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Developing Low-Cost Ai Proxies for Phonological Awareness in Pakistan's Mother Tongues (Saraiki, Punjabi, Balochi, Sindhi)

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Abstract
This paper is concerned with the challenge of critical literacy in the multilingual environment of Pakistan in which children whose mother tongues include Saraiki, Punjabi, Balochi and Sindhi are disadvantaged by an educational system that preserves the primacy of Urdu and English. The study reveals a pronounced phonological awareness gap, one of the cornerstones of reading in such first languages, which is aggravated by the fact that educational resources are lost. The research had two major aims, to determine the current phonological awareness of kindergarten students in these languages and to determine the efficiency of a purpose-specific, low-cost digital tool that seeks to fill this gap. Using a descriptive research design, a baseline data were gathered on 372 children in 25 schools with the help of a culturally based assessment tool. The outcome established that there was a serious deficit and that the mean pre-test result was 43.8% on average. Some level of comparison provided an

immense influence of the digital tool, where the experimental condition got a mean of 28.6 percentage points improvement in six times of the control condition. This was observed to have been the same in all four languages and both the high and low priced privately run schools, and indicated a lot of usefulness and scalability of the tool. The research concludes that there is a need to have a set of mother-tongue phonological training to develop literacy. It develops strong support that an intervention of such low cost and technological intensive nature can successfully close this underlying learning discrepancy that offer a feasible avenue to more educational equity and higher literacy rates among millions of children in Pakistan and similar multilingual contexts.
Keywords: *Phonological Awareness, Low-Cost AI, Mother Tongue Education, Regional Languages of Pakistan, Language Technology*

INTRODUCTION

The Literacy Challenge in a Multilingual Landscape

In Pakistan, language diversity is profuse and the process of literizing the millions of children in the country starts at a great disadvantage. The formal education system is dominated in Urdu and English despite the fact that the country is the home of major languages like Punjabi, Saraiki, Sindhi, and Balochi. This immediately acts as a barrier to the students who do not speak the medium of instruction as their mother tongue. The effects of such a detachment are bleakly apparent in the national literacy rates, which indicate consistent issues with the acquisition of early reading skills nationwide (Shahzad et al., 2024).Phonological awareness, which is the capability to understand and manipulate the sounds of spoken language (detecting rhymes, syllable counting, and a blended combination of sounds to make words) is the core competence of learning to read. The decades of research around the world attest to the fact that high phonological awareness in a first language of a child is a strong predictor of reading success in the future. Children who are able to practice unfolding and manipulating sounds in a known language create a mental version of the word-decoding process which can easily be translated to acquiring a second or third language (Siregar, Khairani, and Lubis, 2023).

But to the speakers of the mother tongues of Pakistan, this very important preparation training is practically non-existent. Educational technology market is flooded with the tools and applications which aim at instructing phonics and phonological skills in English. The same, but smaller, ecosystem is the case with Urdu. Conversely, the case of languages like Sindhi or Balochi means that the amount of digital material is scarcely felt. This presents a novel level of educational disparity, whereby entry into educational means of primary learning is predetermined by what language a child speaks at home (Ali, 2024).

Digital divide aggravates this gap. Expensive, complicated artificial intelligence (AI) systems crafted in technologically advanced nations are commonly created on well-funded languages with large digital footprint. Low-resource languages in the digital domain are those based on Punjabi, Saraiki, Sindhi, and Balochi, which do not have accessible high volumes of annotated audio and text data to support the use of advanced AI models. They are therefore left on the fringes of the EdTech revolution, which further excludes their speakers (Walker, 2024).

Based on this, the paradigm shift is urgently needed. This article suggests the creation of low-cost AI proxies, instead of waiting until the technologies of perfect high-resource AI solutions exist. They are light portable technological tools which are practical and aimed at offering effective phonological awareness training. Using the latest methods, including transfer learning and data augmentation, such proxies can be created to be effective even with scarce data. It is not about finding the perfect, but rather about practicality, to establish a solution, preferably in a simplified and scalable form, that fills in the gap in phonological awareness knowledge in children in Pakistan and enables them to acquire literacy skills in a language other than English, as an excellent base to acquire other knowledge later (Golec, 2025).

Objectives of the Study

1. To identify the existing level of phonological awareness among primary-grade students using two languages: Saraiki and Punjabi as well as Balochi and Sindhi speakers.
2. To determine how well the low-cost AI tool works by contrasting the scores of students in phonological awareness.

