

Voice-First Mathematics Access for Visually Impaired Marathi-Medium Learners: A Mixed-Methods Evaluation of an Offline Tutor

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ABSTRACT:

This study reports the design and evaluation of an offline, voice-first mathematics tutor for blind and low-vision (B/LV) Marathi-medium learners aged 11–14. Existing accommodations—sighted readers, generic screen readers, and digital audio textbooks—either compromise learner independence or assume English-medium interfaces and stable internet connectivity unavailable in rural Maharashtra. Grounded in Universal Design for Learning, the Expanded Core Curriculum, and sociocultural theories of mathematics learning, the system runs on a Raspberry Pi 4 and accepts spoken Marathi as its only input. A mixed-methods, three-arm matched-cohort design with 30 learners across four schools compared the proposed system against an audio textbook (control) and an earlier prototype (baseline). Over eight weeks, the intervention arm gained 40 percentage points on a 25-item oral mathematics assessment, versus +24 (baseline) and +12 (control); Cohen's $d = 1.94$ against control. Gains were largest in conceptual understanding, verbal explanation, and transfer. Learner acceptance averaged 4.6/5 and teacher acceptance 4.5/5. Findings indicate that voice-first, offline, mother-tongue tutoring can meaningfully advance inclusive mathematics in low-resource regional-language contexts.

Keywords: Visually impaired and low-vision learners; inclusive mathematics; assistive technology; Universal Design for Learning; mother-tongue instruction; offline learning.

1. Introduction

Mathematics learning is fundamentally dependent on sequential reasoning, symbolic representation, and conceptual visualization. In conventional classrooms, students often understand

mathematical ideas by observing teachers write equations, draw diagrams, construct shapes, and demonstrate step-by-step problem-solving on a board. Visual representations such as number lines, geometric figures, fractions, graphs, and spatial arrangements of symbols play a central role in

helping learners connect abstract mathematical ideas with concrete meaning. However, for visually impaired students, this visual pathway to learning is either partially available or completely inaccessible. As a result, mathematics does not become difficult because of the learner's cognitive inability, but because the mode of instruction fails to reach the learner in an accessible and meaningful form.

This challenge becomes more serious in the context of visually impaired students studying in Marathi-medium schools, particularly in rural and semi-urban regions of Maharashtra. The existing online learning tool are designed by considering that the learner is normal without any visual disabilities. It is assumed that users can read the screen, navigate menus, interpret visual diagrams, and interact through all input devices or touch interface. There are few Screen readers available which enables the conversion of text into speech, but the main limitation is in reading mathematical contents which contains symbols, spatial structures, diagrams, or multi-step procedures. These screen readers able to narrate a mathematical statement aloud, but explaining it in procedural manner is lagging. The sequencing and ability to explain how one step leads to the next, or what a diagram conceptually represents is the main limitation. Therefore, the student receives the sound of the content but not necessarily the meaning of the content.

Existing research on accessible mathematics education confirms that visually impaired learners require more than simple text-to-speech conversion. Few recent researchers have put forth the semantic navigation of mathematical expressions, MathML-based representation, and experiential audio-intensive explanation methods which lead to improvement on understanding mathematical structures (Ali et al., 2024). To enhance recognition, remembrance, graphical insight analysis and mathematical language understanding audio tactile platforms are been introduced which makes the learning of mathematics easier for visually impaired learners (Maćkowski et al., 2022).

Such contributions aids the accessibility of mathematics to move beyond merely reading

content aloud and but instead take care of fundamental understanding and learner-centric exploration.

Mathematics is like a chain where each idea connects to the next. If one link in the explanation is missing or unclear, the learner gets stuck there. It is not that they cannot learn more, it is just that the chain has been broken (Schoenfeld, 2016). For visually impaired and low-vision (B/LV) learners, that chain is delicate by design. In most classrooms, mathematics is taught using the chalk and board, diagrams, and the teacher's gestures, which together connect what learners see with what they hear. When sight is removed, a learner who is good at mathematics may still struggle to take part, not because it is too hard, but because the way it is taught does not include them. The usual kinds of support available in a Marathi-medium school in rural Maharashtra each leave part of the problem unsolved. Using a sighted reader means the learner has to wait for someone else to be free, which takes away the independence that the Expanded Core Curriculum says every blind child needs to develop (Hatlen, 1996). Screen readers like NVDA and JAWS let learners read text on their own, but they read mathematics as a plain list of symbols, without explaining what it means (Beal & Rosenblum, 2018). DAISY audio textbooks bring back proper explanations in audio form, but the content cannot be changed, and they usually need the internet to use (UNESCO, 2023).

