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Unpacking Contextual Parameters Influencing the Quality of Personalized Adaptive Learning EdTech Applications

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Abstract: Personalized Adaptive Learning (PAL) EdTech products are specialized applications geared towards fostering self-regulated learning of individual students. The design of these applications incorporates specific features to afford such kinds of interaction. As such, the quality of the applications is judged by the presence or absence of such specific features. However, such an approach towards designing and evaluating PAL applications is unlikely to attend to contextual parameters on the ground that may influence students' perception of the quality of the application. Large scale user studies previously done using such applications typically focus on infrastructural capabilities needed to deploy the application on the ground or the learning outcomes for a large set of users because of using the application. Such studies overlook the need to understand why certain applications are well-received by students and hence may lead to significant learning gains while others are not viewed favorably. Moreover, such an approach to designing and evaluating PAL applications and lack of such user studies likely lead to the creation of contextually insensitive applications that do not appeal to the intended students. This study aims to unpack the contextual parameters that might affect a PAL application's quality when used in the classroom. We use a design-based implementation research (DBIR) approach since it enables researchers and practitioners to work closely with each other and understand the nuances of application implementation on the ground, inform generation of local theories, and work towards a sustainable change on the ground. We present six contextual parameters from Indian classrooms that are likely to influence the quality of 'PAL at school' EdTech applications. These findings advance our knowledge of both classroom learning and implementation of PAL applications, and inform the design of contextually sensitive applications.

Keywords: User studies, Personalized adaptive learning (PAL), Quality of EdTech, DBIR, context sensitive

1. Introduction

India is one of the biggest potential educational technology (EdTech) markets with a student population of 250 million. There is a growing interest from global EdTech companies to implement at scale in India and an upsurge of Indian EdTech startups catering to local needs. The EdTech space is powered by the need for quality products having a strong focal point on innovation, scalability, acceleration, value for money and a systematic change (Sikander & Rahman, 2021). Researchers have also highlighted the importance and benefits of designing educational technology that are context-sensitive (Mishra & Koehler, 2009; Zimmerman, Land, & Jung, 2016). In fact, research suggests that being sensitive to context enables students to demonstrate their strengths during the learning process (Sternberg, 2018). Thus, the presence or degree of context-sensitivity has bearing on EdTech applications' quality and knowledge of context-sensitivity in the Indian EdTech market is the need of the hour.

One of the ways of understanding what comprises an EdTech application's context is by forming insights from real classroom settings. While large scale user studies on Personalized Adaptive Learning (PAL) applications have been conducted in the past, these studies focused on measuring students' learning outcomes (Muralidharan, Singh, & Ganiman, 2019) and the infrastructural

capabilities needed to deploy EdTech applications at scale (CSF EdTech Lab 1 Report, 2019). Thus, existing user studies provide little insight into the problem of practice of what comprises an EdTech application's context and how we can inform a systemic change towards designing context-sensitive EdTech applications to fulfill local and global demand for quality applications. To address this gap, in this study, a team of researchers (authors of this paper) from a leading research institution Indian Institute of Technology Bombay - worked with Central Square Foundation, a non-governmental organization focusing on educational policy and strategy and Teach for India (TFI), a non-profit organization which runs a fellowship that brings India's brightest and most promising youths, from the nation's best universities and workplaces, to serve as full-time teachers to children from low-income communities in under-resourced schools. The problem of practice resonated with all these three stakeholders who have been working towards establishing a healthy EdTech ecosystem in India (Patel et al., 2021). This case study is part of a larger project informed by the design-based implementation research (DBIR) approach which facilitates the collaboration of research and practice in order to bring the effectiveness, sustainability, and scalability in educational interventions (Fishman et al., 2013). In this study we look at a subset of EdTech applications i.e., Personalized Adaptive Learning (PAL) deployed in Indian classrooms.

2. Background and Need

The concept of personalized learning can be traced back to Confucius's "teaching students according to their aptitude" and Socrates's elicitation teaching theory (Peng, Ma, & Spector, 2019). It started gaining importance again with the boom in student-centered approach in education. With the emergence of technology and rise of big data, the concept of adaptivity was integrated into personalized learning. Based on the four elements of individual characteristics, individual performance, personal development, and adaptive adjustment, Personalized Adaptive Learning (PAL) can be defined as a technology-empowered effective pedagogy which can adaptively adjust teaching strategies timely based on real-time monitoring of learners' differences and changes in individual characteristics, individual performance, and personal development (Peng, Ma & Spector, 2019). Thus, 'PAL at school' (or PAL, in short) EdTech applications are expected to provide personalized and adaptive instructions according to the individual learners' needs and pace (Badhe, Banerjee, & Dasgupta, 2021).

