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We see You: Understanding Math Teachers from Brazilian Public Schools to Design Equitable Educational Technology

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Abstract

Students from Brazilian public schools need help with mathematics. In this sense, the scientific literature has explored ways, through technology, to help teachers and students in the teaching-learning process. However, research generally aims to propose solutions without first investigating the needs of those on the front lines: teachers. Thus, this paper aims to investigate relevant aspects of everyday life in the classroom from the point of view of mathematics teachers in Brazilian public schools. We used the first two phases of Design Thinking: empathize and define. In the first phase, we carried out a focus group with four teachers from four primary public schools, which we analyzed qualitatively using the Grounded Theory (GT). Based on the results of the GT, in the second phase of Design Thinking, we proposed the persona and the empathy map. Our results provide practical implications for designers and developers of educational technology solutions from the practical application of user experience research. Furthermore, we hope that our study will be a starting point for new researchers in the area to explore the needs of Brazilian public school teachers.

Keywords: *Focus Group; Persona; Empathy Map; Math Teacher; State School*

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1 Introduction

Mathematics (or Math) is one of the most important subjects. Along with science, The Organisation for Economic Co-operation and Development (OECD) considers math a fundamental subject for social participation and that it is required to find complex, real-world problem solutions (OECD, 2016b). Similarly, the European Education, Audiovisual and Culture Executive Agency (Eurydice) highlight that acquiring numeracy skills is one of the main priorities in Europe, considering that math competencies are needed for several reasons, including employability, social inclusion, active citizenship, and personal fulfillment (Education et al., 2015).

Despite math's importance, studies show that teaching and learning math are long-term societal struggles. International, large-scale studies reveal that several students face difficulties and perform below the expected math expectations, as demonstrated by the 2015, 2018, and 2022 PISA results (OECD, 2016a, 2019, 2023). Those reports also highlight that Brazilian students struggle in math. SAEB, the Brazilian's National System of Elementary Education Assessment (*Sistema Nacional de Avaliação da Educação Básica*), corroborates those findings, demonstrating that over half of the Brazilian students are below level four (out of eight levels) in math performance (Instituto Nacional de Estudos e Pesquisas Educacionais Anísio Teixeira (Inep), 2022).

Given the challenges associated with math teaching and learning, researchers started exploring educational technology to mitigate them. As a result, we have witnessed an increasing body of research on the use of such tools in school settings (e.g., (Alabdulaziz, 2021; Kinzie & Joseph, 2008; Ma et al., 2014)), and several studies have examined their impact on student achievement (e.g., (Fadhli et al., 2020; Fang et al., 2019; Steenbergen-Hu & Cooper, 2013)). From the teacher's perspective, a recent study (Fraillon et al., 2020) has found that teachers from varied countries consider technologies to help students by improving interest in learning, collaboration with peers, and enabling them to work at a level aligned with their needs. Nevertheless, the study also revealed teachers' concerns, such as that technologies might distract students from learning.

From the perspective of student achievement, empirical studies demonstrate that digital tools hold great potential, as shown in the meta-analysis by Hillmayr et al. (Hillmayr et al., 2020). This study summarized the results from 92 primary empirical studies that compared the learning outcomes of students who used digital tools to those of learners who did not. They found a positive, moderate, statistically significant effect in favor of using digital tools. They discovered that training teachers on digital tools significantly moderates those results. Moreover, they found that some tools were more effective than others: Simulations and Intelligent Tutoring Systems (ITS) were associated with better results than hypermedia systems (Hillmayr et al., 2020).

In summary, that context highlights four key points. First, Brazilian math education needs help. Second, while technology alone cannot solve such a complex problem, we understand that digital tools, especially Simulations, and ITS, might provide valuable support for math education. Third, such technologies must be designed to prevent teachers' concerns. Fourth, improving teachers' proficiency in using those tools is prominent in extracting the most from digital educational tools. Therefore, we understand that a User-Centered Design process offers appropriate guidance for designing and developing digital tools aligned with users' (i.e., teachers') goals and needs (Barbosa et al., 2021). A long-term practice to start that process is understanding the users (Martinelli et al., 2022).

To the best of our knowledge, however, prior research on digital tools for math teaching and learning has not been developed by including teachers in the process. In contrast, based on the studies in (Hillmayr et al., 2020), most were not designed to increase teachers' proficiency and attend to their needs and concerns. Specifically concerning ITS, which Hillmayr et al. (Hillmayr et al., 2020) found to be one of the most effective tools, researchers have recently proposed including teachers in the development loop (Dermeval & Bittencourt, 2020; Tenório et al., 2020). Nevertheless, to our knowledge, previous studies have not provided insights about the needs of mathematics teachers in Brazilian public schools from the application of User-Centered Design practices or User Experience (UX) methods.

To address that gap, this study aimed to understand Brazilian public school math teachers' challenges and, ultimately, provide insights that inform the design of digital tools with the potential to enhance the math teaching-learning process. To achieve this goal, we used the first two stages of Design Thinking: in the empathize stage, we used the focus group technique with public school teachers who teach math, which revealed the issues they face in helping students learn and use digital tools during lessons; in the define stage, based on the focus group results, we created the persona and the empathy map, which might be used to inform the design of teacher-centered digital tools. Therefore, this paper reports on how the practical UX work involving the focus group results and the creation of artifacts was done.

Thereby, this article contributes empirical evidence on the reality of math teachers from Brazilian public schools and UX resources to inform the design of digital tools. Notably, some of our findings led to subject-independent insights, despite our focus on math teachers, which might be attributed to these teachers teaching math and other subjects in the Brazilian's elementary stage. Thus, we inform designers of teachers' goals and needs, as well as researchers on requirements for developing math digital tools aligned to Brazilian public schools' reality, towards ultimately contributing to improving the math teaching-learning process in our country.

The remainder of this paper is organized as follows. Section 2 provides background information on math education and technology used in Brazil's public education system. Then, Section 3 describes this study's method, and Section 4 presents our results. Subsequently, Section 5 introduces the artifacts generated from our results. Next, Section 6 discusses this paper's findings. Finally, Section 7 draws our final considerations.