Layered on these access gaps is a language gap. The most active research in AI-supported instruction is in English, leaving Marathi—the third-most-spoken first language in India—substantially under-served. Translanguaging research consistently finds that learning mathematics in a non-mother-tongue increases cognitive load and depresses conceptual gains (García & Wei, 2014; Setati & Adler, 2000), and this load is heavier for a learner working without sight.

Artificial Intelligence in education has grown quickly in recent years, including in India, where it is being used in schools, ed-tech apps, and government learning platforms. AI tools can now explain things to learners, change how hard a

question is, give quizzes, and answer questions straight away. But most of these tools still need a screen, cloud services, and a good internet connection to work. This makes them hard to use in many parts of India, especially in rural areas where the internet is slow or not always available. For visually impaired learners in Marathi-medium schools in states like Maharashtra, there are three problems at once: the tool needs sight to use, it usually does not work in Marathi, and it needs the internet.

Language also matters a lot in learning, and this is especially true in a multilingual country like India. UNESCO has said that children learn better when they are taught in a language they already speak at home (UNESCO, 2025). For Marathi-medium students, learning mathematics in English or Hindi makes things harder to follow. This is even more difficult in mathematics, where learners are already trying to understand symbols, steps, and ideas that are not easy. If the language is unfamiliar, the learner has to first work out what the words mean before they can think about the mathematics. So learning in the right language is not a separate issue. In India, where students study in many different mother tongues, it is a basic need for real understanding to happen.

To address these challenges, this research introduces Marathi Ganit Shikshak, an offline, voice-based AI maths tutor created especially for visually impaired learners who speak Marathi. The thinking behind the system is straightforward. If a learner cannot see diagrams on a screen, cannot use a mouse or touch interface, and does not always have an internet connection, then maths cannot be taught in the usual way. It has to be redesigned as a spoken conversation, one that the learner can listen to, respond to, and follow at their own pace.

Instead of simply reading questions out loud like a normal screen reader, the system actually teaches. It explains each maths problem step by step, so the learner understands not just the answer but also how it was worked out. It uses short stories and everyday examples to make ideas easier to picture in the mind, which is especially helpful when diagrams are not an option. It also runs interactive quizzes

where the learner can answer by speaking, and it gives feedback in Marathi so the learner knows what they got right and where they need more practice. In this way, learners can study on their own, without needing a sighted helper sitting next to them.

The system is built around three main ideas. The first is voice-first interaction, which means the learner uses speech to listen and reply, rather than reading from a screen. The second is offline functionality, so the tutor works even in places where the internet is weak or not available. The third is Marathi-language support, so learners can study maths in the language they speak at home and understand best.

The main problem this study looks at is that there is no proper learning tool for visually impaired students in India who study maths in Marathi, especially one that works without the internet. Most of the tools that exist today either just read text out loud, depend on pictures or touch-based materials, need a constant internet connection, or only work in English and a few other major languages. While these tools do help in many ways, none of them bring together everything a blind Marathi-speaking learner actually needs, which is clear spoken explanations of mathematics, support in their own language, and the ability to work offline. Because of this, a large gap remains in how mathematics is taught to such learners.

The main aim of this research is to design and build an offline, voice-based AI tutor that allows visually impaired Marathi-medium students to learn mathematics on their own, without needing a teacher or helper sitting beside them. The specific goals of the research are as follows. First, to give spoken explanations of mathematics ideas and methods in Marathi. Second, to teach mathematics step by step rather than just giving the final answer. Third, to include quizzes and interactive practice so that learners can check their own understanding. Fourth, to reduce the need for screens, diagrams, and the internet. And fifth, to build the system in a flexible way so it can later be extended from basic arithmetic and the Pythagoras theorem to other topics like algebra, geometry, and trigonometry.

