



## Modernizing Vocal Schooling: Impact of Training Devices and Software Tools



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### Abstract

*As time progresses, traditional music is undergoing significant transformations in various aspects. One such crucial aspect is the method of schooling. The Guru-Shishya (teacher-disciple) tradition of learning is evolving with the advent of modern technological opportunities available now a days. Among these, vocal trainer devices and software stand out to be notable innovations. This paper explores various Raspberry Pi-based projects and Python algorithms that are designed to assist vocal students. It demonstrates how an Raspberry Pi-based device can effectively help a vocal student in improving his/her pitch accuracy. The research also includes the development of Software applications that support music learners in fine-tuning their pitch and improving timing- both of which play a key role in singing. Challenges and limitations of these projects are discussed in the Conclusion section.*

**Keywords:** Vcal Schooling, Guru-Shishya Tradition, Vocal Trainer Devices, Software application.

### Research Paper

#### Introduction

Carnatic music is regarded as one of the greatest forms of Indian classical art. Tracing its roots through Sama Veda, where hymns were shaped into melodic patterns, it has grown into a vast forest of knowledge and divinity. Over time, works like Sangita Ratnakara by Sarngadeva enriched this tradition, offering detailed insights into theory, performance, and pedagogy (Shringy 1003-1005). Rooted in devotion, discipline, and a strong teacher-student connection, these traditions have blossomed across centuries guiding countless generations of musicians and learners. They emphasize personal transmission of knowledge, where student learns by observing, repeating and correcting under the direct guidance of guru. However, as years passed and modernity emerged, this system of pedagogy began facing some limitations (Ramanathan 102-117).

#### Research Problem

Students today are facing difficulties in accessing experienced gurus due to geographical distances, time constraints and an increased demand for individual attention. Moreover, independent practice is also becoming difficult as they lack real time feedback to

identify and correct the faults they are making while singing. These conditions define the central problem addressed in this study. To address these challenges, this research proposes an innovative approach through vocal training software tools and hardware devices. The focus is on developing such tools and demonstrating their role in complementing the Guru-Shishya system without attempting to replace it (Srivaralaxmi and Uma Maheswari 21).

#### Objectives of the Study

Main objectives of this research are as follows:

- To develop a vocal training software using Python and Dart to assist vocal students.
- To design and implement a Raspberry Pi based device that helps in guiding learners and practitioners, thereby reducing dependence on mobile phones.
- To evaluate the effectiveness of these tools with learners and practitioners at different levels of expertise.
- To examine the role of such technology in complementing the Guru-Shishya tradition by enhancing opportunities for self-practice.

## Hypothesis

It is hypothesized that students using simple and affordable technologies like vocal trainer devices and software in their vocal practice will demonstrate measurable improvements in pitch accuracy, timing, and confidence compared to the those who don't use them.

Following evidence strengthens this view:

A 2024 study in Membrane Technology Journal found that students taught with a hybrid of traditional and digital methods showed greater improvisation, rhythm skills, and engagement compared to those using only conventional approaches (Singh 145-158).

## Relevance of the Study

This study holds significance for multiple reasons:

**Pedagogical Relevance:** It proposes a solution that bridges the gap between traditional and modern methods of schooling.

**Accessibility:** It makes quality training more accessible to the students of diverse backgrounds and reduces dropout rates among beginners who may otherwise feel discouraged by slow progress.

**Cultural Preservation:** It ensures continuity of Carnatic Music, especially among younger generations by providing supportive tools during practice.

**Societal Impact:** By encouraging systematic and technology-supported learning, it builds cultural engagement among working professionals and students with limited time.

## Research Methodology

The research methodology adopted in this study is two-fold: software development and hardware prototyping, both designed to complement the traditional Guru-Shishya system in Indian Classical music training. The software component revolves around the development of the NAADA ABHYAS application, while the hardware component involves of developing a Raspberry Pi-based vocal trainer device.

## Technologies Used

- **Python:** Python is a high-level programming language created by Guido van Rossum in 1991. Its known for its simplicity and versatility. It is widely used in data analysis, artificial intelligence, and audio processing, making it ideal for building the base functionalities of this project. Additionally, Python served as the

primary language for programming the Raspberry Pi (Sandhya et al. 1855-1861).