Based on prior research (Patel et. al, 2021), the EdTech Tulna index has been created as a public good that evaluates the quality of EdTech applications along 3 dimensions - Content quality, Pedagogical alignment and Technology & Design. Each dimension contains multiple evaluation criteria. Content quality measures the accuracy and content/ skill coverage through the criteria of content accuracy and clarity, alignment to national standards, and inclusivity in content representations. Pedagogical Alignment includes criteria of adaptivity, learner-centered pedagogy, enhancing learner experience, assessment of learning, and teacher support. It measures the extent of alignment of the pedagogical strategies with national educational policies, Learning Sciences theories and design principles to create a meaningful learning experience. Technology & Design measures the impact of technological affordances and the user interface design integration with the pedagogy and context and includes criteria like user interface design and affordances that facilitate learning.

3. Role of context in EdTech and inherent challenges

The learning context is defined as a depiction of the current situation of a learner related to a learning activity in addition to the attributes of the physical world model and as the information and content used to guide a specific learning activity (individual or collaborative) in a particular physical environment (Guabassi et al., 2018). The context supports and guides the learners in the learning process. Prekop and Burnet (2003) divided learning contexts into two dimensions - internal (which surrounds the user) and external (which surrounds the application).

According to Gwizdka (2000), the external dimensions consist of location, temperature, time, lighting levels and so on. To extend context-aware application into more cognitive domains, such as information retrieval, decision making, situation monitoring, product design, and so on, the cognitive domain consists of context such as users' goals, tasks, work context, business processes, personal events, communication, emotional and physical state (Gwizdka, 2000). According to Gumbheer et al.

(2022), the extrinsic context comprises Learning design (Subject, Learning Objectives, Pedagogical strategy, Learning Activities, and Learning Resources), Device Wearable & Handheld, and Hardware and Software Resources. Configuration and Physical Properties and Surrounding (nearby Resources, Learning Partners, Activities). Intrinsic context comprises contextual information that is related to the learner's profile including the knowledge level, concentration, motivation level, learning style, cognitive load, and learning behavior.

These extrinsic and intrinsic factors influence the context of use of EdTech products. The context of use is crucial, especially in developing nations like India which comprise diverse contexts, as it talks about how the EdTech applications' quality is perceived by the students. According to Datta (2019) in "one size does not fit all" article, the challenge in implementing EdTech applications in Bottom of the Pyramid (BoP) context is that it becomes a time consuming task since these applications are not designed with multiple contexts in mind. Apart from the practical challenges such as device and internet availability, the article suggests that there needs to be customization according to the demographic and context so it boosts learners' engagement and experience with the application.

Taking into account the existing categories of quality and the external and internal aspects of context mentioned above, the paper focuses on these specific dimensions of the learning context to inform and comment on the context-sensitiveness of PAL EdTech applications. The research question explored in the study is: What are the contextual parameters that influence the quality of PAL Ed-Tech applications?

3. Method

The user-study process started with taking prior consent from Grades 6-8 students, parents and TFI teachers to ensure the willingness of all the stakeholders. The teacher and student demographic survey along with the student diagnostic tests were taken. After collecting the survey data, each classroom was allocated one of two the PAL EdTech applications - PAL 1 and PAL 2. We proceeded with the two PAL applications for our user study in Grades 6-8 since they had national and international presence and had been found to be well-designed for classroom use. The Learning Unit's (LUs) that students needed to work on were chosen by researchers in consultation with the teachers based on the topics covered in the respective classrooms. The teachers were given access to the application and trained on the usage of the application and time to test the application before they implement it with their students. Training included familiarizing them with the application's features and introducing them to the survey tools to be answered by students after using the application. Researchers and the teachers jointly ensured the hardware and software availability before the user studies. Each grade-wise user study took 3-5 days to complete as the students were expected to spend a minimum of 5 hours with the application after school. The teachers and researchers observed the students use the PAL application and supported them wherever needed. The Learning Object Evaluation Survey-Students (LOESS) and Learning Object Evaluation Survey-Teachers (LOEST) was conducted on the last day of the user study (Kay, Robin, Knaack, & Liesel, 2009). The broad process followed in the user study is represented in Figure 1:

