of remote education are acknowledged (Morgan et al., 2022; Ozdamli & Karagozlu, 2022).

Now, we refer to the limitations of our study. Although the use of written narratives is pertinent for the study of PMTs' experiences, they were written in response to an invitation with questions that guided the writing (see Sect. 4.2). The invitation did not include questions referring to mathematics learning, the use of specific mathematical software, or the PMTs' teaching practice, in case they were in their internship period. In this sense, the account of "that which happened to the PMTs" was conditioned by the invitation. Complementing the narratives with unstructured individual interviews would have allowed us to scrutinize other aspects of the experiences or to better understand some ideas presented in the narratives. Another aspect that may be considered a limitation of our study is that the group of participants cannot be considered representative of the set of PMTs in our countries. Meanwhile, since we are interested in the PMTs' experiences and, as Larrosa (2006) states, each person's experience is unique and unrepeatable, our study allowed us to bring to the forefront multiple voices of PMTs who wrote about their difficulties, their achievements, their changes, their desires and their perspectives regarding the teaching profession. We consider that our work complements results obtained in studies involving PTs education in the pandemic, carried out using other types of methodologies.

Finally, based on our study, we offer some reflections that suggest the need for further research around three
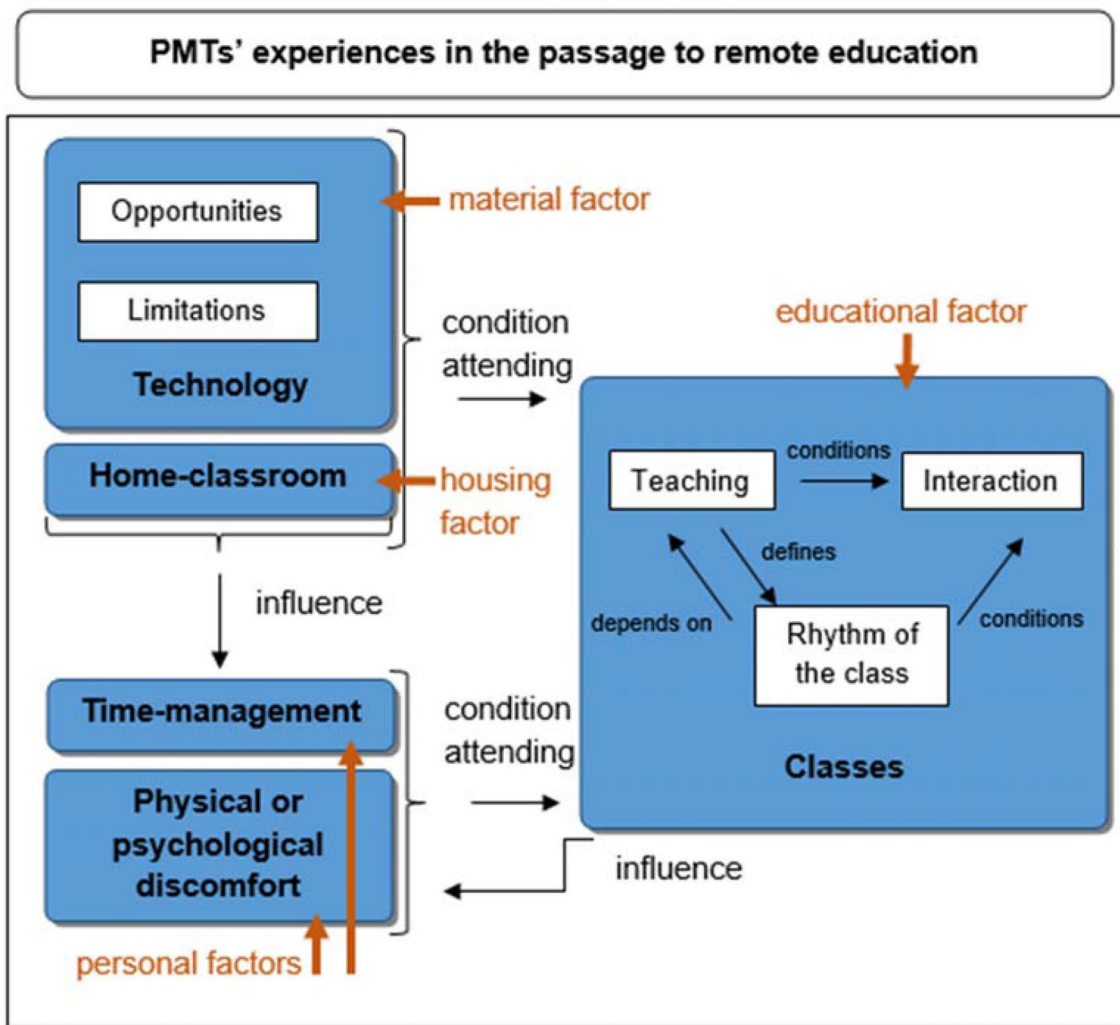
Fig. 2 Web of factors in the passage to RE

themes: (1) pedagogical use of technology in PMTs education; (2) implementation of hybrid education programs for PMTs; and (3) teacher training for distance education. Regarding the use of technology in education programs for PMTs, it is necessary to think about its pedagogical integration so that it becomes a central actor in the mathematics learning process, not only as a means of communication. This is not a new requirement but the compulsive passage to RE mode has made it more noticeable and urgent. The implementation of hybrid education programs for PMTs, in a generalized and systematic way, is a proposal that deserves consideration. This proposal requires research on the organization and creation of dynamic and flexible hybrid education models adapted to the particular needs of teacher education. What occurred during the pandemic motivates the need to rethink and redesign the education of PMTs, taking into account possible future demands for distance education models for the secondary

level. These issues constitute challenges for both teacher education and research.

References

Abu Talib, M., Bettayeb, A. M., & Omer, R. I. (2021). Analytical study on the impact of technology in higher education during the age of