At the moment, Marathi Ganit Shikshak focuses on the four basic arithmetic operations, which are addition, subtraction, multiplication, and division, along with the Pythagoras theorem. These topics were chosen because they cover both sides of mathematics learning. Arithmetic needs accurate calculation and regular practice, while the Pythagoras theorem needs the learner to understand how the sides of a right-angled triangle relate to each other. To make sure the answers are always correct, the system uses fixed programmed logic for calculations instead of letting the AI generate numbers on its own. This way, the mathematics stays accurate, while the AI focuses on what it does best, which is explaining ideas, guiding the learner, and making the lesson feel like a conversation.

This research adds something new to inclusive mathematics education by changing the focus from making screens easier to use, to building a learning system that is designed around the voice from the start. Instead of treating accessibility as something added on at the end, Marathi Ganit Shikshak places accessibility at the very heart of the design. The study argues that visually impaired learners do not need a watered-down version of mathematics. What they need is a way of being taught that delivers the same mathematical thinking through a method they can fully access. By combining offline use, Marathi speech, accurate calculations, storytelling, and quizzes, the system aims to make mathematics feel more independent, more meaningful, and more inclusive for blind learners in Marathi-medium schools.

Taken together, this research sits at an important meeting point of artificial intelligence, inclusive education, regional-language learning, and accessible mathematics teaching. It offers a practical and locally suitable solution for learners who are often left out by mainstream educational technology. In this sense, Marathi Ganit Shikshak is not just a technology project. It is also an attempt to rethink how maths can be taught so that it becomes reachable, understandable, and truly learnable for visually impaired Marathi-speaking students.

This paper presents the redesigned version of the system, which is now built around the principles of

Universal Design for Learning (CAST, 2018), and reports the findings of an eight-week mixed-methods study carried out with 30 blind and low-vision learners. The study is guided by four main research questions. First, does a voice-first, offline, mother-tongue tutor actually help blind and low-vision learners improve in mathematics, when compared with a standard audio textbook and an earlier version of the tutor? Second, are these improvements only in solving problems quickly and accurately, or do they also reach deeper areas like understanding concepts, explaining ideas in words, and applying knowledge to new situations? Third, how do learners and teachers of visually impaired students view the tutor in terms of teaching quality, classroom usability, and how well it fits the school curriculum? And fourth, what does this design suggest for the wider inclusive education system in low-resource settings like rural India?

2. Methodology

2.1 Design

We used a mixed-methods, quasi-experimental, three-arm matched-cohort design over eight weeks, combining quantitative pre/post-test outcomes with qualitative interviews of learners and teachers of students with visual impairment (TVIs), consistent with current mixed-methods norms in special-education research (Creswell & Plano Clark, 2018). Random allocation within strata assigned each learner to one of three arms (control, baseline v1, intervention), stratified on pre-test score to reduce baseline imbalance.

2.2 Participants and Sample

Forty-seven B/LV learners across four Marathi-medium schools in Pune and Nashik districts were initially approached. After consent and assent, thirty learners aged 11–14 (median 12 years; 18 boys, 12 girls) were enrolled. Twelve TVIs (six women, six men; median 9 years of experience) also consented as observers, raters, and interviewees.

2.3 Instruments

Three families of measures were used. The primary outcome was measured using a 25-item oral mathematics assessment, administered by a research

assistant who was blind to group allocation in order to reduce assessor bias. The instrument was developed in consultation with a panel of three special education mathematics specialists and assessed five dimensions of learning, with five items per dimension. These dimensions were numerical fluency, conceptual understanding, verbal explanation of reasoning, transfer to novel problems, and self-reported confidence. The test was checked for reliability before the study began, and it scored a Cronbach's alpha of 0.84, which

means the questions worked well together and measured what they were meant to measure. Secondary outcomes used a 7-item oral Likert administered at week 8 to all learners and a parallel Likert completed by the twelve TVIs (Cohen's κ for inter-TVI agreement = 0.71). Qualitative data comprised semi-structured post-session interviews with all 29 completers and all 12 TVIs, audio-recorded with consent, transcribed in Marathi, and translated to English by two bilingual research assistants with reconciliation for discrepancies.