- **Dart:** Dart, developed by Google in 2011, is a programming language optimized for building fast and scalable cross-platform applications. It is widely used with the Flutter framework to create mobile and desktop apps, making it suitable for developing the NAADA ABHYAS.
- **Raspberry Pi:** The Raspberry Pi is a low-cost, credit-card-sized computer, launched by the Raspberry Pi Foundation in 2012. Its ability to connect with microphones, speakers, and LCDs made it suitable for creating our hardware prototype of the vocal trainer. It supports multiple programming languages, with Python being the most commonly used (Mathe et al.).

## Foundation and approach

This research evolved from a series of Python-based projects developed to address specific challenges in vocal training. Over time, these scripts were refined and unified into a single platform. They were later restructured in Dart, forming the fully integrated application NAADA ABHYAS.

In parallel, a hardware prototype was built using the Raspberry Pi. This step was inspired by the idea of offering a distraction free learning device which can work without the constant interruptions of mobile phones and laptops.

## Software Development – NAADA ABHYAS Application

The software component of this research culminated in the creation of an application named Naada Abhyas developed using Dart and supported by Python-based algorithms at its core.



# Naada Abhyas

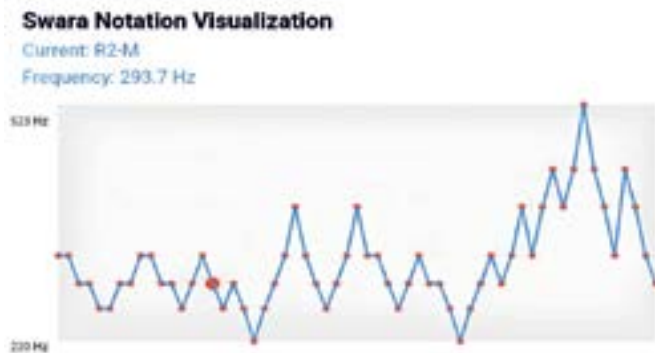


The name Naada Abhyas signifies “the devoted practice undertaken to truly understand and experience the essence of Naada”.

The application has many features that can help both learner and practitioner in various ways. Below are the key functionalities developed and integrated into the application

### Notation to Swara Graph Generator

To make the learning experience more interactive, the application includes a Swara Graph Generator. This module converts a given Carnatic music notation into a synchronized audio–visual output. Alongside the playback of the notation, the system generates a frequency vs time graph, dynamically highlighting the current note being played along with its frequency value.



The figure above illustrates the swara graph of the pallavi part of the Mohana Varnam- Ninnu Kori, generated by the swara graph generator in Naada Abhyas.

A notable feature is the ability to customize the scale, swaras, and tempo for generating any notation, though Bhashanga ragas with Anya swaras are not yet supported. The tool also allows specifying details like sthaya (octave), kaalam (speed), and extension, following traditional notation practices. By integrating notation, sound, and frequency graphs into one module, it offers a holistic learning environment for students and practitioners of Carnatic music

### Notation to Live Tala video Generator

The application introduces another innovative tool that converts notation into synchronized videos showing tala beats along with the audio of the notation played in background.

This helps students who struggle with maintaining tala by offering visual guidance while they sing. Learners can practice directly with the generated video, ensuring they stay in rhythm while also focusing on pitch. Like the Swara Graph Generator, it supports customization of

scale, swaras, and tempo, with the added feature of tala selection. In this way, by integrating notation, sound, and tala, it enables learners to achieve both rhythmic balance and pitch accuracy together.



The figure above illustrates the third kriya of Aadhi Talam video generated for the Sarali swaras, by the Tala video generator in Naada Abhyas.

### Carnatic Swara visualizer

To make the learning experience more interactive, Naada Abhyas includes a Swara graph visualizer. This feature plots a frequency vs. time graph, with swaras labeled on the y-axis. As the student sings, the graph dynamically displays the sung pitch relative to the tonic along with the corresponding frequency.

