MathAIde in the Classroom: A Qualitative Analysis of Teachers' Perspectives of Intelligent Tutoring Systems Unplugged

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Abstract. *Intelligent Tutoring Systems (ITS) have shown significant promise in enhancing math education by providing personalized and adaptive learning experiences. However, their adoption in resource-constrained environments is limited by the need for dedicated computing devices for each student. To address this issue, the concept of ITS unplugged has emerged, which helps deliver ITS benefits in resource-constrained settings, for instance, without the necessity for individual computers. However, past research has not investigated how ITS unplugged contributes to mathematics education when deployed in real classrooms. This paper presents a qualitative evaluation of MathAIde, an ITS unplugged designed to support numeracy education, where three teachers used MathAIde in 12 lessons, involving 49 students, and their experiences were captured through semi-structured interviews. Thematic analysis revealed that MathAIde facilitated lesson planning and execution, provided valuable feedback and learning analytics, but faced challenges such as technical issues and the need for more adaptive content. This study contributes empirical evidence on the impact of ITS unplugged in real classrooms, offering insights for future development and adoption of such technologies to promote equitable access to ITS benefits in education.*

1. Introduction

Intelligent Tutoring Systems (ITS) have emerged as powerful tools in educational technology, particularly in the realm of math education [Hillmayr et al. 2020, Nkambou et al. 2010]. These systems leverage artificial intelligence to provide personalized and adaptive learning experiences, making them highly effective in improving students' skills and understanding [Steenbergen-Hu and Cooper 2014, Xu et al. 2019]. By

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tailoring instruction to individual learning needs and pacing, ITS can enhance student engagement, motivation and, ultimately, academic achievement [Guo et al. 2021].

However, the widespread adoption of ITS faces significant challenges, particularly in resource-constrained environments such as underserved classrooms [Rodrigues et al. 2023b]. A major limitation lies in the requirement for dedicated computing devices for each student [Mousavinasab et al. 2021], which can be costly and impractical for schools with limited resources [Gasevic et al. 2018]. This disparity in access creates inequities in educational opportunities, as students in such classrooms may not benefit from the advantages that ITS offer [Isotani et al. 2023, Lin et al. 2023].

To address these accessibility issues and promote equitable access to ITS, the concept of Artificial Intelligence in Education (AIED) unplugged has gained traction [Isotani et al. 2023]. Unplugged AIED aims to democratize access to ITSs and other AIED systems, particularly in resource-constrained settings, by utilizing existing infrastructure and minimizing technological barriers. For this, it advocates towards exploring available resources to provide solutions that easy to use and maintain. Accordingly, a step towards implementing AIED unplugged is developing ITS that do not rely on individual computers for each student, but explore resources likely to be available in most learning settings [Veloso et al. 2023].

At the time of writing, a few studies have been investigating similar issues. One research line concerns a assyncronous approach to explore ITS's benefits. In this line, the idea is that students solve learning exercises using paper and pen, then teachers digitalize the solutions (e.g., through a scanner), which are sent to a server that use ITS features to process the solutions and generate printable feedback for teachers [Portela et al. 2023, Patel et al. 2022]. Another line concerns exploring ITS's benefits in a synchronous approach. Considering most people has a smartphone, this approach adovocates towards using smartphones to capture learners' solutions, preprocess them, and generate real-time feedback [Davis et al. 2020, Veloso et al. 2023]. Notably, the synchronous approach is more technically challenging, as it demands performing mobile-based preprocessing of students solution and feedback generation. However, it is more similar to standard ITSs wherein students solve learning exercises and received instantaneous feedback [Mousavinasab et al. 2021]. Hence, it holds greater potential to provide ITS's benefits to underserved classrooms.

Despite the potential of unplugged ITS to bridge the digital divide in education, there remains a notable gap in empirical evidence regarding teachers' perceptions and experiences with this innovative approach in real classroom settings. Understanding teachers' perspectives, challenges, and successes in implementing unplugged ITS is crucial for informing further development and widespread adoption, ensuring that such tools are useful and likely to be adopted by teachers and, consequently, that all students can benefit from the transformative power of ITS regardless of their technological environment [Xia et al. 2022, Modén et al. 2021]. However, past studies towards ITS unplugged have either been focused on proposing implementation models [Veloso et al. 2023, Patel et al. 2022, Davis et al. 2020] or limited to exploring teachers' perceptions in a prototype-based controlled setting [Rodrigues et al. 2024].