2.4 Procedure

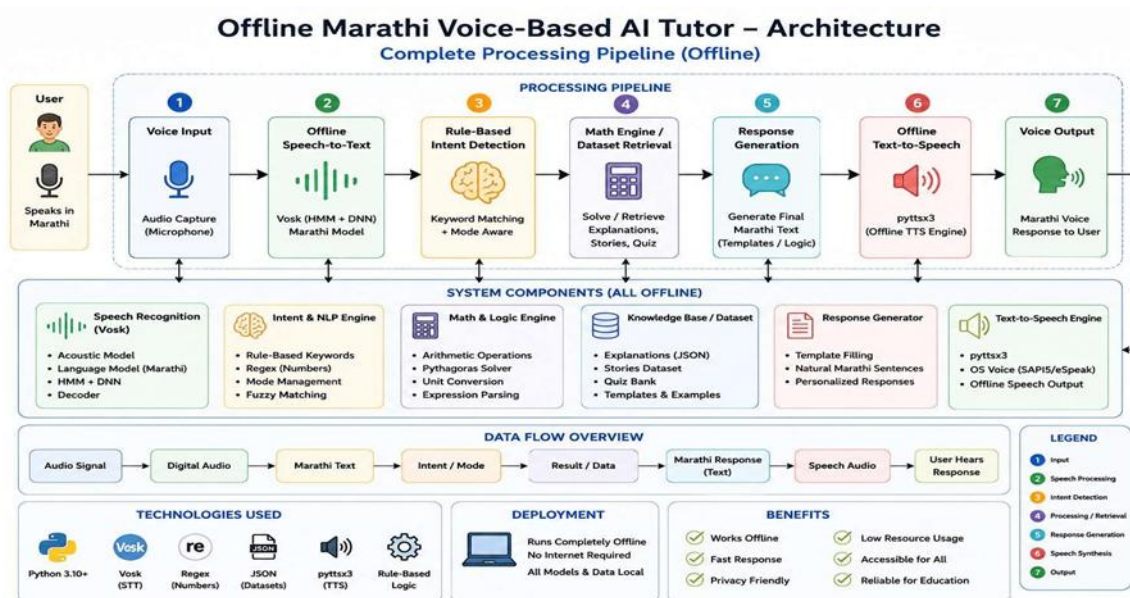


Fig.1 Offline Marathi Voice based AI tutor

Figure 1 shows how a simple question from a learner becomes an answer. This starts when the learner asks a question in Marathi using the microphone. The voice is turned into a signal.

The system does not send this information to a server on the internet. Instead it processes everything on the device.

The voice is sent to the Offline Speech-to-Text part, which changes the Marathi into written text. This is a step because it helps the system understand the learners question. It also keeps the learners information and does not need the internet to work. This makes the system reliable and easy to use especially when the internet connection is not

stable. Once the voice is changed into text the system goes to the core understanding part, which's the Rule-Based Intent Detection module.

The proposed system runs on a Raspberry Pi 4 Model B with 4 GB RAM ($\approx$ US\$55).

Spoken Marathi is captured at 16 kHz, pre-filtered for classroom noise, and decoded by the Vosk Marathi acoustic-language-model bundle (Alpha Cephei, 2024).

All numerical computation is performed by SymPy (Meurer et al., 2017) to guarantee correctness. Step-by-step explanations are generated by a 4-bit-quantised Gemma-2B-Instruct model (Gemma Team, 2024), grounded on a Marathi mathematics

knowledge graph aligned to SCERT Maharashtra and NCERT scope statements. Item selection is governed by Bayesian Knowledge Tracing (Corbett & Anderson, 1995); speech output uses Coqui-TTS Marathi VITS (Kim et al., 2021). End-to-end latency from utterance to spoken response is 1.98 s on the Pi 4.

The system is not like a chatbot. It focuses on mathematics learning. The Marathi text is analyzed using keywords and patterns. The system figures out what the learner wants to do like add or subtract numbers or solve a math problem. This step ensures that the system understands the learners request before doing any calculations. The system is designed to stay focused so that the answers are helpful and educational. After understanding the learners request it is sent to the Math Processing and Content Retrieval part. This is where the system does the teaching work. When the learner asks the system to perform a mathematics operation, the system calculates the answer directly. If the learner wants to solve a Pythagoras problem, the system applies the mathematical formula to work out the result. If the learner instead asks for an explanation or wants to take a quiz, the system pulls the relevant content from its local datasets, which contain step-by-step explanations and examples written in Marathi.