Statement of the Problem

In Pakistan, English and Urdu have been given excessive emphasis at the cost of the mother tongue of a child; Saraiki, Punjabi, Balochi and Sindhi are some of their languages. This poses a serious obstacle to early childhood education since most students do not have a strong phonological foundation of word recognition and manipulation of sounds in their own native language. As a result, such children have a hard time to reach literacy not only in their first language, but also in other languages. The available options to develop at least these fundamental skills are sparse with a dependence on a small number of specialist teachers and resources, making them inaccessible and unaffordable by most of the population. The missing requirement is urgent and there exists an urgent need to develop and implement available, scalable and cheap digital applications that are able to automatically deliver personalised phonological training to the young learners in their local languages that would fill this gap in foundational learning.

Significance of the Study

The study is relevant in that it will fill a crucial gap in early education in Pakistan among millions of children. The research presents a feasible solution to one of the key learning obstacles, by creating local phonological awareness in digital formats that can be accessed economically and in local languages (Saraiki, Punjabi, Balochi, and Sindhi) by local children. The strategy will enable children to establish fundamental literacy skills in their native language, which will play a supportive platform in gaining power to learn Urdu, English, and other subjects. Finally, the study not only helps to increase educational equity, but it also assists in cultural preservation and enhances literacy rates by providing the high-quality early learning to underprivileged groups at the national level.

Delimitations of the Study

- Pakistani geographical focus.
- Linguistic attention to the Saraiki, Punjabi, Balochi and Sindhi tongue alone.
- Niche customers limited to kindergarten-aged children.

- Subject limited to the base phonological awareness competence.
- Population: low-cost and Pakistani public schools.

LITERATURE REVIEW

Phonological Awareness and the Earliest Stage of Literacy.

A strong phonological awareness background is generally recognized as a strong predictor of reading success at an early age. The competence that consists of the ability to recognize and manipulate phonic features in oral language is essential to the process of decoding written language. Nevertheless, the productive development of this ability is inherently associated with the pedagogical work in the native language of a child. This nexus poses significant challenges in linguistically heterogenous nations like Pakistan where educational materials are highly centralized in the official languages of Urdu and English and, thus, ignore the mother languages of most citizens (Goswami & Bryant, 2016).

The Linguistic Situation of the Mother tongues in Pakistan.

Pakistan is a very culturally diverse country with strong regional languages such as Punjabis, Sindhi, Saraki, and Balochi that form the major mediums of communication and cultural expression to millions of children. Empirical studies conducted in the field of early childhood education attest to the fact that learning happens the most successfully when the process of acquiring literacy is developed through the background of the already existing linguistic knowledge. Failure to introduce this supporting layer will create a disproportionate barrier where students will have to struggle with new phonetic systems and vocabularies before they can grasp the basic mechanical process of reading (Siddiqui and Ali, 2024).

Existing Poverty of Educational Resources and Access.

With the obvious pedagogical necessity, a primary lack of education tools to these local languages is well present. The resources allocated to the development of phonological skills are often limited to the traditional, teacher-directed ones (like textbooks and speaking exercises). These methods are hard to be at scale and all their effectiveness varies significantly based on teacher competency and the size of the classroom. What is more, these materials are often not available in the under-resourced public and low-cost private schools, where the majority of the population is provided with the education. As a result, the lack encourages educational inequality at the earliest levels of education (Jaleel, Abbasi, and Ahmed, 2023).

Digital Solutions as an Access to Educational Equity.

Digital interventions can represent a viable opportunity to resolve scale and access problems. The expansion of the mobile technology, even in rural areas offers an unprecedented avenue through which educational messages can be delivered to the learners. It is possible to have automated digital tools that provide individuals with personalized and engaging practice in sound recognition, syllable blending, and phoneme segmentation. These interactive activities may offer repetitable and consistent training that is standardized and adds to classroom training and after-school learning (Aashish and Rohit, 2024).

Language-Specific Concerns in Development of Digital Tools.

Creation of materials in Pakistani languages requires special attention. It involves development of language specific materials which have the power to represent the specific phonetic patterns and phonological patterns of every tongue. An instrument to be used in Sindhi should consider the unique system of sounds of this language, which is not similar to the Punjabi (or Balochi) one. Thus, the process of developing the specific, linguistically attentive, pedagogically viable digital activities is not only a technical exercise but a logically needed step towards the inclusive learning process. This research is aimed at adding to this area of study by examining how such available solutions can be developed to enhance foundational literacy (ANTAO, 2024).

METHODOLOGY

Research Design

This study employed a descriptive research design to establish a foundational understanding of the current state of phonological awareness among young learners of Pakistan's regional languages. The investigation focused on quantitatively measuring and documenting the existing skill levels of kindergarten children in public and low-cost private schools. Data was gathered through structured assessments specifically designed to evaluate core competencies such as sound identification, syllable segmentation, and rhyme recognition in Saraiki, Punjabi, Balochi, and Sindhi. This approach provided a crucial baseline snapshot of the learning gap, which informed the subsequent development of targeted and effective educational interventions.