Based on that gap, this paper's goals is to understand how ITS unplugged contributes to math education. For this, we present a qualitative evaluation of MathAIde, an ITS unplugged aimed to support numeracy teachers in exploring ITS's benefits in classrooms (see Section 3). In summary, we recruited three teachers who used MathAIde to generate exercise lists, assess students' solutions, visualize performance reports, and deploy personalized interventions in a total of 12 lessons over a four-week period. Then, we interviewed these teachers to capture in-deep insights concerning how MathAIde contributed to their learning practices. Thus, this paper expands the literature with empirical evidence on how ITS unplugged contribute to numeracy education based on MathAIde's usage in real classrooms, revealing valuable insights for practitioners and researchers interested in deploying and developing such a technology.

2. Background and Related Work

This section presents background information on ITSs and AIED unplugged, then discusses related work.

ITSs are known by their four-model architecture, as discussed in [Nkambou et al. 2010]. The *domain model* serves as the repository of knowledge, encompassing the subject matter to be taught. The *student model* assesses and tracks the learner's progress, adapting the system's response based on individual needs and performance. The *tutoring model* embodies the system's pedagogical strategies, delivering instructional content and personalized feedback. Finally, the *interface component* facilitates user interaction, presenting the learning material and providing a seamless experience. Together, these components enable creating a robust and effective learning environment tailored to each student's needs, which is mainly centered in recommending learning exercises, assessing their solutions to provide personalized feedback, and restart the loop (i.e., generate new recommendations) [VanLehn 2006].

ITSs capabilities to provide personalized feedback and instruction are often associated with improved learning experiences. Several meta analyses provide empirical evidence that ITSs might enhance learning outcomes across a wide range of subjects and educational levels [Xu et al. 2019, Fang et al. 2019, Steenbergen-Hu and Cooper 2014]. Moreover, there is evidence that ITS is an educational technology that stands out compared to other digital tools [Hillmayr et al. 2020]. Notably, ITS-based learning is often accomplished by a student directly interacting with the ITS through a computer [Mousavinasab et al. 2021]. Consequently, students from resource-constrained regions, which computers laboratories on enough devices for a whole class, are disadvantaged in comparison to those who do not lack technological resources, contributing to widening inequalities among learners.

AIED unplugged has been recently proposed to avoid that AIED systems increase rather than decrease learning inequalities [Isotani et al. 2023]. Given that several regions lack access to technological resources, such as computers and internet [Gasevic et al. 2018], the idea is that AIED systems should be designed to comply to these restrictions and prevent that AIED leads to uneven advantages among learners from different realities. For this, the concept builds upon five key elements. *Conformity* highlights the need to align AIED systems with existing resources and teaching methods. This philosophy extends to addressing the digital *disconnect* by designing such systems that function offline while leveraging online capabilities when available. The concept of *proxy* emerges as a vital link, empowering users with diverse digital competencies to access and benefit from AI tools. *Multi-User* considerations recognize the shared nature of technology in educational settings, advocating for inclusive designs. Simplicity, encapsulated in *unskillfulness*, ensures user interfaces remain accessible and intuitive, fostering widespread usability [Isotani et al. 2023].

To exemplify the idea of AIED unplugged, [Isotani et al. 2023] introduce a case study in the writing domain. The proposed solution conforms to standard classroom standards, in which students write essays using paper and pen, acknowledging the lack of a computer for each student. Then, once technology becomes available, teachers can digitalize students' essays, which are sent to a server that uses learning analytics to assess and provide personalized feedback that teachers can redirect to students [Freitas et al. 2022]. A similar solution, but concerning math education, is introduced in [Patel et al. 2022]. Notably, the asynchronous nature of this procedure might delay learning interventions, are feedback timing is prominent for learning experiences [Wisniewski et al. 2020].