2 Educational Technology in Brazilian Public Schools

Math is vital for its practical applications, logical reasoning, and career opportunities (Education et al., 2015; OECD, 2016b). Also, studying it can enhance cognitive development. However, the SAEB report (Instituto Nacional de Estudos e Pesquisas Educacionais Anísio Teixeira (Inep), 2022) reveals additional math teaching and learning issues in Brazil. For instance, the report found a decrease in overall performance compared to prior assessments, likely explained by the COVID-19 pandemic that was faced throughout this period. Additionally, the report demonstrates wide discrepancies in performance across the country, with several states achieving below the average, some reaching around the average, and a few yielding results above the average (Instituto Nacional de Estudos e Pesquisas Educacionais Anísio Teixeira (Inep), 2022)

Furthermore, Brazil's 2022 census[1] also reveals essential concerns. According to this census, only a tiny fraction of school actors have access to the in-service training (e.g., school managers that took management courses), and over 30% of the teachers would benefit from specific courses related to the subjects they teach (Instituto Nacional de Estudos e Pesquisas Educacionais Anísio Teixeira (Inep), 2021). Those findings corroborate teachers' perceptions that they need further training to improve their teaching practices (Medina Larroza & da Silva Santana, 2020; Santos & Vidal, 2017).

Moreover, Brazil's 2022 census also demonstrates that most public schools have limited infrastructure. Specifically, it reveals a common lack of technological resources, such as computers, tablets, and internet access (Instituto Nacional de Estudos e Pesquisas Educacionais Anísio Teixeira (Inep), 2021). Additionally, despite not limited to public schools, ANATEL[2] found that almost 70% of Brazilian schools have no informatics laboratory and that over 20% of the schools from five Brazilian states have no access to the internet. These findings is aligned with worldwide discussions highlighting that global south countries, such as Brazil, have suffered from a lack of technology available, especially during the covid-19 pandemic (Gašević, 2018; Reimers, 2022).

That context demonstrates that Brazilian math education faces equity and performance issues. In addition, the analysis demonstrates there are inequalities among Brazil's states (Instituto Nacional de Estudos e Pesquisas Educacionais Anísio Teixeira (Inep), 2022) and compared to other countries (OECD, 2016a, 2019). In contrast, the United Nations has argued for reducing inequalities within and among countries through sustainable development goals (Nations, 2015).

Because Brazil, like several global south countries, has technology availability issues (Gašević, 2018; Instituto Nacional de Estudos e Pesquisas Educacionais Anísio Teixeira (Inep), 2021), addressing the math issues is especially challenging, considering digital tools benefits (Hillmayr et al., 2020). Therefore, given the particular interest in math teachers from Brazilian public schools, understanding their needs - including infrastructure concerns - is prominent in designing digital tools to include as many people as possible, which is a substantial concern from the United Nations (Nations, 2015).

3 Method

As a research method, we used the first two steps of Design Thinking: empathize and define. In the empathize stage of design thinking, we used the focus group method, using qualitative data collection. In the define stage, we created persona and empathy map methods to summarize the main results obtained in the first stage. The planning and results of the empathize stage are described in Section 3 and Section 4 to structure the paper. The results achieved by the define stage are shown in Section 5.

The focus group, used in the empathize stage, is a UX technique used to collect data through collective discussion and group activities and is suitable for obtaining initial feedback on new concepts and discovering motivations about the object of study (Edmunds, 1999; Kontio et al.,

[1] Brazilian's main instrument/research to collect information regarding public, basic education.

[2] The Brazilian Agency for Telecommunications. Data available in: https://informacoes.anatel.gov.br/paineis/infraestrutura/conectividade-nas-escolas

2008). The steps of the focus group were defined according to previous studies (de França et al., 2015; Kontio et al., 2008) and are organized into (i) planning; (ii) execution; and (iii) data analysis and reporting of results.

3.1 Planning and Execution

3.1.1 Participant selection

Four public school mathematics teachers from *[omitted]* participated in this focus group. The participants were invited from the disclosure of the research in public groups, and convenience sampling was used as a selection strategy, in which teachers who had availability on the date and time suggested participated. In addition to the participants, two moderators conducted the focus group session; two observers noted points of attention throughout the study, and two technical supporters helped prepare the study environment.

3.1.2 Study design and strategy

The design used in this focus group was defined through a script with tasks conducted throughout the study. Some tasks were performed individually by the participants, others in pairs (in which the participants were randomly divided), and others involving the whole group. In all, four tasks were defined:

- Task 1. Introduction and Characterization
  - Moderators presentation, focus group objectives, and support materials delivery (whole group);
  - Informed Consent Form (ICF) completion and the characterization questionnaire. We used the characterization questionnaire to collect demographic data from the participants, such as gender, race, age group, and teaching experience, as well as infrastructure issues about the school where they work, such as internet access and number of students (individual);
  - Individual presentation of each participant commenting on the characterization questions (individual).
- Task 2. Classroom routine: classroom scenario description in which teachers are inserted and the availability of resources and infrastructure (individual);
- Task 3. Error identification: Discussion to identify errors made by students in addition and subtraction operations (in pair). Afterward, the whole group discusses the errors identified in each pair.
  - Initiating question: What are the main difficulties experienced by students in acquiring knowledge related to arithmetic operations of addition and subtraction?
  - Deepening question: Is it possible to classify these difficulties?
  - Closing question: What methodological strategies are used to minimize such difficulties?

Figura 1: Record of the focus group.

- Task 4. Case Study and Brainstorming: Each participant received an example of a math exercise composed of a case study of a task commonly performed by a student in the 2nd year of Elementary School. Participants are invited to raise hypotheses about the students' difficulties in acquiring knowledge of the four skills defined for the study (whole group).