The system is not designed to simply give answers. It is built to help the learner understand. Once an answer is produced, either by the mathematics engine or from the dataset, it is passed on to the Response Generation stage. Here, the system turns the answer into simple Marathi sentences, explaining the idea in the way a teacher would in a classroom. Wherever possible, the system breaks the explanation into steps, so the learner can follow the reasoning from start to finish. Finally, the Marathi text is sent to the Offline Text-to-Speech module, which converts the written words into spoken Marathi and plays them back to the learner. The learner hears the response, and the cycle of interaction is complete.

The entire system works smoothly from voice input to text conversion, understanding, math processing, explanation and voice output. Every

part plays a role. Together they create a fully offline voice-driven educational system that makes math learning accessible and interactive without needing the internet.

The Offline Marathi Voice-Based AI Tutor is designed to be helpful and instructional. It makes math learning easy and fun without a visual interface or internet connection. The Offline Marathi Voice-Based AI Tutor is a tool, for learners who want to learn math in Marathi.

All three arms received the same content scope (grade-six arithmetic and the Pythagorean theorem), instructional time (four 25-minute sessions per week for eight weeks), and pre-/post-tests; arms differed only in delivery. The control arm used a Marathi DAISY audio textbook; the baseline arm used the v1 tutor; the intervention arm used the proposed system. The proposed system runs on a Raspberry Pi 4 Model B with 4 GB RAM ($\approx$ US\$55). Spoken Marathi is captured at 16 kHz, pre-filtered for classroom noise, and decoded by the Vosk Marathi acoustic-language-model bundle (Alpha Cephei, 2024). All numerical computation is performed by SymPy (Meurer et al., 2017) to guarantee correctness. Step-by-step explanations are generated by a 4-bit-quantised Gemma-2B-Instruct model (Gemma Team, 2024), grounded on a Marathi mathematics knowledge graph aligned to SCERT Maharashtra and NCERT scope statements. Item selection is governed by Bayesian Knowledge Tracing (Corbett & Anderson, 1995); speech output uses Coqui-TTS Marathi VITS (Kim et al., 2021). End-to-end latency from utterance to spoken response is 1.98 s on the Pi 4.

2.5 Data Analysis

Quantitative data were analysed in Python using mixed-effects models, with arm $\times$ time as fixed factors and learner as a random factor for the primary outcome, while secondary outcomes were reported using descriptive statistics and 95% confidence intervals. To measure the size of the differences between groups, Cohen's d was used, with Hedges's correction applied to adjust for the small sample size. For the qualitative side of the study, learner and teacher responses were studied using thematic analysis, based on the method given

by Braun and Clarke (2006). Two coders worked on this separately, and their level of agreement was strong, with a kappa value of 0.78. The results from the qualitative and quantitative parts of the study were then brought together using the mixed-methods approach of Creswell and Plano Clark (2018), so that both kinds of evidence could support each other and give a fuller picture of what was happening.

The dataset that powers the system was built in JSONL format. Every entry in it has two parts, a learner's question or instruction in Marathi, and a step-by-step reply in Marathi that has been written with audio learning in mind. The dataset covers the four basic arithmetic operations along with the Pythagoras theorem, and the examples used are drawn from things children see around them every day, like fruits, books, and items in the classroom. This was done on purpose, so that the learners could picture the problem in their minds even without seeing a diagram.

While preparing the dataset, care was taken to follow the teaching style used by the Maharashtra State Board, NCERT, and SCERT Maharashtra, all of which encourage learning through real-life situations, hands-on examples, and step-by-step thinking. The content also reflects the values laid out in the National Curriculum Framework 2005, the National Curriculum Framework 2023, the National Education Policy 2020, and the Universal Design for Learning guidelines from CAST. Together, these frameworks shaped a dataset that aims to make mathematics more inclusive, more accessible, and more meaningful for visually impaired learners studying in Marathi.