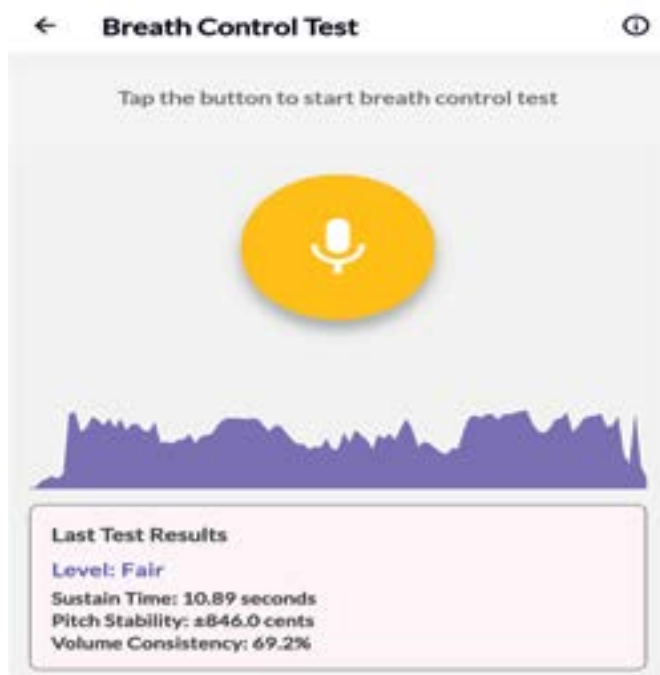


A notable feature is that the user can customize the scale according to their requirements. In this way, it provides clear visual feedback that helps learners improve pitch accuracy and gain confidence while singing.

The figure above illustrates the swara visualization of the arohana part of Mayamalavagowla raga sung by the user, generated by the Swara visualizer in Naada Abhyas.

### Breath Monitoring system

Naada Abhyas also features a Breath Monitoring System that helps learners strengthen their breath control, which is one of the most vital aspects of Carnatic music. The system records the user's voice and estimates sustain time, pitch stability, and volume consistency. This enables students to observe how steady their notes are and how long they can hold them, thereby encouraging regular practice to improve stamina and control in singing.



The figure above illustrates the output of Breath monitoring functionality of Naada Abhyas.

### Additional Features

Several additional features are integrated into the application, including Scale Finder, Pitch Shifting with Correction, and Swara Finder. As these are also implemented in the Raspberry Pi-based device, their detailed explanation is provided in the hardware section.

In essence, Naada Abhyas unifies multiple functionalities such as swara visualization, notation-to-graph and tala

video generation, breath monitoring, and pitch correction into a single, learner-friendly platform. To enhance accessibility, we are in the process of publishing the Naada Abhyas app on the Google Play Store, making these advanced practice tools available to students and practitioners worldwide. This step elevates the research from a prototype stage to a practical, deployable platform that can directly benefit the learning community.

### Hardware Development – Raspberry Pi Vocal Trainer Device

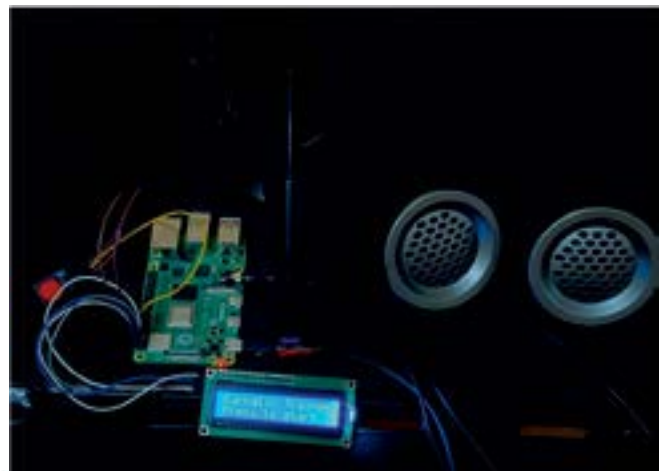
While software applications provide powerful functionality, reliance on mobile phones or laptops can sometimes be distracting for students. To address this, a Raspberry Pi-based hardware device was developed as a dedicated, distraction free vocal trainer.