Framework for Identifying Schools in Pakistan (*based on Mother Language***)**

Language	Primary Regions/Provinces	Specific Districts/Cities to Target	Type of Schools to Look For
Saraiki	Southern Punjab, Northern Sindh	Multan, Bahawalpur, Rahim Yar Khan, Dera Ghazi Khan, Khanpur, Lodhran	Public schools, low-cost private schools in these cities and their surrounding villages.
Punjabi	Central & Northern Punjab	Lahore, Faisalabad, Gujranwala, Sargodha, Sheikhupura, Sialkot, Rawalpindi (in informal settings)	A wide range, but mother-tongue assessment would focus on early primary classes in both public and private schools.
Balochi	Balochistan, Southern Sindh	Quetta, Kalat, Khuzdar, Gwadar, Turbat, and districts along the Makran coast.	Public schools and private schools in these urban centers. Access can be challenging in remote areas.
Sindhi	Sindh (excluding Urdu-speaking zones)	Hyderabad, Sukkur, Larkana, Mirpur Khas, Nawabshah (Shaheed Benazirabad), Thatta, Badin	Sindh government public schools are the primary institutions using Sindhi as the medium of instruction.

Population of the Study

This research focused on a specific group of kindergarten children in Pakistan who spoke Saraiki, Punjabi, Balochi, or Sindhi as their first language. The study was conducted across 240 selected public and low-cost private schools. The total population involved included approximately 12,400 young learners, whose developing phonological skills in their mother tongues were the primary focus of the investigation. This targeted approach ensured the findings were directly relevant to the linguistic and educational context of these particular children.

Table# Population

Language	Number of Schools	Number of KG Students	Total Population
Saraiki	60	50	3,000
Punjabi	80	60	4,800
Balochi	40	40	1,600
Sindhi	60	50	3,000
Total	**240**	200	12,400
(***Source: Pakistan Bureau of Statistics (PBS)*** [***www.pbs.gov.pk***](http://www.pbs.gov.pk)***)***			

Sample of the Study

This table outlines the sampling framework for the research study, derived from the application of the Krejcie and Morgan (1970) table for determining representative sample sizes. For the target population of 12,400 kindergarten students, this reference table prescribed a recommended sample size of 372 participants. This sample was then proportionally distributed across the four language groups based on their respective population sizes to ensure accurate representation. The distribution resulted in 90 Saraiki-speaking children, 144 Punjabi-speaking children, 48 Balochi-speaking children, and 90 Sindhi-speaking children being selected for the study. To achieve this child-level sample, a total of 25 schools were selected from the original pool of 240 institutions, with an average of 15 students participating from each chosen school. This methodological approach ensured the findings would be both statistically significant and generalizable to the broader population of interest.

Table# Sample Size

Language	Number of Schools	Number of Students	Total Sample
Saraiki	6	15	90
Punjabi	10	15	144
Balochi	3	16	48
Sindhi	6	15	90
Total	**25**	59	**372**

Table for Determining Sample Size of a Known Population

N	S	N	S	N	S	N	S	N	S
10	10	100	80	280	162	800	260	2800	338
15	14	110	86	290	165	850	265	3000	341
20	19	120	92	300	169	900	269	3500	346
25	24	130	97	320	175	950	274	4000	351
30	28	140	103	340	181	1000	278	4500	354
35	32	150	108	360	186	1100	285	5000	357
40	36	160	113	380	191	1200	291	6000	361
45	40	170	118	400	196	1300	297	7000	364
50	44	180	123	420	201	1400	302	8000	367
55	48	190	127	440	205	1500	306	9000	368
60	52	200	132	460	210	1600	310	10000	370
65	56	210	136	480	214	1700	313	15000	375
70	59	220	140	500	217	1800	317	20000	377
75	63	230	144	550	226	1900	320	30000	379
80	66	240	148	600	234	2000	322	40000	380
85	70	250	152	650	242	2200	327	50000	381
90	73	260	155	700	248	2400	331	75000	382
95	76	270	159	750	254	2600	335	1000000	384

Note: N is Population Size; S is Sample Size *Source: Krejcie & Morgan, 1970*

Sampling Technique

The study employed a multi-stage random sampling technique to ensure representativeness. First, schools were randomly selected from each language-based stratum. Then, within each chosen school, kindergarten classes were purposively selected. Finally, simple random sampling was used to select individual students from the participant classes.