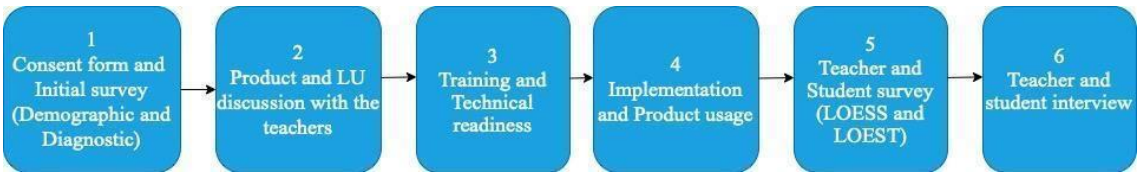

Figure 1: Depicts the broad process of user studies

3.1 Participants

The user study was conducted in four different government schools from Hyderabad and Mumbai with TFI fellows. Some reasons for choosing these classrooms are the homogeneity in the sample group, resource availability since researchers were based in these cities, students with good English language proficiency and TFI fellow volunteers.

Based on both demographic and diagnostics survey data, we followed purposive sampling (Patton, 1990) to ensure that the students who participated in the study had the following characteristics - good English language proficiency level, access to devices, technical skills and knowledge and no previous use of allocated applications. With reference to English language proficiency levels, for PAL 1, 72.97 % (27) of students were at paragraph level in reading, and 27.02% (10) at sentence level. For PAL 2, 84.21% (16) of students were at paragraph level in reading, and 15.78% (3) at sentence level. Some of the educational apps that students had used earlier were Read Along, Bolo, Byju's, and Class edge. The students who were already familiar with one of the PAL applications were assigned the other one to avoid bias due to prior experience with the application.

The compatibility test of the PAL EdTech applications showed that the applications were more than 95% compatible across smartphones and laptops and that the user experience was similar across these devices. For LU allocation, the list of topics covered in the classroom was matched with the units in the respective application according to the grade. The approximate time needed for one LU completion was identified by choosing a sample unit which helped in assigning the number of LUs. The approximate time required to complete one LU was 1 hour 50 minutes for PAL 1 and 1 hour 10 minutes for PAL 2.

Table 1 summarizes the information on grades, city, LUs allocation and number of participants (total number of students who used the application, total number of males and females, and number of students interviewed). Note that the number of students interviewed depended on their availability and hence the numbers varied across the locations.

Table 1: *The details of grade-wise LU allocation*

Grade	PAL Edtech Application	City	Learning Units				Student count (N)
			1	2	3	4	
6	PAL 2	Hyderabad	Integers	Fractions	Mensuration	–	8 (1-M,7-F) Interviewed-4-F
7	PAL 1	Hyderabad	Integers	Operations on Fractions	Lines and Angles	Area and Perimeter	20 (11-M, 9-F,) Interviewed-1-M
8	PAL 2	Hyderabad	Square and Square roots	Exponents and powers	Mensuration	–	11(11-F) Interviewed-4-F
	PAL 1	Mumbai	Real numbers	Exponents and roots	Algebraic expressions	Operations on Fractions	17(6-M, 11-F) Interview-10 (4-M,6-F)

3.2 Data collection and Analysis

The data was collected through surveys, teacher, and student interviews as well as process data from the applications. The demographic survey provided information on the context and background of the students. The diagnostic survey showed the students' reading and conceptual understanding level of mathematics. The teacher demographic survey provided information about usage of technology in the classroom and their perspectives on integration of technology. The LOESS and LOEST survey provided data on three key constructs: Learning, Quality and Engagement (Kay, Robin, Knaack, & Liesel, 2009). Through the student and teacher interviews, additional perceptions on the three constructs and general responses on the PAL application were collected. The PAL applications provided data through teacher dashboards and reports. While the surveys collected both quantitative and qualitative data, the process data was focused on the former and the interviews on the latter. The names of the students and teachers mentioned in this study have been anonymized.

We followed the thematic analysis approach (Braun & Clarke, 2006) to analyze the student and teacher interview data. During the analysis, we sought to identify parameters recommended by literature and evident in the data that likely defined the context of use of the PAL applications in our classroom settings.