3.1.3 Execution

Study participants and team members met in the city on [omitted] 04/01/2023 at 8 am. At first, already entering Task 1, the moderator requested that all participants read and accept the ICF if they agreed. In addition, a copy of the ICF was provided for each participant in case there was any doubt during or after the study. After acceptance, the moderator started recording video and audio. Next, the participants were asked to answer the characterization questionnaire, and the tasks were performed in sequence.

To support the execution of the tasks, we provided participants with some support materials, such as paper, sticky notes, cardboard, and pens. There was also a table with food and drinks in the environment, which all participants had free access to during the entire study. The focus group session lasted four hours. As mentioned, all tasks were recorded using video and audio so that it was possible to analyze the data obtained. Figure 1 shows a record of the focus group.

3.2 Data Analysis

To enable the qualitative analysis, we transcribed the audio of the study. The Transcriber Bot[3] in Telegram and the Google Speech-to-Text[4] tool was used in this step. Therefore, the qualitative

[3]https://web.telegram.org/z/#288460698
[4]https://cloud.google.com/speech-to-text

analysis was carried out by executing the first two phases of Grounded Theory (GT) (Strauss & Corbin, 2014), with the support of Atlas.ti[5] tool. In the first phase, called open coding, the codes were identified based on the participants' statements. In the second phase, called axial coding, categories that emerged from the grouping of codes identified in the previous phase were identified. Also, it is essential to emphasize that the third and last phase of the GT, selective coding, was not used since more studies are needed to refine the categories to reach the grounded theory.

In this sense, the following section comprises the demographic results of the characterization questionnaire. Then, we present the qualitative results with the categories identified through the GT and the participants' speeches that allowed reaching these categories.

4 Results

The following subsections aim to present the results of the demographic and qualitative analyses. Through the analysis, we obtained characterization information of the study participants, presented in subsection 4.1. From the qualitative analysis, we codified and categorized the information the participants commented about the reality experienced in schools. Thus, in subsection 4.2, we present five categories identified: (CAT1) school infrastructure; (CAT2) non-technological resources; (CAT3) technological resources; (CAT4) the teaching of mathematics; and (CAT5) the use of technology in teaching.

4.1 Demographics

The demographic data were analyzed to guide future decisions about the profile of mathematics teachers in Brazilian public schools. Table 1 presents the results obtained for the demographic data.

Regarding the results obtained for demographic data, we highlight heterogeneity in the findings about teaching experience since each one answered a different option when asked how long they have been teaching, ranging from 1 to 2 years to more than 25 years. In addition, we observed that the participants have personal resources since they all have internet with good connections in their homes, computers/notebooks, and smartphones. However, we highlight that no teacher has a personal tablet.

Concerning the student categorization reported by the participants, we observed a variation in responses, as teachers responded that most students have personal computers/notebooks and smartphones/tablets. However, teachers mentioned that only a minority of students have internet access at home. Furthermore, we highlight that all the schools represented by the teachers in the study were municipal and that all teachers were permanent in their schools.

[5]https://atlasti.com/pt

Tabela 1: Demographics of participants.

Questions	**N**
What is your gender?	
Female	*2*
Male	*2*
What is your race?	
Brown	*3*
White	*1*
What is your age group?	
From 25 to 29 years old	*1*
From 40 to 49 years old	*2*
From 50 to 54 years old	*1*
How long have you been teaching?	
From 1 to 2 years	*1*
From 11 to 15 years	*1*
From 16 to 20 years	*1*
More than 25 years	*1*
How many schools do you work at?	
In 2 schools	*3*
In 3 or more	*1*
Do you have internet access at your home?	
Yes, with good connection	*4*
Do you have a personal computer/notebook?	
Yes	*4*
Do you have a personal smartphone?	
Yes	*4*
Do you have a personal tablet?	
No	*4*
How many students does the current school have?	
From 51 to 200 students	*2*
From 201 to 500 students	*2*
Do your students have internet access at home?	
Minority students have	*2*
Most students have	*1*
All students have	*1*
Do your students have access to a computer/notebook at home?	
Most students have	*2*
Minority students have	*1*
I do not know answer	*1*
Do your students have access to a smartphone/tablet at home?	
Most students have	*3*
Minority students have	*1*

4.2 Qualitative Analysis

4.2.1 CAT 1 - School infrastructure

Regarding school infrastructure, we identified that the schools of the study participants have several areas for improvement, mainly related to the classroom itself. For example, a participant cited that the classrooms are hot and lack ventilation (see quote C1), besides being overcrowded (see quote C2). These inadequate conditions hinder the child's learning not only in mathematics (see quote C3). Besides, overcrowding challenges the teacher's personalized attention to students (see quote C4), causing occasional doubts to go unnoticed. Also, participants cited that the internet school is unstable and frequently fluctuates (see quote C5).

- C1: *"In third grade, [I have] thirty-three students. [...] It's very small [the room], it's hot. It's scalding. We really come out dripping sweat. The kids make a fan with the paper. There are three fans in the room. But only one works, and it doesn't even turn."* (P1)
- C2: *"Our situation is very similar with a small classroom and a larger number of students than would fit in that room."* (P2)
- C3: *"So, all of this makes it difficult for the child, they get tired, stressed, hot, for you to be working on math or any other subject. It's boring."* (P1)
- C4: *"Overcrowded classrooms make this personalized attention difficult. And then we really need monitors inside the room that help us so you can reach the other students."*(P3)
- C5: *"The problem at our school specifically is the digital mesh issue. The internet at school is not good quality. It keeps dropping, oscillating."* (P3)

4.2.2 CAT2 - Non-technological resources

Concerning non-technological resources, two subcategories were identified: (CAT2.1) teaching materials and (CAT2.2) concrete alternatives. Regarding teaching materials (CAT2.1), we noticed a difference in the realities of the participants' schools. For example, P2 mentioned that all students in his school have access to the National Textbook Program (in Portuguese, Programa Nacional do Livro Didático, PNLD) (see quote C6). However, P1 mentioned that besides some children not having the PNLD in her school (see quote C7), she had difficulty accessing the book when hired (see quote C8).