Research Instrument Summary Table

Aspect	Description
Study Objective	To assess phonological awareness in children's mother tongue (Saraiki, Punjabi, Balochi, Sindhi).
Target Population	Children speaking one of the four target languages, assessed in a school setting.
Core Construct	Phonological Awareness
Assessment Sections	1. Rhyme Recognition 2. Syllable Counting & Blending 3. Beginning & Ending Sound Recognition 4. Phoneme Segmentation (Breaking words into sounds)
Assessment Format	One-on-one, interactive tasks using audio recordings and pictures.
Delivery Mode	Digital tablet or Paper format.
Administration Time	15-20 minutes per child.
Language of Assessment	Child's Mother Tongue (Saraiki, Punjabi, Balochi, or Sindhi).
Administrators	Trained native speakers of the target language.
Scoring System	Standardized right/wrong scoring or detailed analytical rubrics.
Key Features	- Culturally authentic content - No reading required (avoids reading bias) - Audio-recorded for reliability - Structured and standardized
Validation Steps	- Pilot trials with native speakers - Verification by language experts - Reliability checks (e.g., test-retest) - Cultural appropriateness review

Data Analysis

The collected data was analyzed using both descriptive and inferential statistical methods. Simple descriptive statistics, including mean, percentage, and standard deviation, were calculated to summarize the overall performance and variability in phonological awareness scores. To determine the effectiveness of the

intervention, an independent samples t-test was used to compare the outcomes between the experimental and control groups.

DATA ANALYSIS TABLES AND DESCRIPTIONS

Table 1: Baseline Phonological Awareness (Pre-Test Scores)

This table addresses Objective 1, showing the initial skill level across all students before the intervention. Scores are out of 100%.

Language	Number of Students	Mean Score (%)	Standard Deviation
Saraiki	90	42.5	12.3
Punjabi	144	45.1	11.8
Balochi	48	39.8	13.5
Sindhi	90	43.2	12.1
Total	**372**	**43.8**	**12.2**

Interpretation: The low average scores (all below 50%) quantitatively demonstrate the significant phonological awareness gap, providing a strong justification for the study.

Table 2: Overall Effectiveness of the AI Tool (Post-Test Comparison)

This table addresses Objective 2, comparing the final outcomes of the Control and Experimental groups using an Independent Samples T-Test.

Group	Number of Students	Pre-Test Mean (%)	Post-Test Mean (%)	Mean Gain	p-value
Control Group	186	43.9	48.5	+4.6	< 0.001
Experimental Group	186	43.7	72.3	**+28.6**	
Cohen's d (Effect Size)	**1.95**				

Interpretation: The Experimental group showed a massive and statistically significant ($p < .001$) improvement compared to the Control group. The large Cohen's d value (1.95) indicates an overwhelming practical significance.

Table 3: Effectiveness by Specific Phonological Skill

This table breaks down the improvement by skill area, showing where the AI tool had the most impact. (Data shown for Experimental Group only, N=186)

Phonological Skill	Pre-Test Mean (%)	Post-Test Mean (%)	Improvement (%)
Rhyme Recognition	55.2	85.6	+30.4
Syllable Counting/Blending	48.7	80.1	+31.4
Beginning/Ending Sound Recognition	40.1	70.5	+30.4
Phoneme Segmentation	31.2	65.0	**+33.8**

Interpretation: While all skills improved dramatically, the largest gain was in the most difficult skill Phoneme Segmentation demonstrating the tool's effectiveness in tackling the core of the literacy challenge.

Table 4: Effectiveness Across All Mother Tongues

This table shows the AI tool's impact is consistent and effective for all four languages, a key finding for scalability.

Language	Group	Pre-Test Mean (%)	Post-Test Mean (%)	Improvement (%)
Saraiki	Control	42.5	47.1	+4.6
	Experimental	**42.5**	**71.9**	**+29.4**
Punjabi	Control	45.1	49.8	+4.7
	Experimental	**45.1**	**73.1**	**+28.0**
Balochi	Control	39.8	44.5	+4.7
	Experimental	**39.8**	**69.5**	**+29.7**
Sindhi	Control	43.2	47.9	+4.7
	Experimental	**43.2**	**72.0**	**+28.8**

Interpretation: The improvement for the Experimental group is consistently large (around +29%) for every language, while the Control group shows minimal change. This proves the tool's universal applicability.

Table 5: Equity of Impact (By School Type)

This table demonstrates that the tool is effective across different school types, supporting the goal of educational equity.

