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IMPACT OF TECH-ENABLED AUDIO-TACTILE AID IN TEACHING IMPORTANT HISTORICAL PLACES TO CHILDREN WITH VISUAL IMPAIRMENT

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SUMMARY

This paper discusses how an audio-tactile learning aid is made more effective through technology, enhancing children with visual impairments' knowledge of historical sites. Conventional teaching and learning methods that include verbal descriptions and Braille usually do not provide sufficient spatial and contextual understanding, and thus limit effective learning experiences in history. To close the gap, the current study proposes a multisensory intervention combining tactile representations with an audio sequence. A quasi-experimental pre-test and post-test design was adopted, with 40 students with visual impairments from both special and inclusive schools in Coimbatore, Tamil Nadu, participating. The intervention was centered on the sampled historical locations, and standardized knowledge tests were used to measure learning outcomes. Paired sample t-tests showed that statistical analysis showed significant improvements in all variables at the 0.01 level. An example is that the mean female students' scores were 38.67 (SD = 2.497) in the post-test compared to 18.90 (SD = 3.032) in the pre-test ($t = 26.04$), and the same thing was in male students, who scored 40.79 (SD = 2.371) versus 22.37 (SD = 5.047) ($t = 21.69$). In the same way, students in inclusive schools showed an increase of 21.96 to 39.48 ($t = 33.96$), which showed the high effectiveness of the intervention. Similar improvements were found within the levels of classes and locality, which validated the strength of the strategy. The results indicate that a udio-tactile supports can have a strong impact on spatial cognition, knowledge retention, and engagement of learners. The research finds that inclusion and experiential learning in history education can be facilitated by incorporating assistive technologies in learning. Nonetheless, the issues of cost, scalability, and teacher training should be considered to expand it on a wider scale.

Key words: *audio-tactile learning, visual impairment, assistive technology, inclusive education, multisensory learning, historical education, spatial cognition.*

INTRODUCTION

Inclusive education is now a global priority, and attention is being paid to ensuring that students with different abilities have equal access to educational resources. Of these, children with visual impairment struggle very hard to learn material that requires extensive visual representation, especially in subjects like history and geography. Knowledge of historical places entails the capability of seeing spatial layouts, architectural buildings, and settings of contexts, which cannot always be explained using conventional pedagogical means like verbal presentation and Braille.

Traditional teaching methods do not typically offer meaningful experiential learning for visually impaired learners, leading to minimal interaction, limited understanding, and low retention [31]. In recent years, innovations, which are assistive technologies, have presented new ways of overcoming such limitations [32]. Audio-tactile systems, a new type of system that combines audio feedback with tactile exploration, have become a potentially interesting strategy to support multisensory learning [2][5]. The systems allow users to build mental images of spatial data, thus boosting cognitive mapping and mental ideas [20].

In spite of the developed and successful application of audio-tactile technologies in areas like navigation, STEM learning, and online accessibility, their implementation in higher historical place education is a rather under-researched area, especially in school-level history in less developed areas [10][13]. This is a critical gap because cultural and historical awareness are vital in social inclusion, developing identity, and whole-person education.

To contain this problem, this paper suggests and analyzes a technology-based audio-tactile learning resource that would be used to educate children with visual impairment about key historical sites in Tamil Nadu. The study evaluates the effect of the intervention on the knowledge acquisition, engagement, and learning outcomes of students based on their demographic variables through a structured pre-test and post-test approach to the study.

This research has both information and technology value. Educationally, it is incorporated into inclusive pedagogy through the introduction of an experiential learning method that enhances access to culturally relevant learning. It also allows students with visual impairments to participate actively in learning about history, which helps them understand the historical information better, develop confidence, and self-sufficiency.

Regarding technology, the research study shows the feasibility of audio-tactile systems in actual classroom settings. This research is a validation of the effectiveness of such tools as opposed to most of the solutions available in the market, which are still in the prototype phase or in the analysis stage. Besides, the paper discusses contextual issues of the Indian education system, such as the diversity of types of schools and the availability of resources.