- C6: *"In the municipality of [omitted], they have a material that is for teaching use; all the students have it."* (P2)
- C7: *"Some [children]. They had some that were missing [the PNLD]. So even in that, it leaves something to be desired."* (P1)
- C8: *"I arrived at school now, and they didn't have it. It took three days to get the book for me. I had to ask another school if they had it so they could give it to me."* (P1)

Regarding concrete alternatives (CAT2.2), one participant mentioned that his school has materials for building educational games (see quote C9). In addition, the golden material can be used as a non-technological resource depending on the level of the student (see quote C10). However, most of the resources are produced by themselves (see quote C11), and they work with scrap material, games, and play (see quote C12). Furthermore, participants mentioned that teachers learn to handle the resources in training for use in the classroom (see quote C13).

- C9: *"We have materials where we can build the games, we can ask the coordination, and they make them available to us."* (P3)
- C10: *"That is why the teacher needs to have these resources available, such as the golden material so that he can use it there. Depending on [the student's] level, he will use some of those resources."* (P3)
- C11: *"Books come, there are some games, but most of the resources we work with to facilitate the child's learning is up to us."* (P1)
- C12: *"We work a lot with scrap materials, invent games, games, to facilitate their understanding, to try to let them be the protagonists of the business."* (P1)
- C13: *"In general, as a trainer, each training we had one or some materials like games and the teacher went to the training, learned how to handle and how to apply in the classroom."* (P3)

4.2.3 CAT3 - Technological resources

According to the participants' statements, we highlighted four school technological resources that can assist teaching: (CAT3.1) tablets, (CAT3.2) Google Rooms, (CAT3.3) Chromebooks, and (CAT3.4) digital whiteboards. Regarding the tablet (CAT3.1), we observed that students from Elementary II (6th to 9th grade) received from the city government (see quote C14) a conventional tablet, i.e., it can be used in various contexts and has no educational focus (see quote C15). However, we also noted a social challenge regarding the device, as cases were highlighted where students' parents sold or disposed of the tablets given to them by the municipality (see quote C16). In addition, participants mentioned that the tablets should be more utilized because students do not take them to school due to crime in the school's area (see quote C17).

- C14: *"The students received the tablet now in [omitted]. All the ninth, eighth, and sixth graders. Seventh grade didn't get it because they got it the other year."* (P3)
- C15: *"Apparently, it's a regular tablet [received by students]."* (P3)
- C16: *"There have been several comments that some fifth graders [...] Parents take over, and some parents have taken [the tablet] to sell, to dispose of, so that's been happening."* (P1)
- C17: *"So generally, they don't take the tablet to school, also because in the region crime is very high, so they are afraid to take it, so the tablet is left aside. It's being underused."* (P3)

Another resource mentioned was the "Google Room"(CAT3.2), a space prepared for Computer and technology activities (see quote C18). However, participants pointed out that prior planning is necessary for using the area because there is only one Google Room for the whole school (see quote C19). Also, participants mentioned that the Google Room is usually used to show a movie to the children and that the children do not handle the computers in the room (see quote C20).

- C18: *"The school is going through a renovation, but we have a Google Room, a room prepared for activities in Computer Science and technologies."* (P3)
- C19: *"There is only one room for the whole school, so we have to plan the day for each class. We have to plan the day for each class. I have to plan so I can schedule the day and time, and then the teachers can organize themselves."* (P1)
- C20: *"The Google Room is currently used just to show a movie to the kids, it's on the plan, and then we take them there, and there we have access to the movie. We don't have it yet to put the child to work and handle the computer. It is just a room adapted and made available just for this, for a movie."* (P1)

Also, the availability of Chromebooks (CAT3.3) to public school teachers was mentioned (see quote C21). These Chromebooks are linked to the Google Room mentioned earlier (see quote C22). Also, a digital whiteboard (CAT3.4) that can be moved to other rooms was highlighted (see quote C23).

- C21: *"The teachers received Chromebooks. All the teachers last year received them."* (P3)
- C22: *"The school has a Chromebook collection. And the Chromebook is linked to the Google Room. So the teacher who reserves the Google Room, he can use the Chromebooks."* (P3)
- C23: *"At school, we have a digital whiteboard for the whole school that teachers mark and schedule for use. And it doesn't have to be used in the Google Room; it can go into the classroom."* (P3)

4.2.4 CAT4 - The teaching of mathematics

Five subcategories were created regarding teaching mathematics in schools: (CAT4.1) challenges for the teacher, (CAT4.2) strategies to overcome the challenges, (CAT4.3) use of concrete material, (CAT4.4) exercise solving, and (CAT4.5) activities. Regarding the specific challenges in mathematics experienced by teachers (CAT4.1), we verified that many of them are associated with the correction of activities. For example, teachers cannot identify if a student did the exercise or if he/she copied from a classmate when he/she brings the exercise book with the whole exercise solved (see quote C24). In addition, participants mentioned that the student often solves the exercises. Still, teachers cannot identify if the student knows how to do it (see quote C25) since, in some cases, the student enters the final value of the calculation without thinking about the resolution (see quote C26). Another challenge for teachers is student participation, involvement, and pronouncement during lessons. Participants mentioned that students with shyness are a challenge to the teacher because they do not speak up (see quote C27), which makes it challenging to map the problems of the class. These difficulties can generate student indiscipline, lack of interest, and class participation (see quote C28), creating new challenges teachers must overcome. In all these cases, the problem is that concealing the difficulties delays the student's learning, and the teacher becomes powerless in the situation.