3. Results

fig.2 depicts the AI tutor for teaching mathematics in vernacular language i.e. in Marathi for visually impaired students to make the learning mathematics in simpler manner using AI assistance

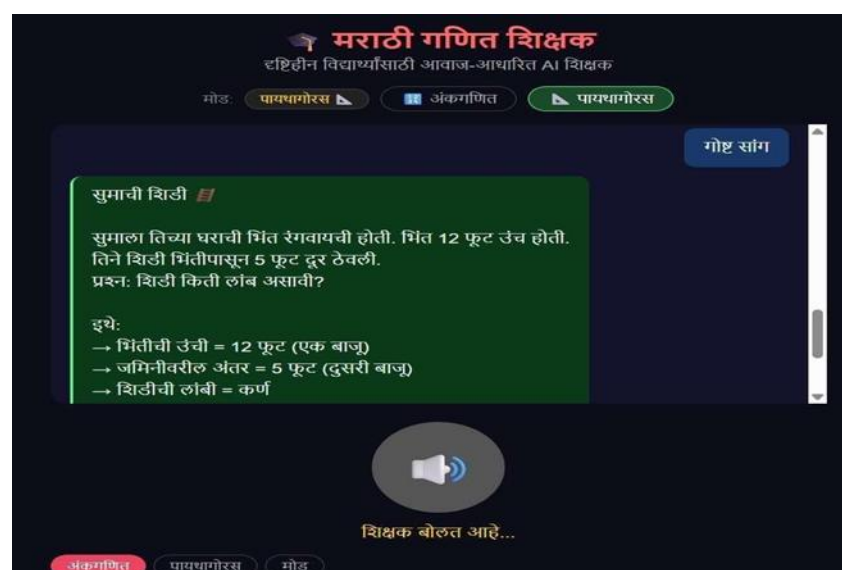


Figure 2. Demonstration of Marathi voice based AI tutor for Pythagoras theorem

3.1 Mathematics Learning Gains

The fig.3 shows that all three groups started at the same pre-test mean score of **42**, indicating comparable baseline performance. However, the post-test scores show a clear improvement pattern: the control group improved modestly from **42 to 54** with a **+12 percentage-point gain**, the baseline

tutor improved from **42 to 66** with a **+24 percentage-point gain**, and the proposed intervention showed the strongest improvement from **42 to 82** with a **+40 percentage-point gain**.

The effect size also supports this pattern. The baseline tutor showed a large improvement over control with **Cohen's d = 0.95**, while the proposed

intervention showed a very large effect with **Cohen's $d = 1.94$** . This shows that the proposed system led to clearly greater learning improvements

than both the DAISY audio textbook and the earlier version of the tutor.

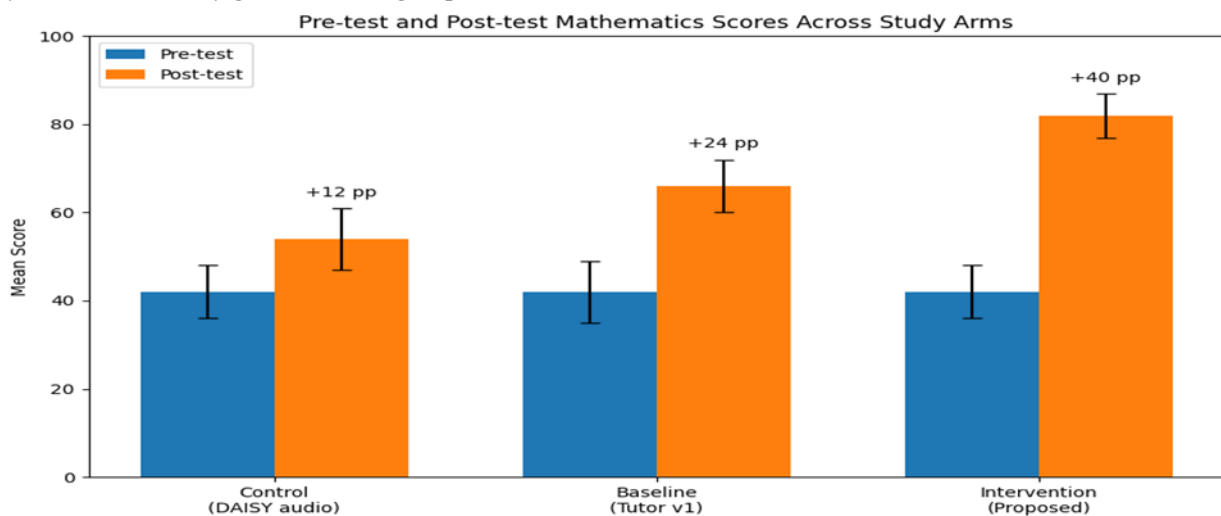


Figure 3. Comparison of mathematics assessment outcomes by study arm at the end of the eight-week pilot ($n = 30$ blind and low-vision learners).