The policy, teacher, and assistive technology developer implications are also based on the findings that highlight the need for scalable, affordable, and user-friendly solutions in inclusive education.

The major contributions of this research are as follows:

- a multisensory educational device is a combination of a touch representation with structured audio presentations of historical sites.
- applies audio-tactile technology outside of stem fields into the field of history education, which is a less-studied field of research.
- shows the efficiency of the intervention provided by the pre-test and post-test design with a statistically significant value ($p < 0.01$).
- comparisons of learning outcomes according to gender, level of the classes, type of school, and locality give a clear picture of the effects of the intervention.
- provides a model of scaffolding assistive technologies to mainstream and special education systems.

- focusing on educating about historical sites in tamil nadu, the research made it culturally applicable and flexible towards local curricula.

The paper follows the following structure: Section 2 provides an overview of pertinent literature on the subject of audio-tactile learning and assistive technologies. Section 3 presents the proposed methodology, system design, and experimental setup. The results and analysis are discussed in Section 4. Lastly, Section 5 is the conclusion of the research and recommendations for future research.

LITERATURE SURVEY

The recent progress in assistive technologies has made a great contribution to the possibility of accessibility of people with visual impairments, especially with the creation of multimodal learning systems that combine auditory and tactile feedback. These technologies are designed to improve spatial cognition, mental mapping, and information storage, which are usually restricted in conventional learning setups [14][15][27].

A number of studies point to the effectiveness of audio-tactile systems as far as the improvement of the perception of the graphical and spatial information is concerned [17]. According to the recent research, interactive audio-tactile graphics play a significant role in promoting the capacity of visually impaired users to perceive complicated visual information [8][16]. On the same note, another research came up with a smart tactile sound system that enhances interaction with the user by responding to feedback, which can help in understanding and interacting better [11]. These results are indicative of the fact that a multi-sensory combination can counter the drawbacks of unimodal learning techniques.

The former studies in the area of navigation and spatial cognition created dynamic audio navigation interfaces, which enable people to locate items in the tactile graphics more efficiently [4][12]. This was also expanded in the study by making fully digital audio-haptic maps, where it showed enhanced spatial awareness, and the usability of such maps improved among blind subjects [3][7][23][33]. These works highlight the importance of multisensory interfaces to promote the process of mental map formation and the process of spatial reasoning [21][28].

New advances in technology that have been made in the field of tactile learning have helped in improving the process of learning as well. This study proposed the design of electro-tactile feedback capabilities to enhance the understanding of charts, whereas the research presented microcapsule-based 2.5D tactile interfaces that allow playing with graphical content interactively [15][18]. These developments point to a change towards the more dynamic and responsive tactile systems that can support advanced educational materials.

Educationally, the work had derived a convenient tutoring tool through audio-tactile graphics, and the results showed enhanced learning results in the case of visually impaired students [9]. This previous research examined remote teaching practices with the help of tactile objects and the significance of developing assistive technologies in collaboration with teachers to guarantee usability and pedagogical fit [19]. The study also examined the aspects of feedback in assistive systems and made a point about the issue of user-centered design that should be used to make learning more efficient [24].

This new study was contextualized in cultural and heritage research studies in reference to inclusive smart museum spaces that incorporate assistive technologies to attract neurodiverse audiences [1] [6]. In the same way, 3D thematic maps were rated, and another study was able to conclude that tactile interaction is important in enhancing spatial and cultural knowledge to the user [22] [25]. These experiments suggest that audio-tactile systems have the potential to be useful in transmitting historical and cultural information [26].

In spite of all these advances, there is an urgent need for the implementation of audio-tactile technologies in the teaching of history in schools, especially in the less developed world. The majority of literature is on the topics of navigation, STEM learners, or experimental prototypes, and there is little literature on curriculum-based teaching of historical sites [29][30]. Moreover, empirical research to support the use

of such tools in actual classroom environments with the involvement of various groups of learners is missing.