- C24: *"If they bring us an exercise book that is all correct and we can't identify that they copied it from their classmate, we will think that they know it, that everything is ok. So, we won't make that time they need, so we keep going, and they fall further behind."* (P4)
- C25: *"In math, the student has often done it, but we don't know if the student knows."* (P3)
- C26: *"Many times, they just solve the question. They don't stop to think if their answer is correct. They do; they find the number, and if the question is objective, they mark it there. They don't worry about the question of validation: Is it correct? On what parameters?"* (P3)
- C27: *"[...] there are those quiet students who don't speak up. They don't go to the teacher to say they have a doubt, but they have the doubt. Sometimes they even copy from a classmate. [...]. So there is this issue of the problem of students with shyness."* (P3)
- C28: *"[...] The student's indiscipline, lack of interest and lack of participation in class was linked to the student has difficulty."* (P3)

Based on the difficulties mentioned, teachers develop several strategies (CAT4.2) to overcome them. One is personalized attention (see quote C29) since the proximity of the teacher and the student with difficulty can help the problem and motivate them (see quote C30). Another strategy identified was to make the student feel useful and protagonist in teaching. For this, the teachers use monitoring (see quote C31) and the student-leader (see quote C32), who will be actors within the classroom who will help the teachers map and solve other students' difficulties. In addition, teachers propose challenges to students who like this approach, especially when it involves some form of competition (see quote C33).

- C29: *"The more personalized the service to the student, the better the result. And greater the perception of the teacher with the student's difficulty."* (P2)
- C30: *"[...] So when you bring a student close to you, you can talk to them and show them that it's not such a big deal as they think; we can motivate them to like math."* (P1)
- C31: *"We really need classroom monitors that help us reach the other students."* (P3)
- C32: *"So I use this technique [student leader] because they like to be bossy and in charge of everything, and it works. And automatically, the leader is an example and can't be playing during class time or stay without doing activities; everyone has to follow the leader. They are well-behaved, do everything right, and the others too."* (P1)

- C33: *"They love challenges, mainly when you use it as a competition, boys vs. girls, divide the class in half [...]. Then they love it. They won't win anything, but just that little 'dash' there, they are already happy."* (P1)

To support the teaching of mathematics and overcome challenges from the strategies, students use concrete material (CAT4.3), especially in the first year (see quote C34). In this sense, students in the early stages use pencils to assist in addition (see quote C35) or pet bottle caps (see quote C36). Notably, in the second grade, the relationship between the concrete and the written resolution is made (see quote C37). Thus, transitioning from concrete to abstract is crucial in learning mathematics (see quote C38).

- C34: *"In the first year, the children work with concrete, they are handling, taking, grouping, putting together, so it is more concrete than the written, practically the written is very little. Not that it doesn't exist, but it's very little."* (P1)
- C35: *"I teach them to use the resource they have; if they have difficulty counting, they use the pencils a lot."* (P4)
- C36: *"There are students who are still a little lower and use the concrete; they will use the pencil, the pet bottle cap."* (P3)
- C37: *"In the first year, we don't charge so much for writing. In the second year, we go deeper, we go to writing"* (P1)
- C38: *"The issue we raised here is the transition from concrete to abstract. We must break through this issue of needing a pet bottle cap to do the math."* (P3)

In this sense, in the written resolution, we verified that the student's strategy for solving exercises (CAT4.4) would depend on their cognitive level (see quote C39). Three levels were perceived: (i) the medium/low level, which will use small lines or little balls for counting (see quote C40); (ii) the medium/high level, which will use the usual addition or subtraction algorithms (see quote C41); (iii) the high level, which will solve the operation using mental calculation (see quote C42). It is worth noting that before entering these levels, students operate with the concrete materials mentioned above.

- C39: *"It will depend a lot on the cognitive level of each student [the resolution strategy]. We know that each class has a diversity of cognitive levels."* (P3)
- C40: *"There will be students, as P2 said, making little lines and then counting. When they count, they are automatically adding up those quantities."* (P3)
- C41: *"You'll have students who will do the usual addition algorithm, they identify an idea of adding, and they'll add."* (P3)
- C42: *"And then, according to the student's cognitive level, there will be the student who will do the mental operation that we call mental calculation."* (P3)

Thus, activities (CAT4.5) are proposed throughout the course to assess student progress between the skills defined by the Brazilian Common National Curricular Base (Base Nacional Comum Curricular - BNCC)[6]. For example, an activity to assess the student's evolution from skill EF01MA06 to EF02MA05 is the relationship between number and quantity (see quote C43). Thus, for each of the skills, there are several activity items that, depending on the student's answer, reveal the difficulties the student has (see quote C44). In addition, participants mentioned that these answers should range from numerical to written to aid the student's understanding of the operation they are solving (see quote C45).

- C43: *"Relate the number to the quantity. If I realized that they already know how to do that, that they are sure that five objects, five units, represent the number five, then I already know that from there I can go on to the algorithm."* (P1)
- C44: *"Even within the same skill, you can do several items. And the feedback from each type of item, each distractor, reveals to you a student has difficulty."* (P3)
- C45: *"So it is very important to vary the types of activities. You often demand a numerical answer; many times, you demand a written one. Nilson José Machado talks about the mother tongue. You use the mathematical language but also work the mother tongue, the Portuguese language itself, or other representations."* (P3)

4.2.5 CAT 5 - The use of technology in teaching

Regarding the use of technology in teaching, three subcategories were identified: (CAT5.1) past experiences teachers had, (CAT5.2) difficulties faced, and (CAT5.3) suggestions. About the past experiences experienced by teachers (CAT5.1), the use of Google Forms, podcasts, and videos for remote classes during the pandemic period was observed (see quote C46). In addition, an experience with a math game in which the students were inspired was described (see quote C47).

- C46: *"In my case, I would post questions from my classes through Google Forms, and I was available to the students if they had any questions; they would look for me privately. Then I would record a podcast or video for students to try to understand the subject and answer the questions."* (P3)
- C47: *"I took all the devices from my house and brought them to my classroom. It's a little game that the numbers go away. They disappear, and others appear. [...] But I saw how bright their eyes were to be in line waiting to mess around to solve it."* (P4)

Regarding the difficulties (CAT5.2) in using technology in teaching, the main one is the availability of technological resources, which is often only a facade (see quote C48). In some cases, the student has no personal technological resource (see quote C49); in others, he/she depends on family members' devices (see quote C50). Also, participants mentioned that students do not know how to handle the computer at school (see quote C51) and that when they do, they are attracted to certain types of different resources (see quote C52). Also, regarding teachers, there is a motivational issue involved since many of them usually do not use technological resources at school, only the classic materials, such as golden material and tangram (see quote C53).