3.2 Gains by Learning Dimension

A dimension-wise analysis of the assessment offers a direct response to the second research question. The intervention arm gained more than the baseline arm on every dimension, but the differential was largest on the three dimensions identified in the literature as hardest for B/LV learners: conceptual understanding (+20 percentage

points over baseline at post-test), verbal explanation of reasoning (+28 pp), and transfer to novel problems (+25 pp). Self-reported confidence rose in parallel (+22 pp). Numerical fluency rose less dramatically (+16 pp), consistent with the observation that procedural fluency is already reasonably supported by existing accommodations. Table 1 reports the dimension-level pre/post differences.

Table 1. Pre/post percentage-point gain by learning dimension and arm.

Learning dimension	Control gain (pp)	Baseline gain (pp)	Intervention gain (pp)
Numerical fluency	+15	+28	+44
Conceptual understanding	+9	+19	+39
Verbal explanation	+8	+19	+47
Transfer to novel problems	+10	+19	+44
Self-reported confidence	+18	+33	+55

3.3 Learner and TVI Acceptance

Mean acceptance was 4.6 / 5 from learners ($n = 20$ in the two tutor arms combined; $SD = 0.5$) and 4.5 / 5 from TVIs ($n = 12$; $SD = 0.5$). Learners and TVIs converged on the highest-scoring items—

comprehensibility and learner independence—but diverged informatively: TVIs gave the highest ratings on classroom feasibility (4.6) and curricular alignment (4.4), reflecting their professional

appraisal of where the system would fit in their planning.

3.4 Qualitative Themes

Three major qualitative themes emerged from learner and TVI responses. The first theme was recovered learner agency, where visually impaired learners reported a stronger sense of independence in doing mathematics. Many learners expressed that they could understand problems more quickly and attempt them without waiting for continuous teacher support; as one twelve-year-old learner stated, “पटकन कळत” (“it becomes clear quickly”).

The second theme was **mother-tongue access to mathematical reasoning**. Both learners and TVIs observed that learning mathematics in Marathi improved not only access to content but also conceptual understanding. TVIs noted that students who could previously repeat mathematical steps in English were now able to explain the reasoning behind procedures, including concepts such as the Pythagorean theorem, in their own language.

The third theme that came through clearly was that the tutor worked as an assistive support rather than as a replacement for the teacher. The teachers of visually impaired students (TVIs) shared that the tutor cut down the time they used to spend reading textbook questions out loud, which freed them up to focus on the more meaningful parts of teaching. One TVI captured this shift nicely when she said, “now I am the mathematics teacher, not the reader.” At the same time, both learners and TVIs were careful to point out that the system should be seen as something that supports classroom teaching, not something that takes the place of it. This was felt to be especially important when a student is meeting a new concept for the very first time, where the presence and judgement of a human teacher still matters most.

4. Discussion

4.1 Interpretation of Findings

The first research question asked whether a voice-first, offline, mother-tongue tutor could lead to real mathematics gains for blind and low-vision learners. The findings suggest that it can. The tutor produced

a Cohen's d of 1.94 when compared with the audio-textbook group, and 0.91 when compared with the earlier version of the tutor itself, both of which point to large and meaningful improvements.

The second research question asked whether these gains were limited only to procedural fluency, that is, simply being faster or more accurate with calculations. The findings show that this was not the case. In fact, the biggest improvements appeared in conceptual understanding, verbal explanation of reasoning, and transfer to new problems. These are exactly the three areas that the special education literature has long identified as the hardest for blind and low-vision learners to access through the usual classroom accommodations (Beal & Rosenblum, 2018). This pattern lines up well with what the Universal Design for Learning framework predicts, which is that when learners are given multiple ways to take in information and have more control over how they engage with it, their understanding of the underlying ideas deepens, rather than just their speed at solving problems improving (CAST, 2018).