The analyzed literature makes it clear that audio-tactile and multimodal systems improve the spatial cognition, engagement, and learning performance of visually impaired users. Nevertheless, little research was conducted on how it can be used to teach historical and cultural material in formal education systems. In its attempt to fill this gap, this study will design and empirically test a technology-based audio-tactile aid specifically to teach historical sites to visually impaired children, thus expanding the use of assistive technologies to the study of humanities in education and making its contribution to inclusive pedagogy.

PROPOSED METHODOLOGY

The present paper presents an audio-tactile learning system based on technology and aimed at stimulating the knowledge of the historical sites by children with visual impairment. The approach combines the system design, experimental validation, and statistical analysis in order to test the effectiveness of the proposed intervention.

System Overview

The targeted system is based on the combination of tactile graphics, audio narration, and interactive input devices to establish a multisensory learning environment. The structure is created on the concept of multimodal interaction and the principles of universal design learning (UDL), which are also accessible and simple to use.

The system consists of three primary modules:

1. Content Module – Describes historical sites, spatial layouts, and descriptions.
2. Audio Module – Offers audio descriptions in a structured way when the user interacts with it.
3. Tactile Interface Module – Representing physical characteristics of historical sites in elevated surfaces and textures.

These elements combine to allow users to learn and discover the historical sites by touching and listening at the same time.

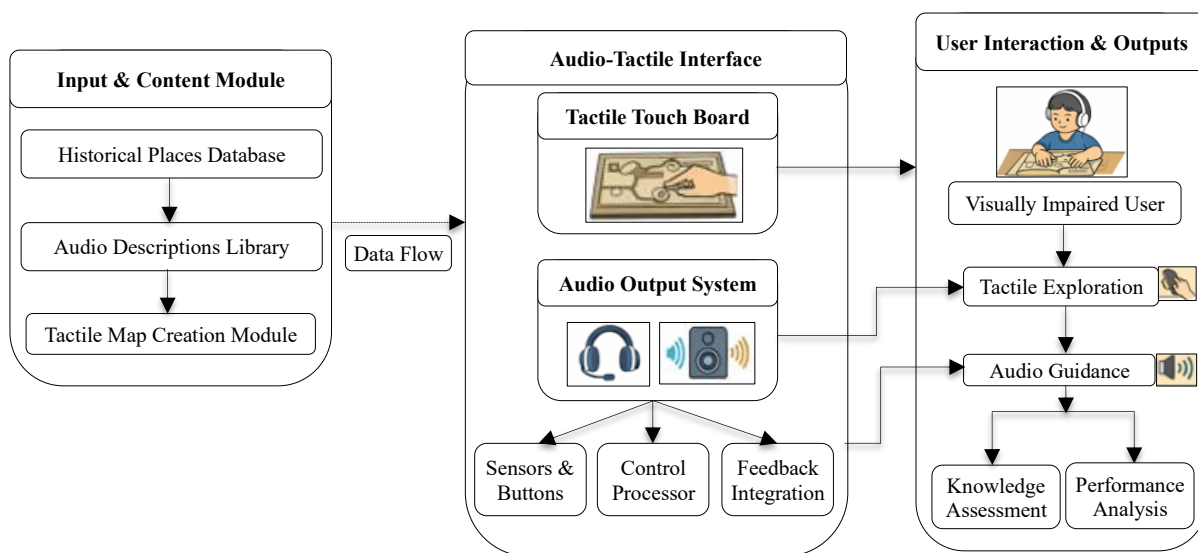


Figure 1. Architecture of the proposed audio-tactile learning system

The design of the suggested audio-tactile learning equipment that can be used by visually impaired students is demonstrated in figure 1. It is a system comprising three big modules: the Input and Content

Module, which deals with historical data and audio descriptions; the Audio-Tactile interface, which deals with the audio output by sensors and control measures; and the User Interaction Module, which deals with engaging the learners in the exploration of the tactile surfaces, including the audio guidance. The system enables multisensory interaction that results in better acquisition of knowledge and measuring performance.