#### Hardware setup

The hardware prototype integrates both processing and interactive elements to deliver an efficient and user-friendly system.

It consists of:

- **Raspberry Pi 4 Model B:** Serves as the central processing unit, handling audio analysis and correction. It functions as the “brain” of the device.
- **Microphone:** Captures the learner's singing input and delivers it to the Raspberry Pi for analysis.
- **Speaker Output:** Provides real-time playback of tonic sounds and corrected audio generated by the Raspberry Pi.
- **16×2 LCD Display:** Displays instructions and detected swaras instantly, ensuring better user interaction.
- **Push Buttons:** Enable mode selection, navigation, and playback control.



The figure above illustrates the hardware prototype of the vocal trainer device.

Similar to the software application the Vocal Trainer device also offers key features that support music learners and practitioners in improving their vocal skills.

Some of those key features are:

### Real-Time Swara Detector

To provide the learners with an instant feedback, the system incorporates a real-time swara detection module. Firstly, it allows the user to select the scale they are willing to practice and then it plays the tonic selected by them. After playing the tonic, it instructs the user to start singing and when the user starts singing it captures the audio and analyzes the frequency of the audio. Based on this frequency, the corresponding Carnatic swara is identified and displayed instantly on the LCD screen.



The figure above illustrates the result produced by the Vocal trainer device when the user sung SA Note in C scale with a frequency of 134.3Hz.

A notable feature of this functionality is that, in addition to the swara, the device also displays the frequency value, the corresponding Western note, and the octave, giving learners a more comprehensive understanding of their pitch accuracy.

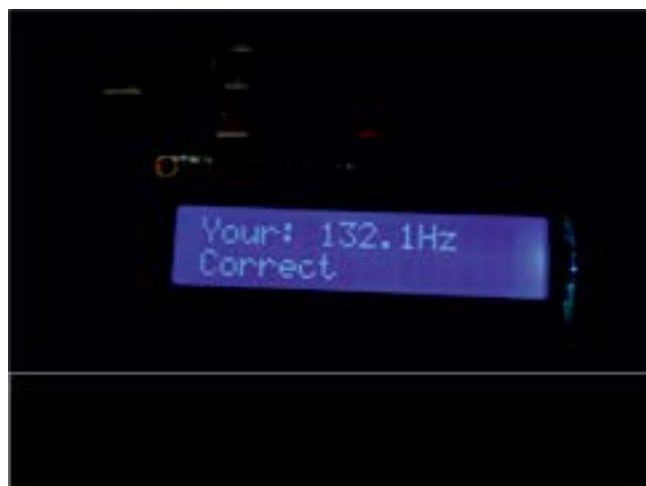
### Pitch Shifter and Corrector

Another significant functionality of the device is the pitch shifting and correction module. When a student sings slightly off-pitch, the system automatically detects the deviation and shifts the note to the nearest correct frequency.

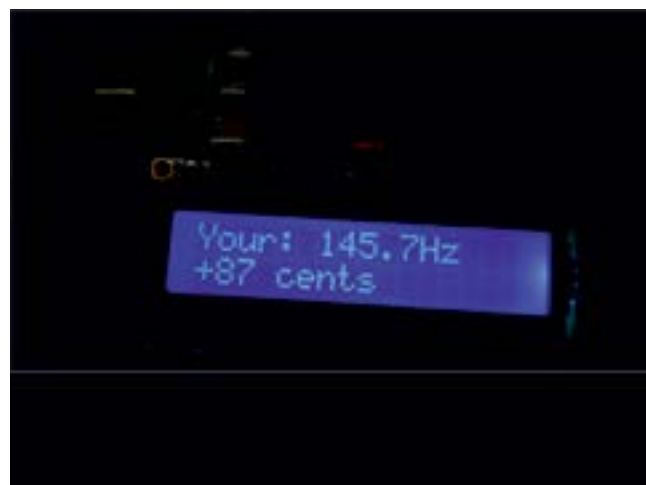
Similar to the swara detector, the process begins by asking the user to select the scale they wish to practice. Additionally, the user specifies the target swara. The

device then plays the selected note and prompts user to reproduce it. If the sung pitch matches the target frequency, the device confirms the correctness by displaying a “Correct” message along with frequency sung on the LCD screen. However, if the pitch deviates, the system instantly shifts the user’s audio to the accurate frequency of the corresponding octave.