[6]http://basenacionalcomum.mec.gov.br/a-base

- C48: *"And technological resources are few; they only have them on the facade, let's say. There's the propaganda of the city government, but inside the classroom, in reality, a lot is missing."* (P1)
- C49: *"And concerning the technological resource in the municipality of [omitted] even, we don't have, the students don't have resources."* (P2)
- C50: *"Not always the moments were synchronous because the student often depended on the parent's cell phone. Then you have to wait for the parent to come home from work to be able to access."* (P3)
- C51: *"As I said, the Google Room is only for watching movies. They don't have to handle the tablet or the computer, nothing. Because it was supposed to have several computers for the kids to access, but no."* (P1)
- C52: *"Each student has an attraction to a certain type of resource; as P2 said, there are students who like Roblox, but there are students who don't."* (P3)
- C53: *"But generally, teachers don't use these digital resources much at school. And what we have available are the old materials like the golden material, tangram, the classics. The other teachers really have to adapt and instruct their students."* (P3)

Regarding suggestions (CAT5.3) for using technology in mathematics teaching, the possibility of a mathematics game being accessed on the tablet (see quote C54) or a system to support students' difficulties through podcasts or games (see quote C55). Whatever the technology, we noticed the importance of its pedagogical intentionality (see quote C56), i.e., its use must have a clearly defined purpose. Also, participants recommended having specific events or days to use the technology rather than daily (see quote C57). Finally, participants suggested that teacher participation should be included in planning the activities that will be made available to students in the technology (see quote C58) and that it should include students with disabilities (see quote C59).

- C54: *"I believe that almost eighty percent of my classroom, if I had a tablet available for them, for certain little mathematical games, they would be even more interested, it would be more interesting."* (P4)
- C55: *"One suggestion would be to develop activities that could perceive the difficulties of students and from each difficulty have podcast possibilities, a game, [...] to help overcome these obstacles. Creating a system that gives this possibility to the student is very nice."* (P3)
- C56: *"Remembering that technology is the medium. It is also a challenge for the teacher. The student sometimes just wants to play with the tablet. Technology has to have a real pedagogical intentionality because that is the challenge. Technology is a means to achieve that goal."* (P3)
- C57: *"Not for every day, but at least one day a week to have "math day", "math day on the tablet", "technology math day", a name like that, would already draw a lot of attention, they like that, they live it, and that is their world."* (P4)

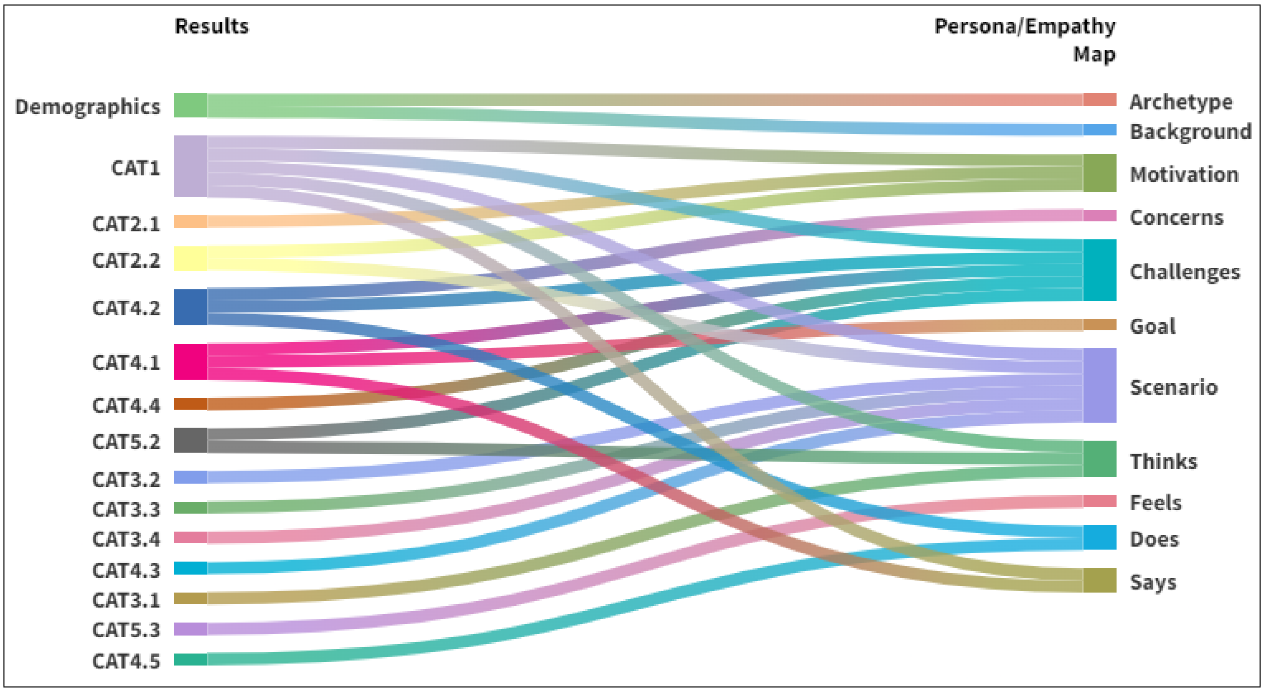

Figura 2: Relationship between the results of the qualitative analysis and the persona components.

- C58: *"And if you can count on the teacher's participation too because the teacher has to enter this space beforehand, plan beforehand what he or she can use to really help each one's difficulty."* (P3)
- C59: *"One thing that cannot be ignored is the inclusion of students with disabilities. Thinking about this issue of including the student who is deaf, the student who is blind, the student who has ADHD. We have to do inclusive activities for these students."* (P3)

5 UX Artifacts

In the define stage of Design Thinking, from the demographic and qualitative results, we created a persona and a user empathy map to synthesize the findings and support the design and development team. The persona comprises your archetype, background, motivations, concerns, challenges, goals, and scenarios. On the other hand, the empathy map was divided into what the teacher sees, speaks and does, listens, thinks, and feels. All decisions to use these techniques were made based on the focus group results, and the relationship between them can be seen in Figure 2. The empathy map is described in Figure 3, and the persona in Figure 4.