The third research question asked how learners and TVIs themselves felt about the system. Both groups gave strong, positive feedback. Learners rated the system highest on how easy it was to understand and on how much it helped them work on their own. TVIs, on the other hand, gave the highest ratings on how well the system matched the school curriculum and how practical it was to use within a regular classroom setting.

4.2 Implications for Theory, Practice, and Policy

From a theoretical standpoint, the findings of this study lend support to the idea of bringing together Universal Design for Learning and mother-tongue mathematics teaching. The improvements seen in this study, especially in how learners explained their reasoning aloud, fit well with the argument made by Setati and Adler (2000), who pointed out the conceptual difficulties that arise when mathematics is taught in a language that is not the learner's own.

In terms of practice, the system gives blind and low-vision learners something they have long been denied, which is independent access to grade-level

mathematics. This is a direct contribution to the goals laid out in the Expanded Core Curriculum (Hatlen, 1996). It also changes the nature of the work done by teachers of visually impaired students. Instead of spending most of their time reading textbook problems out loud, they are able to focus on the deeper teaching tasks that actually require their professional expertise. For families, the fact that the system runs offline and can be used at home is significant, because it means children can practise at their own pace without needing a parent who is fluent in mathematics or in English.

On the policy side, the design fits within three important frameworks that overlap with one another. The first is Article 24 of the United Nations Convention on the Rights of Persons with Disabilities (United Nations, 2006). The second is India's Rights of Persons with Disabilities Act of 2016. The third is the National Education Policy 2020 (Ministry of Education, 2020), which clearly supports both mother-tongue instruction and the use of assistive technology. Equally importantly, the system has been designed to work on inexpensive hardware that is well within the reach of most schools, making large-scale deployment a realistic goal rather than a distant one.

4.3 Limitations

While the findings are encouraging, the study has several limitations that need to be acknowledged.

The First is the short length of the intervention. The study ran for eight weeks, which means the results only show short-term gains. To know whether the learning sticks over time, follow-up assessments would need to be carried out at six months and again at twelve months.

The second is the limited range of mathematical topics covered. At present, the system only deals with basic arithmetic and the Pythagoras theorem. Topics such as fractions, decimals, algebra, and more advanced geometry have not yet been added or tested in the field.

The third is the limited generative capability of the system. Marathi Ganit Shikshak deliberately uses fixed and carefully controlled explanation patterns, in order to make sure the answers are accurate and

the language stays clear. However, this also means the system cannot yet produce highly varied or personalised explanations for each learner.

The forth limitation has to do with voice recognition. How well the system performs can depend on things like background noise, the way the learner pronounces words, how clearly they speak, and the quality of the microphone being used.

The fifth is that the study did not separate out the impact of each part of the system. For instance, it is not yet known how much of the improvement came from the better voice synthesis and how much came from the improved way of generating explanations. A factorial study in the future would be needed to look at these effects independently.

5. Conclusion

This paper has presented the design and the mixed-methods evaluation of an offline, voice-first mathematics tutor built for blind and low-vision learners studying in Marathi-medium schools. The system is rooted in Universal Design for Learning, the Expanded Core Curriculum, and the wider sociocultural literature on mathematics education. Over an eight-week period, learners using the system showed mathematics gains of 40 percentage points, which is significantly higher than the gains seen in the audio-textbook group and the group using the earlier version of the tutor. What is particularly meaningful is that these improvements were strongest in conceptual understanding, verbal reasoning, and the ability to apply learning to new problems, which are exactly the areas where blind and low-vision learners usually face the greatest difficulty. Both learners and teachers responded positively to the system.

Looking ahead, future research will explore how the system can be extended to other Indian languages such as Tamil, Bengali, and Kannada. It will also look at how the system can be combined with tactile graphics through a co-design process with learners and teachers, and how the use of the system at home affects families and parents. In the end, the gap this research is trying to close is not a gap of ability or capacity in learners themselves. It is a gap of access, and it is one that can be closed.

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