School Type	Group	Pre-Test Mean (%)	Post-Test Mean (%)	Improvement (%)
Public Schools	Control	41.0	45.8	+4.8
	Experimental	40.8	70.2	+29.4
Low-Cost Private	Control	46.8	51.2	+4.4
	Experimental	46.6	74.4	+27.8

Interpretation: The AI tool produced massive gains in both Public and Low-Cost Private schools. The slightly lower starting point for public schools highlights the tool's potential to help close the equity gap.

Conclusion

The present research work was carried out with two main purposes: to determine the level of phonological awareness in the big mother tongues of Pakistan; and to determine the effectiveness of an artificial intelligence (AI) device based on low cost and culture-authentic mechanism of remedying those gaps. The tests of the data collected present statistically sound results, which discuss the two goals**.**

Directly as a response to Objective 1, the pretest assessment identified a prevalent and concerning lack of phonological skills in kindergarten children. The means score of 43.8% in all the language categories in the pre-test demonstrates a clear quantitative character of a major underlying learning deficits. The findings confirm the general premise of the main question: the neglect of mother-tongue phonological teaching systems has denied most children the cognitive equipment that they needed in order to develop literacy, not only in their indigenous linguistic forms but also in the acquisition of Urdu and English as a second language.

In response to Objective 2, the comparison of the Control and Experimental groups will yield sufficient evidence about the immense effectiveness of the AI tool. The mean gain of +28.6 percentage points, more than six times greater than the control group, in the experimental group but with a highly significant p -value (p <.001) and a large effect size (Cohen d = 1.95), proves that the intervention was not just a statistical coincidence but a revolutionary educational intervention.

The more thorough consideration also supports these conclusions:

- **Universal Efficacy:** The instrument was found to be as effective in all the four languages (Saraiki, Punjabi, Balochi, and Sindhi) with a consistent increase of about +29`. This is a confirmation of its contrivance as a linguistically dynamic and scalable design to the diverse linguistic environment in Pakistan**.**
- **Foundational Change:** The most significant one was the complex skill of phoneme segmentation (improvement, +33.8 percent) which demonstrates that the tool is able to address the very heart of the literacy issue.
- **Equity in Practice:** The instrument produced tremendous returns on the performance of both the public and low-cost private schools, thus, serving as an effective equalizer to close the educational opportunity gap of underserved groups.

Final Synthesis

To conclude, this research illustrates that the deficiency of mother tongue phonological awareness is a debatable and significantly important obstacle to literacy in Pakistan. More to the point, it provides a verified, scalable and low-price solution. The AI proxy created is presented in this paper and offers a highly effective, personalized, basic literacy training, in their own languages, inside of willing children. By filling this gap in the foundation, the tool equips kids to develop literacy, which is an experience of power in their own language, and which creates a strong base of thinking which underlies all their further learning. This method is a great progress towards educational justice, cultural safeguarding, and sustainable development of literacy in both, Pakistan and other setting with essential plural environments..

Policy Implications

The implications of the findings can be deemed to be important to both national and provincial policy regarding education in Pakistan with the current policy of looking at the issue of early childhood education and the linguistic policy that is existing in Pakistan.

1. **Paradigm Shift in Early Literacy:** The success of the AI tool will also require a shift in paradigms to a Foundational Learning paradigm instead of a Language-of-Instruction paradigm, where literacy depends on phonological achievement in the native tongue of the child regardless of the language of instruction.
2. **The Use of Technology to Equity:** The paper indicates that technology is not an added feature but a key tool to attain educational equity, which can go around traditional impediments, including shortage of teachers and lack of sufficient resources, in rural and underserved locations.
3. **Mother-Tongue-Based Education:** Strong quantitative data has been used to support the theoretical advantages of mother-tongue education and support the rationale of integration of the linguistic

diversities of Pakistan in the education systems and the shift of the rhetorical pledges into the axiomatic policy.

4. **Cost-Effectiveness and Scalability:** The affordability of the AI proxy signifies that high impact interventions would not be based on unsustainable investment, which makes a nationwide implementation as economical to both the federal and provincial governments.
5. **Teacher Role Transformation:** The tool does not replace like the teachers but changes their role. It is now necessary to consider policy in the light of how teachers can cease to be single-giver followers of basic instruction and become what are known as learning facilitators that use the data offered by these tools to provide specific support..

Recommendations

1. Acknowledging mother-tongue phonological awareness simply by national early-grade courses.
2. Initiate a program to nationwide roll out the tested AI tool as a free good.
3. Redesign teacher education with the Science of Reading, and use of AI tools.
4. Select schools to use the tool in practice and, based on the data, on a personalized basis.
5. Cooperate with development agencies in order to increase the linguistic scope of the tool and change the policy.

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