An alternative approach towards implementing AIED unplugged explores synchronous interactions. [Veloso et al. 2023] presents a framework in that direction, building upon the idea that, even in underserved regions, a large part of the population has access to a smartphone nowadays [de Pesquisa 2022, Citaristi 2022, Kizilcec et al. 2021]. The idea is that a teacher uses its smartphone to generate a list of exercises, which they can attribute for students to solve using paper and pen. Once the student finished the exercise, the teacher can use their smartphone to take a picture and receive instantaneous feedback regarding that solution (e.g., error types), learning analytics (e.g., a dashboard), and personalized recommendations (e.g., a new exercise list) [Veloso et al. 2023]. [Davis et al. 2020] proposes a similar solution, but focusing on homeworking rather than empowering classroom orchestration.

Notably, most studies towards implementing AIED unplugged have not investigated how these proposal fit within the classroom reality. On the one hand, most research is concerned with proposing conceptual approaches [Veloso et al. 2023, Patel et al. 2022], understanding users to gather requirements [Rodrigues et al. 2023a] or developing (some components of the) solutions [Davis et al. 2020, Freitas et al. 2022]. On the other hand, research aimed to understand how ITS unplugged fit teachers' contexts, to our best knowledge, has been limited prototype-based usability tests in controlled settings [Rodrigues et al. 2024]. Therefore, there is an empirical gap in terms of understanding how teachers perceive ITS unplugged's role in real classrooms. Thus, this paper expands the literature with a qualitative study that investigates numeracy teachers' perspectives on the contribution of ITS unplugged in real classrooms based on the MathAIde, an ITS aimed to implement AIED unplugged and support numeracy education (see Section 3).

3. MathAIde

MathAIde's is an ITS aimed to support numeracy education based on the AIED unplugged's principles. While it provides standard ITS features, such as recommending learning exercises and providing personalized feedback, it is based on the framework proposed by [Veloso et al. 2023] so that it follows the idea of the unplugged principle. Notably, creating such a solution involves several challenges, from gathering requirements and designing its interface component to developing and testing its domain and student models. Therefore, given that MathAIde is an instrument rather the subject of matter of this paper, this section is limited to introducing its features and its main components' implementations. Nevertheless, we refer the reader to the relevant references throughout the text for completeness.

In terms of the AIED unplugged concept, MathAIde *conforms* to existing resources by being designed for smartphones [de Pesquisa 2022, Citaristi 2022, Kizilcec et al. 2021]. Additionally, MathAIde acknowledges the *multi-user* nature of underserved regions by targeting teachers as the final users. Hence, rather than demanding individual logins or individual interactions, such as with standard ITS, the teacher uses MathAIde to capture students solutions, then receive and provide feedback accordingly [Veloso et al. 2023]. Moreover, to ensure it is user-friendly and straightforward to use (i.e., *unskillfulness*), ensuring even those with limited digital skills can benefit from it (i.e., *proxy*), MathAIde has been designed following an iterative, user-centered approach [Rodrigues et al. 2023a, Rodrigues et al. 2024]. Finally, MathAIde aims to implement the *disconnect* element by being executable even when one's smartphone has no access to the internet.

In terms of features, MathAIde empowers numeracy education in four main directions. First, it enables providing personalized instruction by generating exercises lists. In that regard, MathAIde's domain model has a database of math items developed by experts in math education. Each item was designed to address a single skill of the Brazilian National Common Curricular Base (BNCC). Therefore, teachers can use MathAIde to help them plan a given lesson according to the contextual need of Brazilian teachers that are expected to teach based on BNCC. To generate those lists, MathAIde's student model uses a knowledge tracing approach designed to the unplugged context as well. Accordingly, in contrast to standard ITS that rely on fine-grained data from students interactions, this student model is built upon students' previous solutions and items characteristics (e.g., difficulty level). In that context, MathAIde uses knowledge tracing along with information gain theory, a lightweight, well-established approach, to identify the most recommend items and provide personalize instruction through exercise lists.

Second, MathAIde provides personalized feedback for students solutions. The first step, then, is to capture a students solution to the exercise list. For this, the teacher only needs to take a picture of the paper sheet in which the student solved the exercises. Then, MathAIde uses object (i.e., equation) detection and handwritten math equation recognition algorithms to find regions in which the student solved the exercises and transcribe each equation, respectively. Subsequently, for each equation, MathAIde uses a knowledge-based system to identify possible mistakes in the solution and provide error-specific insights. Hence, teachers can use MathAIde to streamline classroom assessments and receive expert-designed feedback on how to address students' mistakes, empowering them in providing personalized feedback for students.