Design and Development of Audio-Tactile Aid

The aim of the audio-tactile learning tool was to represent the historical places chosen in Tamil Nadu as listed in table 1, and enable the visually impaired learners to feel the spatial and contextual data by feeling two or more directions at a given moment. The design process involved the use of tactile representation, audio assistance, and interactivity. The architectural and spatial features of historical sites that had the highest significance were transferred into the realm of touch, where the embossed diagrams and the textured surfaces make people touch the physical structures with their hands. These physical characteristics were aligned with the recordings of audio data of descriptions that provided comprehensive data on the historical significance, structural aspects, and cultural background of each location. It involved an interactive feature whereby the user was enabled to touch some parts of the touchable surface to make an audio reaction and, in so doing, stimulate a self-directed and discovery-driven learning process.

Table 1. Selected historical places for intervention

Districts of Tamil Nadu	Historical Places
Coimbatore	Isha, Marudhamalai Temple
Kancheepuram	Mahabalipuram, Kanchi Kailasanathar Temple
Thanjavur	Tanjore Big Temple
Vellore	Vellore Fort
Cuddalore	Thillai Natarajah Temple
Tiruchirappalli	Srirangam Temple
Tiruvannamalai	Tiruvannamalai Temple
Madurai	Meenakshi Amman Temple

In general, it was created with simplicity and user-friendliness in mind, and in a manner such that the physical components and the audio clues had a visible and obvious mapping as well as uniformity in navigating the device, as well as interaction. This combination approach helps to provide effective cognitive processing, engagement, and independent learning among visually impaired students in learning. table 1 includes the historical sites that would be used as part of the intervention. Those were chosen based on their cultural value and the role that it contributes to the regional curriculum and enable students to learn in a meaningful and context-sensitive way.

Research Design

In order to establish the efficacy of the intervention, a quasi-experimental research design comprising a pre-test and post-test design was adopted to assess the effectiveness of the intervention.

- Pre-test: Knowledge of historical places at an assessed baseline level.
- Intervention: Contact with the audio-tactile learning device.
- Post-test: Measured knowledge acquisition after the intervention

The design may also facilitate a direct comparison of outcomes of pre- and post-system learning.

Participants and Sampling

It entailed the use of 40 children with visual impairments who were selected in special and inclusive schools in the Coimbatore district. Diversity was represented in the sample in terms of: Gender (Male/

Female), Class (Primary/Secondary), Locality (Rural/Urban), and Type of School (Special/ Inclusive). Such variation will guarantee a thorough assessment of the system among various learner profiles.

In table 2 reveals the population of the participants in different schools. The sample population of 40 visually impaired students in the special and inclusive schools, respectively, will be represented equally in each gender and the learning environment.

Table 2. Distribution of sample across schools

Name of the School	Number of Children	Boys	Girls
Govt. Blind School, Ulliyampalayam	13	5	8
Avinashi lingam Higher Secondary School for Girls, and Avinashi lingam Primary School, Coimbatore	14	2	12
Ramakrishna Mission Vidyalaya TAT Kalanilayam Middle School, Coimbatore	1	1	0
Sri Ramakrishna Vidyalaya Gurukulam Matriculation Higher Secondary School, Coimbatore	5	5	0
Ramakrishna Mission Vidyalaya Swamy Sivanandha Higher Secondary School, Coimbatore	7	7	0
Total	40	20	20

Experimental Procedure

The experiment was done in several organized phases to determine the efficiency of the audio-tactile learning tool. To start with, an orientation was arranged to introduce the participants to the tool and how it could be used. This was preceded by a pre-test to determine the historical knowledge of the students on the chosen historical places. In the intervention phase, the participants were exposed to the audio-tactile aid through the interactive sessions guided by listening to the audio descriptions synchronized with exploring the tactile maps. A post-test was done after the intervention to determine the improvement in knowledge. Also, observations and student feedback were gathered by the teachers to determine the level of engagement, usability, and general learning experience.

Variables of the Study

Table 3. Independent variables of the study

Variables	Levels
Class	Primary / Secondary
Gender	Male / Female
Locality	Rural / Urban
Type of School	Inclusive / Special

The independent variables that are to be taken into account in the study are stated in table 3. These variables were chosen to evaluate the effect of the audio-tactile intervention on various demographic and educational variables.