5.1 Persona

The persona created is female, and her name is Cláudia. Cláudia's description can be seen in Figure 4. Regarding the archetype and background, we defined our persona using demographic data as an elementary school teacher with a degree in pedagogy. Regarding her motivations, we

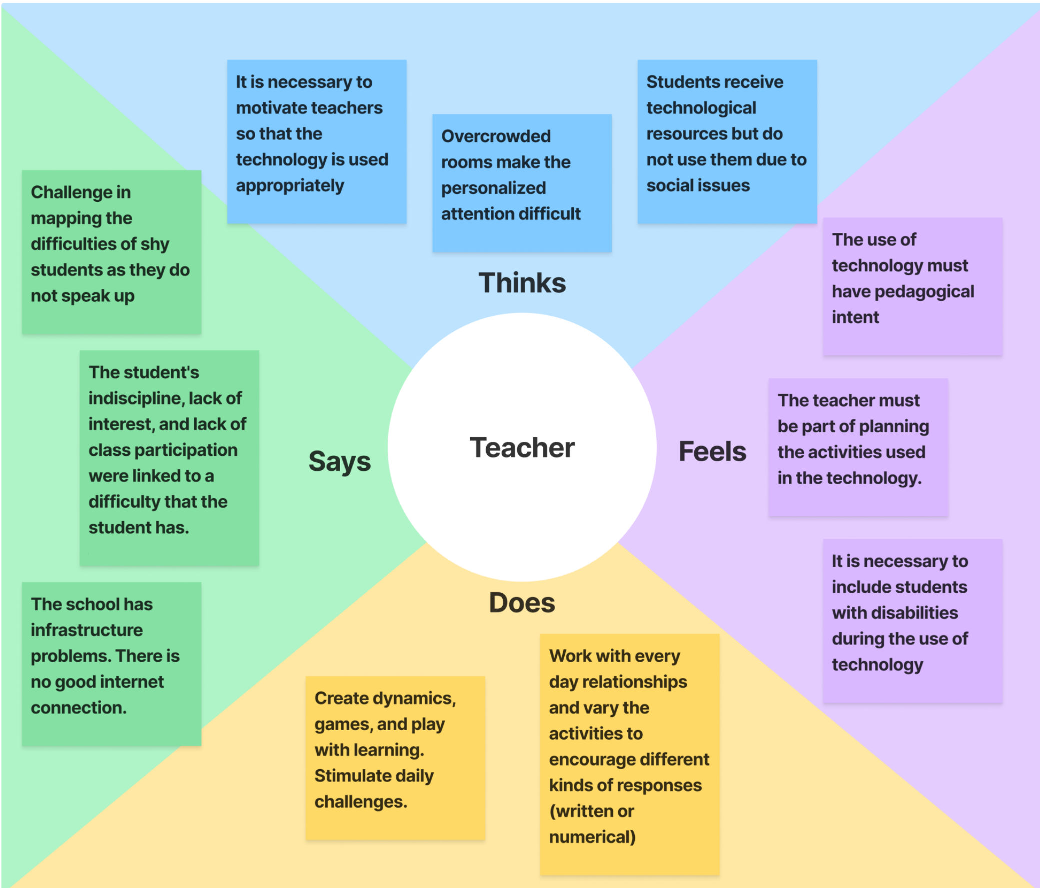

Figura 3: User empathy map description.

highlight that her main goal is to teach mathematics to children efficiently, even with all of Brazil's public education challenges and needs. About her concerns, we highlight that they are linked to strategies to face challenges, often making the student more autonomous and providing continuous challenges to stimulate participation.

Cláudia

ARCHETYPE	Elementary Teacher
BACKGROUND	Pedagogue
MOTIVATIONS	To teach basic mathematics (addition and subtraction) efficiently and playfully to her students between 7 and 10 years old. She believes municipal public education presents several difficulties in achieving its purpose.
CONCERNS	1. Purpose and playfulness are tools for engaging students in learning; 2. Autonomy for students to develop strategies for learning mathematics; 3. Continuous challenges to encourage students to learn.
CHALLENGES	1. Lack of curriculum frameworks that align skills and competencies for learning basic mathematics in the everyday lives of its students; 2. Identifying in the classroom the degree of student performance x degree of difficulty to perform mathematical exercises; 3. Developing and maintaining students' engagement in learning basic mathematics; 4. Technological tools to assist during the classroom learning of basic mathematics.
GOALS	Ensure that your students learn basic mathematical operations and can apply them to everyday life in various situations.
SCENARIOS	She teaches in two municipal public schools with restricted access to technological devices and Wi-Fi networks for students and teachers. The Google Room of the schools where she works has some Chromebooks and Digital Whiteboard; however, they are shared for all teachers and students, so they can hardly be used to teach mathematics frequently with children. In addition, she needs to use several techniques with physical artifacts to teach math since older students (7-10 years old) are still lagging in learning addition and subtraction.

Figura 4: Persona description.

Regarding her challenges, we highlight the mismatch between the curriculum structure and the competencies/skills for teaching mathematics and the difficulty in verifying student performance in the overcrowded classroom. Also, Cláudia has challenges engaging students during her classes and identifying and using technological tools that can help during teaching.

Claudia's goal, which teachers try to achieve, was inserted: to ensure that students learn and apply the learning in their daily lives. Regarding the scenario where Claudia is inserted, we highlight that it is generally characterized by an unstable internet, in addition to technological support (e.g., Google Room and Chromebooks) that need to be shared by all teachers in the school.