4. Findings

This section outlines the contextual parameters derived from the evidence and inferences gathered from qualitative as well as quantitative data from students, teachers, and process data.

4.1 Contextual parameter 1: Correctness and clarity in assessment

Grade 8 students at government school from Mumbai were provided with a PAL 1 application with a set of learning units as given in Table 1. We observed that students faced difficulty in understanding the assessment even though the questions and their solutions were factually correct with accurate scientific explanations. The wording of the assessment questions conveyed the intended meaning and expectations from the students. Yet students sought clarification from peers and teachers on the questions, answers, and explanations. One of the teachers (Ananya) corroborated this observation when she mentioned that there was confusion with respect to the method and explanation provided for solving the questions.

> Ananya (PAL 1 Teacher): "*...not exactly a misconception but just confusion with respect to the methods on reaching a solution because the app used different sorts of methods and different questions"*

Students also faced difficulty in understanding the assessment questions which were not covered in the classroom. Sonali's account below illustrates this point.

> Sonali (student): *"I did not understand the question because I have not done this type before."*

Commenting on the quality of EdTech application: The assessment questions in the PAL 1 application were correct, clear, and unambiguous. However, in the user studies we observed that students were struggling to comprehend the questions. Students' prior knowledge influenced the clarity of the assessment questions. Further, PAL 1's design promoted a one-right approach to solving the given problems which likely led to confusion when it deviated from the teacher's approach.

4.2 Contextual parameter 2: Language comprehensibility

Language comprehensibility refers to the language used in the PAL application content. The language used should be comprehensible by the target group of students. This emerged as an important consideration for both PAL 1 and PAL 2 applications used by students of grade 8 in the government schools in Mumbai and Hyderabad with a set of learning units as given in Table 1. From the students' interview responses, we gathered that students were facing difficulty in understanding the language used in both the PAL applications. For instance, the teacher (Ananya) mentioned that in PAL 1, "*...not everyone could understand especially word problems."* Pranjali (student) corroborated this in the case of PAL 2 application when she highlighted that the speech pace and accent was problematic.

> Pranjali (student): "*They talk very fast, American English, so I have to repeat 3 times to understand."*

Furthermore, students (e.g., Shreya) mentioned that the writing style of PAL 2 was difficult to understand in the content videos.

> Shreya (student): "*English was very fast. handwriting is poor, like we are stuck sometimes like when it is 'l' written and it looks like 's' or 'I'..."*

Commenting on the quality of EdTech application: The above instances highlight the importance of the language used in PAL applications. Unfamiliar pace and accent of the verbal content hindered students' progress. Handwritten texts that are usually preferred due to their personalized and authentic feel were also problematic owing to the poor quality. These findings were also supported by the LOESS survey data, in which 13 students out of 19 have reported obscurity in handwriting and accent.

4.3 Contextual parameter 3: Motivational features

Motivational features such as virtual agents and rewards prompt the learners to engage with the content. We found that the presence of such features was highly motivating for the students. For instance, grade 8 students from the government school in Mumbai were using PAL 1 for a set of learning units as given in Table 1. Students experienced an increase in motivation due to the sparkies, coins, rewards, and points in PAL 1 application.

> *Drishti (student): "I like the sparkies that I get and also, I see the friends' sparkies too. When I feel that I have less sparkies than friends then I feel that I have to solve more questions to get more sparkies. I liked that whenever one topic was completed, the game was enabled. So, for games, I asked more questions."*

Similarly, another student mentioned about the motivating effect of the rewards, points, etc.

> *Vinit (student): "To get more coins, rewards, points, I want to do more questions and whatever I have gained that means more coins, more better rank. Those who have more coin rank are at the top."*

These observations are corroborated from LOESS data for PAL 1 and PAL 2 - 54.05% (20) and 47.36% (9), respectively, strongly agreed that the apps motivated them. The LOEST survey results for PAL 1 and PAL 2 show that three teachers confirmed that the features motivated the students while using the app.

Commenting on the quality of EdTech application: Both PAL 1 and PAL 2 applications included a comprehensive set of motivational features (e.g., Sparkies, leaderboards, and badges) that were well-integrated and prompted the learners to interact further with the content. These features had similarities with gamified elements and indicate the relevance of considering gamified elements when designing quality PALs.