Statistical Analysis

To determine the efficiency of the suggested audio- tactile approach to learning, paired sample t-tests were used to compare the pre-test and post-test results of students. A significance level of 0.01 was used in order to provide a strict statistical confirmation of the results. Some of the key measures incorporated in the analysis were mean, standard deviation, and t-values, which gave information about the level and reliability of learning improvements. The form of statistical analysis will allow identifying whether these differences in performance are statistically significant and not just the result of random variation, which will prove the effectiveness and integrity of the intervention. The statistical analysis of the data conducted in SPSS and Microsoft Excel to compute the values of means, standard deviations, and paired sample t-tests was to measure the learning outcomes in a valid and dependable way.

Workflow of the Proposed System

The proposed system is designed based on a workflow that facilitates effective multisensory learning. The user selects a historical place first to tour. This is further supplemented by the aspect of touch, where the learner uses embossed maps and textures, which are characteristics of space. Relevant audio descriptions are made through touch-point interaction, and this includes contextual and descriptive information. This is complex sensory information that facilitates thinking and learning. Finally, formal testing is used to test the learning outcomes. It is a closed-loop workflow that engages its user, with the user making a direct contribution towards measurably achievable knowledge and retention improvements.

RESULTS AND DISCUSSION

The implementation and design of the proposed audio-tactile learning system consisted of a blend of both hardware-assisted methods and software tools. Sound material was composed, manipulated, and polished with conventional audio editing software, and playback was accomplished by either an in-built or external audio output unit. Digital drawing tools were used to create tactile maps that were used to depict historical sites and were embossed or handcrafted into a tactile form. The dataset to be used in this study is the primary data of 40 visually impaired students in special and inclusive schools in the Coimbatore district. It contains pre-test and post-test scores that measure the knowledge of the students about the chosen historical locations and such demographic variables as gender, level of classes, area, and the form of school. It is a quantitative and structured dataset, which allows the successful statistical comparison of the learning outcomes.

The experimental assessment was done under controlled conditions and well-defined parameters to achieve consistency and reliability. The sample size was adopted as 40 students, and the level of significance was set as 0.01 in the testing of the hypothesis. Paired sample t-tests were used to compare the outcome of the pre-test and the post-test, and the metrics to assess the outcomes were mean, SD, and t-values. It was done by conducting fixed instructional classes with the help of the audio-tactile tool, and the chosen historical locations within the state of Tamil Nadu were worked on. Equal conditions were applied to all the participants by giving them similar instructions and exposure to give the necessary conditions to conduct a performance assessment.

Gender-Based Analysis

Table 4. Pre and post-Test mean scores on knowledge of historical places with respect to gender

Variable	Level	Testing	N	df	Mean	SD	t-value
Knowledge of Historical Places (Gender)	Female	Pre-Test	20	19	18.90	3.032	26.04
		Post-Test			38.67	2.497	
	Male	Pre-Test	20	19	22.37	5.047	21.69
		Post-Test			40.79	2.371	

Significant at the 0.01 level

As shown in table 4, the scores of both male and female students on knowledge were statistically significantly improved after the intervention ($p < 0.01$). The scores of women students, 18.90 to 38.67, and those of male students, 22.37 to 40.79. The effective audio-tactile aid is seen through the high t-values (26.04 and 21.69).

Though the disadvantages of the female students were also equal, it were rather more consistent (lower SD in post-test) which presupposes that the learning outcomes were more stable. This is because it has the benefit of increased involvement and input to the multisensory system.

Type of School Analysis

Table 5. Pre and post-test mean scores with respect to type of school

Variable	Level	Testing	N	df	Mean	SD	t-value
Knowledge of Historical Places (Type of School)	Special	Pre-Test	13	12	17.62	4.114	27.34
		Post-Test			40.08	1.847	
	Inclusive	Pre-Test	27	26	21.96	3.888	33.96
		Post-Test			39.48	2.953	

Significant at the 0.01 level

As observed in table 5, both students in special programs and inclusive schools achieved a lot after receiving an audio-tactile aid. Students in special schools grew by 17.62 to 40.08, as compared to an increase of 21.96 to 39.48 in inclusive school students.

