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Analyzing Socio-Economic Indicators to Determine Science Engagement Trends in India

Amrutha Muralidhar[1*], Muralidhar Lakkanna[2]

[1] B. M. S College of Engineering, India
[2] National Institute of Advanced Studies, IISc Campus, India
* Corresponding author: amrutham.cs21@bmsce.ac.in

Abstract: Understanding the dynamics of science engagement within a diverse socio-economic landscape like India is crucial for effective policy-making and educational interventions. In this paper, we explore science engagement in India through an analysis of demographic factors and data-driven communication approaches. Using a comprehensive census dataset covering socio-economic indicators and educational aspects, we identify population segments showing varied engagement in science. By examining the influence of socio-demographic elements, our findings reveal trends shaping preferences for science communication. Our findings emphasize the importance of customized strategies for science outreach among diverse demographic groups in India. These findings provide valuable insights for policymakers, educators, and stakeholders seeking to enhance science literacy and foster a more inclusive and equitable scientific culture in India.

Keywords: Science Engagement, Socio-Economic Indicators, Demographic Analysis, Data-Driven Approach, Science Communication.

INTRODUCTION

Engagement with science is not just a matter of personal interest; it's a cornerstone of societal advancement. Despite strides in scientific research and innovation, India grapples with disparities in science engagement across its diverse populace. While some segments exhibit high levels of involvement in scientific pursuits, others remain relatively disconnected. This heterogeneity poses a challenge for policymakers and educators seeking to promote scientific literacy and interest across the nation. To address this challenge effectively, a nuanced understanding of the underlying patterns and preferences driving science engagement is essential. This paper embarks on a comprehensive analysis of science engagement across diverse population groups in India, leveraging demographic factors and data-driven communication strategies.

Our analysis is based on a careful examination of the extensive 2011 India census dataset. This dataset provides a wealth of information on various socio-economic factors and educational metrics. We use

this dataset as a foundation to identify different population groups with varying levels of engagement in science-related activities. By analyzing demographic elements such as age, education, and occupation, our goal is to uncover significant trends that influence preferences in science communication.

The primary objective of our study is to identify and characterize distinct clusters within the Indian population based on their levels of science engagement. By leveraging K-means clustering, we aim to delineate homogeneous groups with similar socio-demographic profiles and science-related behaviors. Through this analytical approach, we seek to uncover actionable insights that can inform targeted communication strategies and educational initiatives aimed at enhancing science engagement across India. This holds significance for multiple stakeholders, including policymakers, educators, and science communicators. By elucidating the nuanced patterns of science engagement across different demographic segments, our findings can guide the development of tailored interventions to bridge existing gaps and promote inclusivity in science participation. Insights gleaned from this study can contribute to the broad-er discourse on science communication and public engagement with science, both in India and globally.

The remainder of this paper is organized as follows: Section 2 provides an overview of the methodology, detailing the process of data collection, preprocessing, and K-means clustering analysis. In Section 3, we present the findings of our analysis, including the identification of distinct population clusters and their characteristics. Section 4 discusses the implications of these findings for science communication and education initiatives. Finally, Section 5 offers concluding remarks and outlines directions for future re-search in this area.

Literature Review

Engaging diverse demographic segments in science is pivotal for societal development. In India, with its complex socio-economic landscape and cultural diversity, comprehending science engagement trends becomes particularly pertinent. This literature review synthesizes insights from various studies, shedding light on factors influencing science engagement and underlining the need for tailored strategies.

Education as a Catalyst for Science Engagement

The evolving landscape of science, technology, engineering, and mathematics (STEM) education emphasizes an integrated approach that applies academic concepts to real-world scenarios, fostering crucial skills like critical thinking and problem-solving. Early exposure to basic STEM concepts during elementary and secondary education lays the groundwork for further technical training, advanced

studies, and career development (National Science and Technology Council (2018)). This emphasis on nurturing STEM literacy and skills at an early age is universal, providing the foundational knowledge necessary for higher education and specialized technical skills in the workplace. The overarching principles of leveraging education to foster science engagement resonate universally. Nurturing STEM education serves as a critical pathway to developing a skilled workforce and creating a scientifically literate society ready to navigate the challenges posed by a rapidly changing global landscape, a central focus in India's pursuit of refined science engagement and communication strategies (National Academies of Sciences, Engineering, and Medicine (2016).