4.4 Contextual parameter 4: Teacher support

Support should be provided to teachers to effectively integrate the LUs in their classroom teaching and to enhance the learning experience. More teacher support with deeper insights on the teacher dashboard about the current student's performance state is required. The support should allow teachers to make choices and customize to a limited extent. One of the teachers from the Hyderabad government school commented in this regard while observing students of grade 7 using PAL 1 application.

> Devashish (teacher): "*We need detailed feedback of what the student is doing presently. There is a teacher dashboard and we are getting all the detailed information for this example this type of conceptual question, they are not able to do it. For example, if I'm getting the information today, that at night they were using it, and this is the question they were struggling with next, I will be preparing the lesson plan like that. In the teacher dashboard, the following data is given: Percentage of progress, Attempts, Number of questions done, Accuracy, Time taken for each question and over all app usage, Number of right and wrong question"*

From LOEST data, two teachers reported that they wanted a more detailed teacher dashboard that gives real time information of the students' progress. They expressed that they should be able to know the practice hours, practice content and efficiency of the students.

Commenting on the quality of EdTech application: Adequate teacher support has been provided including customization and assigning tasks or relevant materials to students. However, in PAL 1, the real time feedback or support while students are using the application is needed to know the real-time status of students and to make the teaching learning process effective.

4.5 Contextual parameter 5: Task value

Task value refers to the perceived value of completing a task by the student. To encourage students to engage with a task and work on it persistently to achieve their learning goals the task should be

meaningful for the students (National Academies of Sciences, Engineering, and Medicine, 2018). We found that once students realized that after attempting a particular number of questions, they will get a game to play, they began guessing answers for questions. Sometimes their guesses were correct and got them through more questions in less time. When their guess was incorrect and the application provided corrective feedback, students ignored the feedback just to attempt more questions in less time. Thus, students were having low task value for completing the questions (task) properly. These insights were collected from students in both Mumbai and Hyderabad for both PAL 1 and PAL 2. The instances below illustrate this point. Students were initially valuing the process of attempting the questions diligently i.e., high-task value.

Rahul (student, PAL 1): "After trying the same question I was thinking what can I do to make it correct."

Swadha (student, PAL 2): "I did not understand the video the first time, so I listened to it again and again, three times."

When students realized that they could enable games after answering a set of questions, they started guessing answers and spent approximately two seconds on a problem. From the teacher dashboard available in PAL 1**,** it was observed that most of the students spent very little time on most of the questions. For example, one student spent 329 minutes in the app and answered 344 questions. The detailed data shows that the student took about 2-3 seconds per question. The interviews also revealed students' focus on solving more questions to play the games.

Vinit (student, PAL 1): "Games are enabled when I do a certain topic when I see and complete a topic. Some games that create fun for us and motivate me to solve more questions. What I like most in the app is the game feature and also examples given in it help me to understand more."

Drishti (student, PAL 1): "I liked that whenever one topic was completed, the game was enabled. So for games, I did more questions."

Commenting on the quality of EdTech application: The presence of games within PAL applications motivates students to engage with more questions. However, this engagement is beneficial only when students find the task meaningful and ascribe high value to completing it diligently. To get to the game, students resorted to a guess and check approach and the PAL application was unable to counter such an approach.

4.6 Contextual parameter 6: Social Learning

PAL applications are considered to be used by individual students. As such, PAL applications are designed for individual work that doesn't support collaborating with one another. However, a typical classroom setting provides opportunities for students to discuss and collaborate with each other. Evidence taken from interviews of grade 8 students from Mumbai and teachers from Hyderabad give insights on social learning while using the application. For instance, a teacher (Devashish) mentioned the following.

"*The first one is, for example, when the students are using in the class, I think, the main advantage is that there, the application has that inbuilt thing that they will find curiosity and all but here I am seeing that, one student is doing it. The second one is more exciting (by looking at it). Okay. He's also doing and he's also using it since the last half an hour. I will also do it, there is something and there is one thing that you see that the group mentality starts working, right, yeah... they start discussing the doubts, they start solving it. So, it's a, I think a collaborative effort starts to kick in when they're using this type of application in the school environment... I think under the school context, in the school environment, it's much more productive than what can be provided at homes, because at homes that I don't think there is such a conducive (collaborative) environment for them to study."*

A student also commented on the importance of social interaction with peers.