The t-value of inclusive schools (33.96) is greater, which suggests a slightly stronger impact, possibly due to their more extensive exposure to technology and differentiated learning environments. However, the fact that the post-test scores are similar indicates that the tool can be employed to fill the gap among the educational settings.

Class-Based Analysis

Table 6. Pre and post-test mean scores with respect to class

Variable	Level	Testing	N	df	Mean	SD	t-value
Knowledge of Historical Places (Class)	Primary	Pre-Test	20	19	18.15	3.438	31.02
		Post-Test			39.30	1.976	
	Secondary	Pre-Test	20	19	22.95	4.019	25.88
		Post-Test			40.05	3.170	

Significant at the 0.01 level

In table 6 reveals that the learning outcomes of the primary and secondary students have improved considerably. The primary students received 18.15 to 39.30, and secondary students received 22.95 to 40.05.

It is possible that the t-value is higher among primary students (31.02) and that, therefore, multisensory learning strategies could be more effective with younger children. It could be due to its increased dynamicity, curiosity, and receptiveness to interactive learning technologies.

Locality-Based Analysis

In table 7 and figure 2 show that there is a huge improvement among urban and rural students.

Table 7. Pre and post-test mean scores with respect to locality

Variable	Level	Testing	N	df	Mean	SD	t-value
Knowledge of Historical Places (Locality)	Urban	Pre-Test	26	25	22.60	7.240	10.33
		Post-Test			36.60	5.508	
	Rural	Pre-Test	14	13	20.28	2.920	23.32
		Post-Test			38.84	2.444	

Significant at the 0.01 level

Urban students showed an increase of 22.60 to 36.60, and the rural students showed an increase of 20.28 to 38.84. Interestingly, the t-value of rural students (23.32) was higher, which means that it had a greater relative improvement. This implies that, in a resource-limited environment where the traditional teaching aids are inadequate, the use of the audio-tactile tool is especially efficient.

The results (including all the variables) demonstrate that the proposed audio-tactile learning system is efficient in enhancing the knowledge image of the historical places among the students. The power and utility of the given intervention is proved by the observed level of statistical significance, which was observed to be significant at the level of 0.01, in all categories. The findings indicate that there is a considerable difference in the information acquired and memorized, and performance increases are sustained, irrespective of diverse demographic characteristics, including gender, grade, locality, and school type. Interestingly, it was found that the system was very effective in both special and inclusive learning environments, and its effect appeared to be larger in primary schools and rural schools.