This unique feature allows learners to hear the correct note in their own voice, creating a personalized feedback loop. By listening to their corrected voice output, students can better perceive the intended pitch and gradually learn to replicate it with improved precision. In this way, the module not only identifies errors but also actively guides the learner towards achieving accurate swara matching.



The figure above illustrates the result produced by the Pitch Shifting and Correction functionality of the Vocal Trainer device when the user successfully matches the target pitch.



The figure shows the Vocal Trainer’s pitch correction result when the user misses the target note, displaying



the sung and required frequencies, their difference, and the corrected playback.

### Additional Features

Along with these key features the system also includes supportive functionalities such as Scale estimator, breath monitor, and this can also be used as the Tanpura box and metronome too.

In summary, the hardware implementation transforms the software-based concept of Naada Abhyas into a self-sufficient physical training tool.

The research methodology adopted in this work brought together both software and hardware approaches to create a comprehensive system for Carnatic music training.

### Discussion

This research demonstrates how integrating software and hardware can transform Carnatic music training into a more interactive and learner-friendly process. The Naada Abhyas application provided digital support through swara visualization, notation playback, and breath monitoring, while the Raspberry Pi-based Vocal Trainer device extended these capabilities into a physical prototype, offering instant feedback and practical engagement. Together, they bridge the gap between traditional pedagogy and modern technology.

### Challenges and Limitations

Despite successful integration of software and hardware for Carnatic music learning, the research faced certain challenges and limitations:

- **Real-Time Accuracy:** Achieving precise swara detection and pitch correction in real time is challenging due to variations in voice quality, background noise, and microphone sensitivity.
- **Feature Constraints:** Some advanced aspects of Carnatic music, such as handling Bhashanga ragas, Gamakas are not yet supported in the current system.
- **Hardware Limitations:** The Raspberry Pi device, while efficient, has processing constraints that may limit performance when handling complex audio tasks simultaneously.
- **Testing Scope:** The system has not yet been extensively tested across a wide group of learners, so its effectiveness across varying skill levels remains to be validated.

### Future Scope

There are several promising directions for advancement. Machine learning can also be employed for more accurate and effective results. Supporting the Bhashanga ragas, Gamakas will broaden musical coverage. Cloud enabled tracking of student progress can further personalize training. Publishing the Naada Abhyas application on platforms such as Google Play Store will make the tool more accessible to learners worldwide. Additionally, structured evaluations with students and teachers will help validate pedagogical effectiveness and guide refinements.

### Conclusion

In Conclusion, this research has presented a holistic approach to complement the traditional pedagogy of Carnatic music. It advances the method of training by combining both software and hardware solutions, thereby bridging the gap between conventional learning methods and modern technological tools. While the current work establishes a strong foundation, it also highlights the need for further testing and refinement to maximize accuracy and usability. Importantly, the integration of technological tools into music education, as demonstrated here, holds significant potential in enhancing learning experiences, preserving cultural authenticity, and inspiring future innovations in the field of Carnatic music training.

### Acknowledgement

This work was carried out collaboratively by a team of students from RGUKT Srikakulam. While I guided the overall design and integration of the project by developing the core Python algorithms, building the backend of the Naada Abhyas app, and completing the Raspberry Pi-based Vocal Trainer device, the collaborative effort of my team members made the work more grounded in practical Carnatic music learning.

S. SAI SANTHOSH (4th year, ECE) led the application build, integrating modules into a cohesive, user-friendly interface.

S. U. P. S. SIREESHA (3rd year, ECE) contributed to interface design and assisted with Raspberry Pi hardware wiring.

P. JEEVAN SRINIVAS (3rd year, CSE) conducted systematic testing of features and validated the generated outputs.

B. CH. S. S. V. AKASH (4th year, ECE) supported device assembly and the collection of demonstration



evidence (figures, recordings, and logs).

Together, these contributions ensured that the system is both technically strong and pedagogically relevant for learners and practitioners of Carnatic music.

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