5.2 User empathy map

The empathy map created can be seen in Figure 3. Concerning what teachers think, we highlight a need for motivation to use technology in the classroom. This need is because teaching with classical materials (e.g., golden material, tangram) is already well established; therefore, it is necessary to present the positive and pedagogical effects that technology would have so that the teacher can use it. In addition, teachers intend to follow each student's evolution separately, but the overcrowded classrooms make this intention difficult. Also, teachers should reflect on the social problems involving the school, the students, and their parents and understand that this can hinder the use of electronic devices.

Regarding teachers' feelings, we identified the desire to participate in planning an activity through technology, not just transferring a ready-made activity to the student. In this sense, the technology to be used in the classroom must have a pedagogical intentionality, i.e., the teacher must know the desired goal when using the technology with their students, whether to correct an activity, check progress, or publish materials. Still, teachers are preoccupied with students with disabilities and emphasize that technology must be accessible to include them.

Concerning what teachers do, there is the creation of dynamics involving students (for example, monitoring, student-leader), challenges, and games so that students feel protagonists in their learning. This makes them more motivated to overcome the challenges of mathematics. Also, as a way to check the evolution of their students, teachers tend to evaluate them in different ways with written or numerical questions, aiming to identify students who learned the concepts from those who just copied or put the final answer without reflecting on the process to achieve it.

Finally, according to teachers, a significant infrastructure problem in Brazilian schools hinders the use of technologies in the classroom, supported by the inexistence of stable internet with a good connection for teachers and students. Still, teachers mention many difficulties students have and develop other problems, such as indiscipline, lack of class participation, and shyness. All these problems make it challenging to map the students' difficulties in class, and those who have them end up slowing their learning down regarding those who learn.

6 Discussion

Our study presents results obtained from the direct opinion of mathematics teachers. With the support of UX methods, we could synthesize our main results, as shown in the previous sections. Our study differs from others in the literature involving UX and mathematics teaching since the studies generally aim to evaluate the UX of some previously developed solutions with students (e.g., (Kiili et al., 2014; Varsaluoma et al., 2016)). In contrast, ours aimed to explore the needs and context of teaching from the teacher's point of view. However, some results can be conflated with published scientific studies.

Regarding the pedagogical intent of the solution to be proposed, our results corroborate Kiili et al. (Kiili et al., 2014), as the authors mention the need for teachers and students to understand the purpose of technology as quickly as possible. Furthermore, Varsaluoma et al. (Varsaluoma et al., 2016) point out that the slowness in using the math application evaluated in their study negatively affected the experience of its users. In this sense, the need for more internet in Brazilian public schools must be taken into account so that it does not affect the UX of the solutions to be developed.

However, the study by Kiili et al. (Kiili et al., 2014), carried out in the context of Finnish and Irish schools, highlights that to engage more in studies with mathematics technologies, each one must have their device. Unfortunately, this result goes against our findings since many students do not have personal equipment. When they receive it from the government, they are subject to criminality involving their parents and society. To overcome this problem, we focused on teachers as users, who tend to have better and more stabilized conditions than students.

6.1 Implications

The practical application of UX methods allowed us to identify and map some teachers' needs that should be considered when creating systems for Brazilian public schools. Regarding the practical implications, we highlight the lack of internet with good connection in schools; thus, designers and developers should pay attention to creating solutions that do not need continuous consideration. Also, we highlight that classrooms are often overcrowded; thus, it is necessary to pay attention to the efficiency aspects of the solutions since their use must be practical and fast considering these conditions. In addition, the solution to be created must have pedagogical intent, i.e., it must be a tool with a clear objective for the teacher so that, besides providing support during the classes, it motivates the teacher to use it.

Regarding the theoretical implications for researchers, we highlight the need to perform more studies considering other realities of Brazilian public schools. For example, even though we have obtained results that can be replicated in other Brazilian contexts (for example, the lack of internet in schools), we believe that schools in other urban areas or specific places also have their specific difficulties, such as schools in riverside regions, indigenous tribes, or prisons. Therefore, if there is a need to develop solutions that can be replicated throughout the national territory, more in-depth studies are needed to observe these other contexts.

6.2 Limitations

A limitation is related to the participants since those with more experience and more extroverts tend to impose their opinions over those of less experienced or introverted participants. The mediators tried to get all participants to express their opinions in each task to mitigate this limitation. Furthermore, we emphasize that the qualitative analysis of the focus group and creation of the persona and empathy map were carried out by UX research professionals who are not education specialists. In this sense, we emphasize that there may be different interpretations of the results from the point of view and expertise of the person who interprets them.

Furthermore, our artifacts specificity is another point to consider. While this study was initially motivated by the necessity to enhance mathematics education, our analysis led to some general-purpose insights. We assume this arises from the common practice among Brazilian elementary school teachers of teaching multiple subjects within the same class, not solely mathematics. Consequently, it is plausible that challenges encountered in teaching mathematics may extend to other subjects, leading our study to insights not exclusively concerned with math. Hence, while this expanded scope may be perceived as limiting our findings' specificity, it offers a venue for extending our findings' external validity.

7 Conclusion and Future Work

This paper showcases the outcomes of employing UX research methods in practical settings, explicitly focusing on mathematics teachers' perspectives in Brazilian public schools. We explored the first two phases of Design Thinking. In the empathize phase, we conducted a focus group with math teachers from Brazilian public schools to identify their needs and understand their contexts. From the focus group results, we created the persona and the empathy map in the second phase (define) of Design Thinking.

As the main contribution of our paper, we produced results and UX artifacts so that designers and developers of educational software can have insights into solutions for the discipline of mathematics. Furthermore, we emphasize that our results are all based on the teachers' discourse, which differs from most related studies, which evaluate the solution with teachers and students after it has been developed. This first stage of identifying teachers' needs is essential for creating a genuinely assertive proposal.

In future work, we intend to advance to the third phase of Design Thinking (ideation), where, together with designers and developers, we will explore possible solutions that solve the persona's problems identified in this paper and detailed in the empathy map. We also intend to continuously conduct exploratory studies with teachers to understand their problems better and refine identified needs.

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