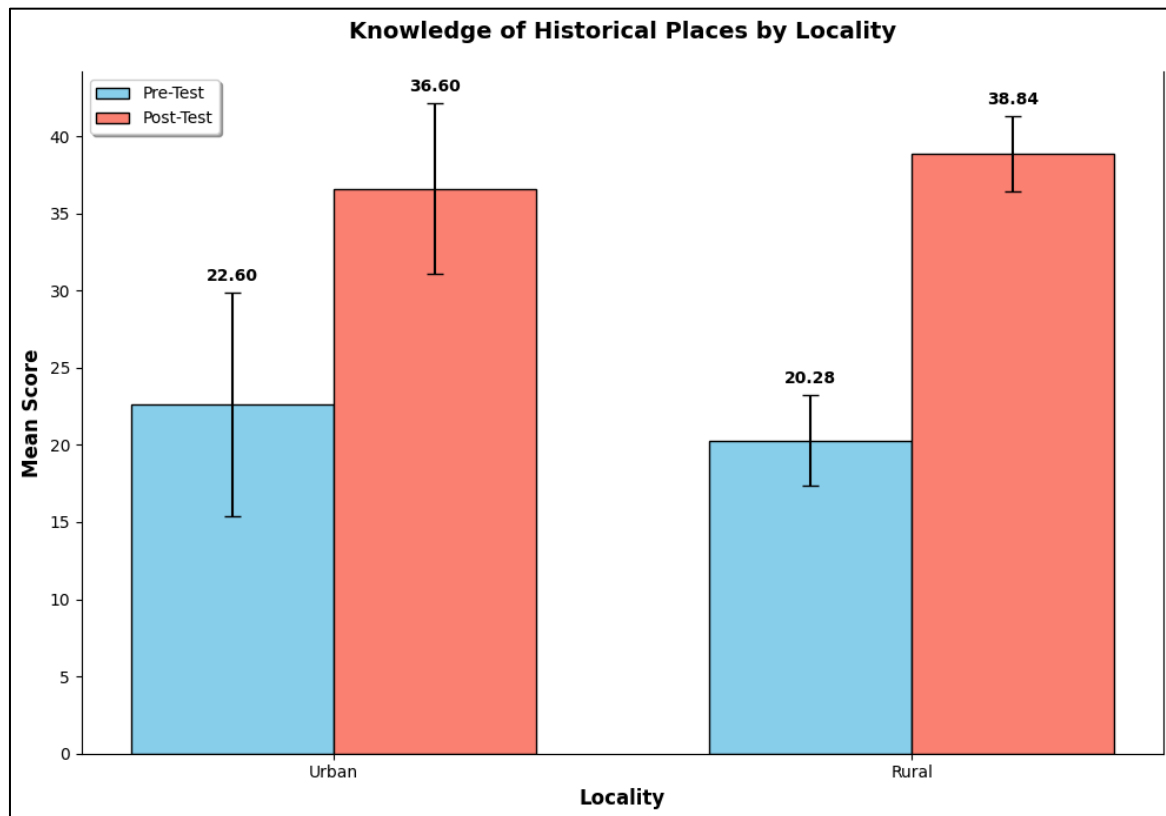


Figure 2. Comparative analysis of pre- and post-intervention knowledge scores based on locality

These findings can be related to the existing research on the topic of multisensory learning, which highlights the importance of incorporating auditory and tactile data to improve cognitive processes and the perception of space. Overall, the results support the hypothesis that using assistive technologies in humanities education may result in inclusion, engagement, and effectiveness of learning among visually impaired students.

CONCLUSION

This study analyzed how an audio-tactile learning resource supported by technology can be useful in enhancing knowledge of historical sites in children with visual impairments. Based on its findings, it is evident that the proposed multisensory strategy is far more powerful in improving knowledge, spatial knowledge and student engagement as compared to the traditional form of instruction. The t-tests on the pairs suggested that the intervention was strong, as the statistically significant changes in the post-test scores were determined to be at the 0.01 level of significance across all variables. The mean scores of the female students by 18.90 to 38.67 ($t = 26.04$) and the mean scores of the male students by 22.37 to

40.79 ($t = 21.69$) as an illustration. Similarly, the students of inclusive schools raised their score by 21.96 to 39.48 ($t = 33.96$), special school students also increased their score by 17.62 to 40.08 ($t = 27.34$). The classes analysis revealed that the gain was greater with the primary students ($t = 31.02$) compared to the secondary students ($t = 25.88$) which can indicate a greater adaptability to multisensory learning among the younger students. In addition, locality-based findings showed that there were considerable positive findings in terms of rural students ($t = 23.32$) and this proves that such technologies can be used to bridge the educational disparities. These findings highlight the relevance of the use of feel and sound in promoting cognitive processing and memory among the visually impaired learners. The study confirms that audio-tactile systems can be powerful tools of inclusive education, in particular, in the ones that require spatial and situational awareness. However, concerns such as cost, availability and teacher training are required to be conquered in order to enable massive implementation. More research should be done on the development of scalable and low-cost solutions, AI-driven adaptive audio descriptions, and investigation of the utilization of virtual and augmented reality in order to further enhance interaction in learning. It will also increase the generalizability of the findings through carrying out the study in larger and more diverse populations.

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