Khushboo (student, PAL 1): "At last I did not understand the question, then I saw my friend doing that question then I understood. "

Commenting on the quality of EdTech application: Learning from peers via discussion and collaboration are often not given a consideration for PAL applications. The design of such applications usually does not support social learning. Our findings show that when PAL applications are used in classrooms, the teacher and peers serve as critical resources for facilitating learning. However, this view of learning using PAL applications that gives importance to the social interactions is at tension with the common notion of PAL being used by individual students to enable it to adapt to the students' needs. Thus, ensuring a balance between social learning and adaptivity in PAL applications becomes important.

These six contextual parameters are related and in sync with the context dimensions specified by Gwizdka (2000) and Gumbheer et.al (2022) as follows - a) parameter 1 is linked to the extrinsic context of learning activities and subject, b) parameter 2 addresses the communication aspect of the learning context, c) parameter 3 is directly related to the intrinsic context of motivation level, d) parameter 4 is aligned to device aspect, more specifically to the software resources, e) parameter 5 is derived from cognitive domains of tasks and goals, and f) parameter 6 is linked to the surrounding, specifically to the learning partners.

5. Discussion and Conclusion

In this research, we set out to unpack the contextual parameters that might affect a PAL application's quality when used in the classroom. We use a DBIR approach that emphasizes transcending research/practice boundaries and integrates wisdom of practice into innovations in a way that informs ongoing design (Penuel & Potvin, 2021). With this approach in mind, the user-study is an outcome of the collaboration between researchers, evaluators, teachers and students where all the stakeholders brought multiple perspectives about the quality of PAL applications.

We found six contextual parameters that potentially affect the quality of PAL EdTech applications when used in real classroom settings. In the first contextual parameter the students and teachers highlighted the confusion due to the difference between the method of teaching in the classroom and the method followed to solve the questions in the applications. The novelty of the type of questions for users who did not know the concept before led to lack of clarity of the assessment questions. Second, we found that the comprehensibility of the content was affected by the accent used and quality of handwritten text. Foreign accents and unfamiliar handwriting slowed down students' progress. These two contextual parameters are tied to the situation of a student and information and content used in specific learning activities (Guabassi et al., 2018). Participants in this study had sufficient mathematics knowledge and reading comprehension level for engaging with the PAL application productively. However, their interaction with the application was affected by the lack of adequate consideration of the context of use in its design. Third, motivational features (e.g., Sparkies, leaderboards, and badges) played an important role in prompting the learners to interact further with the content. Thus, such gamified elements are important in facilitating effective use of the PAL applications in the school setting. However, when students are too much focused on interacting with these elements, there arises the risk of encouraging a guess-and-check approach where students pay minimal attention to the content (fifth parameter). Thus, there is a need to balance the focus on intrinsic context and cognitive domains in PAL applications (Gwizdka, 2000; Gumbheer et al., 2022). The contextual parameter of teacher support notes that the features present in the app don't offer sufficient data and information on student's learning and progress for the teachers to customize their teaching. Finally, we found that in the classroom context, students were learning from each other's mistakes, peer interactions, seeking teacher's support in understanding the questions and then attempting questions correctly. Importance of social interactions while using PAL applications is often overlooked and not supported via the application's design.

These contextual parameters highlight ways in which PAL EdTech applications can be designed to be sensitive to the local context and support teaching and learning effectively. Presence of TFI as an implementation stakeholder was important for arriving at these findings because the TFI fellows brought a unique perspective that comes from having worked with children from low-income communities in under-resourced schools in India. The DBIR approach helped facilitate the partnership with TFI fellows for this user study and impressed upon the significance of attending to context-

sensitivity while designing PAL applications. The contextual parameters are independent in nature, however there can be an indirect dependency which needs to be explored further.

One of the limitations of the study is that the six parameters listed above are not an exhaustive set in this study and more contextual parameters might evolve from further user studies conducted at scale with different methods, students, teachers, and PAL applications. The findings from this study are not generalizable due to the small sample size and lack of longitudinal data from students and teachers across a complete school year. Another limitation would be that the internet speed and technical errors that occurred during the user study may have affected the student experience of the application. These technical challenges may have compounded the issues already faced by the students due to the parameters listed above.

On the whole, the knowledge of the contextual parameters through the user studies can be leveraged in future research to design contextually sensitive EdTech applications. These findings also advance our knowledge of both classroom learning and implementation of PAL applications in classrooms. The contextual parameters identified from this study can inform the design of large-scale user studies which acknowledge the role of context, culture, and students' background in determining the quality of EdTech applications.

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