Third, MathAIde provides learning analytics to facilitate following up with students progresses. While instantaneous feedback is important to readily address a student's misconceptions, understanding how they are progressing overtime is important as well. Moreover, given that crowded classrooms are the standard in some underserved regions, helping teachers understand and address shared needs is prominent. Thereby, MathAIde explores its student model to demonstrate reports, both at individual and classroom levels, depicting how students mastery of a given ability have evolved based on the exercise lists students solved. Additionally, MathAIde offers analytics concerning error types, hence, supporting teachers in understanding areas that demand more or less attention.

Fourth, MathAIde allows teachers to control its decisions and recommendations. While computational automation is one of the most important features of ITS and AIED systems, teachers need to trust AI-based decisions to adopt and deploy such solutions [Xia et al. 2022]. Additionally, it is noticeable that no technology is perfect and, thus, error-prone. Hence, it is important that AIED systems do not force users to accept their decisions, but act as a complement in which teachers are on control. That is, offer a high level of user control. Therefore, MathAIde enables teachers to adjust its recommendations in varied ways, such as changing the equation to be assessed after taking a picture or allowing the teacher to reassess a given answer based on their best judgment. Thus, by allowing teachers to take the final decision, MathAIde's approach is to amplify teachers' intelligence with AI-based recommendations.

4. Method

This research aimed to verify how how ITS unplugged contributes to math education from teachers' perspectives. As ITS unplugged is an emerging research paradigm [Isotani et al. 2023], it is prominent to understand how it contributes to math education from the perspective of its target users, teachers, as well-established by usability and technology adoption literature [Barbosa et al. 2021]. Otherwise, similar to other AIED solutions, it is unlikely to be adopted and used in practice [Xia et al. 2022]. Therefore, this paper contributes to that context by studying MathAIde, a recently proposed ITS unplugged, informed by the following research question (RQ): **What benefits and difficulties did MathAIde bring to teachers when using it in the classroom in practice?**

We used a case study in a real environment followed by semi-structured interviews to achieve this goal and answer the RQ. Each participating teacher used MathAIde at the school where they teach, and the interviews were carried out online. The entire study was carried out from April 2nd to May 2nd, 2024. This section details the methodological procedure.

4.1. Participants and Ethical Considerations

We recruited three math teachers to use MathAIde in their classes. Given the novelty of this app, we chose to consider a limited sample as to generate initial evidence on how it contributes to math education in real contexts, following recommendations from human-computer interaction literature [Barbosa et al. 2021]. The teachers were two men and one woman, two aged between 25 and 29 years old and the other between 50 and 54, all with 6 to 10 years of teaching experience. Teachers used the application with their 4th and 5th-year classes, totaling 49 students.

All ethical precautions were considered in this study, following a protocol approved by the Research Ethics Committee (CAAE: 73285823.2.0000.5390). As this is a study in a real environment (schools), we collected approval from the school management to make the environment available for the studies. Furthermore, we applied and collected the free and informed consent form signatures from the three participating teachers. Finally, as the students were minors, we collected their parents' authorization so that they could participate in the study. After applying and collecting the data, everyone involved was coded by the responsible researchers.

4.2. Procedure

Figure 1 shows the procedure overview. The case study was divided into tasks: i) task 1 - prepare the lesson; ii) task 2 - apply list and record responses; iii) task 3 - view student reports and, if there are more lists to be applied, return to task 1. In task 1, each teacher should create the lists that will be applied to students, one list per lesson:

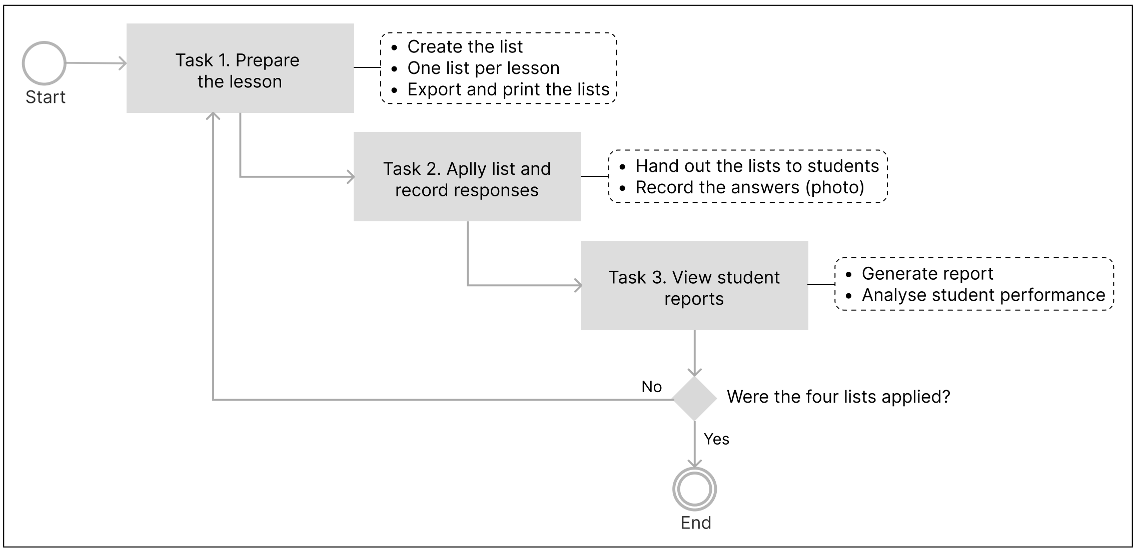

Figure 1. Procedure overview.

- Lesson 1: overall exercise on addition/subtraction skills. Create a list for the EF02MA06 skill.
- Lesson 2: personalized exercises on addition/subtraction skills. Create a list for the EF02MA06 skill.
- Lesson 3: individual exercise on multiplication skills. Create a list for the EF03MA07 skill.
- Lesson 4: personalized exercises on multiplication skills. Create a list for the EF03MA07 skill.

After creating the list to be applied in lesson, teachers should export and print it according to the number of students they have so that students can solve the exercise.

In task 2, teachers should hand out the lists to students during lesson so they can answer the exercises. At the end of the activity, teachers recorded the answers in the MathAIde, taking a photo of each student's entire sheet so that the application could identify each answer (see Section 3 for details).

In task 3, teachers generated the report and analyzed their students' performance after registering all students. Then, teachers should prepare for the next lesson, creating the corresponding list (returning to Task 1) and repeating the cycle until the end of the fourth lesson.

To collect feedback on the experience participants had with the research, we prepared a semi-structured interview script. We conducted the interviews individually with each participant after the last lesson. The overall script was informed by the questions shown in Table 1, although the interviewer would ask follow-up questions to further understand participants' perspectives, as suggested in the qualitative research literature [Blandford et al. 2016].

#	Question
1	What is your general perception of the application?
2	What is your perception of the teaching area? What was your experience like accessing the app's features?
3	What is your perception of the flow of recording the exercises?
4	What is your perception of the exercises proposed by the application? Were they stimulating or discouraging?
5	How do you describe your experience in relation to the class report?
6	How do you perceive the impact of the app on class preparation time?
7	How would you describe your experience with autocorrecting exercises?
8	How has the app influenced your classroom routine?
9	Did you miss something while using the app?

Table 1. Questions used in the post-study interview.

4.3. Data Analysis

We used the thematic analysis method [Clarke and Braun 2017] to analyze the data, which involves identifying patterns and categories in the interview data. We adopted the following steps: transcription of the interviews, where we converted the recorded audio into text; reading transcripts to correct any errors; coding, where we assign codes to represent the interviewees' phrases and ideas; creation of categories grouping related codes into broader themes; and finally, report the results by organizing the categories and quotes (Q) to align them with the objective of the study.

5. Results

The thematic analysis revealed six main themes. Regarding **MathAIde in general**, participants stated that the functionalities are satisfactory if there are no technical problems, such as crashes or incorrect detection of calculations. These technical problems, when they occur, hinder the smooth operation of MathAIde (see Q1). Teachers also praised the usability of MathAIde and saw its potential (see Q2).

- Q1: *"Its functionality is cool, from class preparation to finishing the preparation. I can carry out the entire process from class preparation to completion. If they did not have the technical problems, it would be good if everything ran smoothly, as it already has."* (P1)
- Q2: *"Usability is fluid; it is responsive when it comes to linking questions, which is very good!"* (P3)

About the **impact on the planning and execution of classes**, teachers agreed that automating exercise helps them optimize their planning (see Q3). For P1, two hours of exercises were enough to apply and register, considering there were only 11 students (see Q4). P3 also managed to finish the execution within class time and even needed to do an extra exercise for the more advanced students to make the correction (see Q5). However, P2 required extra time to complete the registration (see Q6).

- Q3: *"In this question, I thought it was cool. It is something new that will help the teacher. I liked."* (P2)
- Q4: *"The 2 hours of classes were enough because I only have 11 students; this is a privilege. I finished with just 10 minutes left to generate the report and talk to them."* (P1)
- Q5: *"Simple preparation. It is part of the routine and does not take much time. Now, I had to do an additional exercise for advanced students in the application."* (P3)
- Q6: *"I needed to use the recess break (15 minutes) to complete the registration (my rest time). I sent them to recess and closed the door."* (P2)

Regarding **pedagogical considerations**, P3 reported that the students were stimulated in the first class; however, in the second class, MathAIde recommended repeated questions, and the students did not want to solve them again, requiring the teacher's insistence (see Q7). P1 stated that there was discomfort in the room due to students questioning the implementation of different exercises among themselves. The teacher had to work around the situation (see Q8).

- Q7: *"The first class I took was stimulating; everyone was excited. In the second class, repeated questions appeared, and the students wanted to avoid solving them again. I had to insist."* (P3)
- Q8: *"The students started to compare the different questions, and I had to explain them carefully. I said there was personalized service so that, in the end, everyone could be on the same level. And then they wanted to know how many mistakes they made to compare with their friend."* (P1)

Concerning the **recommended exercises**, teachers reported that having an exercise generated quickly for them to apply was convenient (see Q9). P1 mentioned that the automatically generated exercise layout could have been better distributed (see Q10). Furthermore, P1 suggested that at the end of each list generated, there should be a sheet with a completed answer sheet to help the teacher (see Q11). P2 stated that due to the school's printing quota, she needed to transform the exercise into an editable file to place the exercise for two students per page to save paper (see Q12). P3 reported that there were questions with very similar wording. However, the exercises worked well because it was a diverse class (see Q13).

- Q9: *"It made it a lot easier; it was a helping hand. There are those days when you need to do something quick."* (P1)
- Q10: *"When distributing the questions, the page layout could be adjusted. To make photography easier. The exercises were smaller in the first list I generated, and much space was left at the bottom."* (P1)
- Q11: *"The application could somehow export a sheet with the answers so we do not have to correct them individually."* (P11)
- Q12: *"I had to export it to word and reduce it because I have a quota, I needed to print two students per page."* (P2)
- Q13: *"There are very similar questions in terms of wording and little changes. The questions worked well for the class because they were diverse."* (P3)

Regarding the **class's evolution with the exercise**, P1 and P2 did not observe evolution in performance. They believed that it could be due to the level of the exercises that were far below their students' skills (see Q14 and Q15). P3 understood the performance of his class, and he found that the exercises were more advanced than he expected (see Q16).

- Q14: *"I did not see much learning progress because of the menu of questions used; the app recommended exercises they already knew, and they continued to know what they already knew."* (P1)
- Q15: *"Because the questions were easy and some were repeated, they wanted to answer quickly and were no longer interested. We are proud because they pay attention to what they read and do, but it becomes tiring for them in the end."* (P2)
- Q16: *"I saw progress because some students I discovered were more advanced than expected."* (P3)

Regarding **suggestions for improvement**, the need for assistance to take the photo correctly (see Q17) was reported, as well as accessibility issues (see Q18).

- Q17: *"I missed the help of framing the photo with light because I think if I had that, it would have helped me take a better photo."* (P1)
- Q18: *"I already had a student with visual impairment. I think I could have designed the application to become inclusive so you could increase the font for people with low vision."* (P1)

6. Discussion

The implementation of MathAIde in the classroom revealed several critical insights regarding the use of ITS unplugged in resource-constrained environments. According to our goal of understanding how ITS unplugged contributes to math education, this section discusses these insights in the context of existing literature, highlighting areas for future research and development in terms of five directions.

First, teacher acceptance and usability. Teachers generally found MathAIde to be functional and beneficial, particularly noting its potential to streamline class preparation and execution. This aligns with previous research suggesting that ITS can significantly reduce teachers' bureacratic burdens and allow for more focused instructional time [Steenbergen-Hu and Cooper 2014]. However, technical issues such as application crashes and incorrect detection of calculations were reported, which can hinder smooth operation and decrease overall user satisfaction. These insights support ITS unplugged's potential while highlighting the technical challenges to design and developed them [Rodrigues et al. 2023b].

Second, impact on planning and execution. The automation provided by MathAIde was appreciated by the teachers, as it helped in optimizing their planning and execution of lessons. The ability to generate exercise lists, assess student solutions, and receive immediate feedback was highlighted as particularly useful. This finding supports the notion that ITS can enhance the teaching process by providing timely feedback and allowing for more dynamic and responsive lesson planning [Xu et al. 2019]. Hence, expanding prior research to the context of ITS unplugged applied to mathematics education.

Third, pedagogical challenges. Despite the advantages, several pedagogical challenges were noted. Teachers reported issues with repeated questions, which led to decreased student engagement over time. This suggests that while ITS can provide personalized learning paths, the diversity and adaptability of the content need to be enhanced to maintain student interest and motivation. Furthermore, some teachers observed that the level of the exercises was not always well-matched to their students' abilities, either being too easy or too advanced. This highlights the importance of adjusting ITS unplugged implementations, such as MathAIde, to include more sophisticated adaptive algorithms that can better tailor content to individual student needs in real-time, despite the challenge of doing so in resource-constrained contexts [Mousavinasab et al. 2021].

Fourth, feedback and learning analytics. MathAIde's provision of personalized feedback and learning analytics was found to be a strong point, as it allowed teachers to track student progress and identify common errors. The ability to control and adjust the system's recommendations was also appreciated, as it empowered teachers to make final instructional decisions, thus enhancing their trust in the system. This is consistent with findings from other studies that emphasize the importance of teacher control in the successful implementation of ITS [Xia et al. 2022], demonstrating its relevance within ITS unplugged for mathematics education as well.

Lastly, suggestions for improvement. Several areas for improvement were identified. Teachers suggested better support for taking clear photos of student work, more inclusive design features for visually impaired students, and enhanced diversity in question wording to avoid repetition. Additionally, integrating an answer sheet export feature was recommended to further streamline the assessment process. These are relevant considerations that should be considered in future ITS unplugged implementations to ensure such solutions properly meet their needs and goal, which would consequently contribute to maximizing usage and adoption [Barbosa et al. 2021].

7. Final Remarks

While ITS are known to contribute to education, resource-constrained contexts are often unable to benefit from them due to the unavailability of technological resources, such as a computer or table for each student. This context motivated research on AIED unplugged, which aims to democratize access to AIED solutions by tailoring them to the available infrastructure so that inequalities are mitigated. Consequently, recent studies have investigated how to design and proposed solutions to implementing ITS unplugged in resource-constrained settings. However, to our best knowledge, there is an empirical gap in terms of how ITS unplugged contribute to mathematics education.

Therefore, this paper contributes to fulfilling that gap by investigating MathAIde. We explored the use of MathAIde, an ITS unplugged solution, in real classroom settings to understand how it contributes numeracy education. Through a qualitative evaluation involving three teachers and their students (n = 49), we observed that MathAIde has significant potential to enhance educational practices, particularly in resource-constrained environments. The ability to provide personalized feedback and learning analytics without the need for individual computing devices presents a viable solution to bridge the digital divide in education. Thus, our findings support the potential from deploying ITS unplugged to optimize mathematics education in resource-constrained contexts.

Importantly, the findings from this study suggest that while MathAIde can streamline the preparation and execution of classes, there are areas for improvement, such as enhancing the usability and reliability of the application. Future research should focus on refining the technical aspects of MathAIde and further investigating its impact on different educational contexts. By addressing these challenges, ITS unplugged solutions like MathAIde can play a crucial role in democratizing access to quality education for all students.

8. Artifacts Availability

The artifacts generated from this study are available from the corresponding author.

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