Social Disparities and Science Engagement

Social disparities, often reflecting broader disadvantage and cultural dominance, emphasize the need to address social determinants for equitable science engagement. Enhancing access, foundational literacies, and reducing socio-economic disparities are crucial for inclusive science engagement among education-ally underserved populations. Allum et al. (2018) mention how rectifying these gaps is pivotal for providing equal opportunities in science engagement, crucial for holistic societal progress. Roche et al. (2020) explore how citizen science can enhance both scientific research and education. They identify challenges such as conflicting goals and values, and also suggest aligning educational outcomes with project goals from the start, using co-creation approaches to ensure inclusivity and accessibility.

Inclusiveness and Diversity in Science Engagement

Inclusive science engagement initiatives must actively embrace and accommodate diverse perspectives, acknowledging the richness that varied backgrounds and experiences bring to scientific endeavors. With-in the intricate fabric of India's socio-economic structure, fostering inclusive science initiatives necessitates a comprehensive understanding of the multifaceted societal compositions. This involves recognizing and valuing diverse social statuses, cultural origins, genders, religious affiliations, literacy levels, and age groups. The emphasis on inclusivity extends beyond mere participation; it encapsulates an earnest endeavor to create equitable opportunities for all individuals to contribute meaningfully to scientific pursuits. Accommodating this diversity not only enriches the scientific dialogue but also enhances the relevance and applicability of research outcomes across a broader spectrum of society as covered by Paleco et al. (2021). Shrivastava et al. (2020) advocate for a fundamental transformation of sustainability science towards a transdisciplinary approach that incorporates insights from the social sciences, humanities, and the arts. They highlight the importance of this transformation in addressing the complex and interconnected challenges of global sustainability. Stinken-Rösner et al. (2020) explore how inclusive teaching methods can be applied effectively in science education. They

argue that while inclusive education and science teaching have been studied separately, there's a need to merge the two fields. Their article outlines key aspects of both inclusive teaching and science education and proposes a framework to combine them.

Public Engagement Drivers and Impact

Research on public engagement with science highlights the evolving nature of engagement dynamics and the broad spectrum of definitions associated with this concept. Weingart, Joubert, and Connoway (2021) investigate motives driving engagement rhetoric across various global regions, offering insights into the complexity of engaging diverse populations. Rodríguez-Hernández, Cascallar, and Kyndt (2020) conducted a systematic literature review to examine the relationship between socio-economic status (SES) and academic performance in higher education. They analyzed 42 studies using mixed-methods, comprising content analysis and meta-analysis. The review revealed that SES is measured through various indicators such as education, occupation, income, and neighborhood resources, while academic performance is assessed based on achievement, competencies, and persistence. The meta-analysis indicated a positive but weak correlation between SES and academic performance in higher education. In their study, Vu, Huy, Trang, and Thach (2021) look at how education in Vietnam affects society and the economy. They use history and a method called dialectical materialism to figure out what influences education in Vietnam. They find that things like Western and Eastern cultures, Buddhism, Confucianism, and the ideas of Ho Chi Minh all play a role. They explore how these factors impact education in Vietnam, especially in today's globalized world. The study also offers suggestions for keeping traditional values and solving educational problems to help Vietnam's economy grow. These suggestions might be useful for other countries facing similar challenges as Vietnam.

Reframing Science Communication

Davies and Horst (2016) propose reframing science communication research and practice. They advocate for moving away from deficit models of communication (viewing the public as lacking scientific knowledge) toward dialogue-based approaches that foster mutual understanding and engagement.

METHOD

This study relies on a robust dataset extracted from the 2011 India census (Registrar General and Census Commissioner of India (2011)), encompassing a wide array of socio-economic and educational indica-tors. This dataset includes vital demographics such as population metrics, gender distribution, literacy rates, and socio-religious details. It delves into educational facets from primary to higher education and encapsulates household-level amenities like internet access.

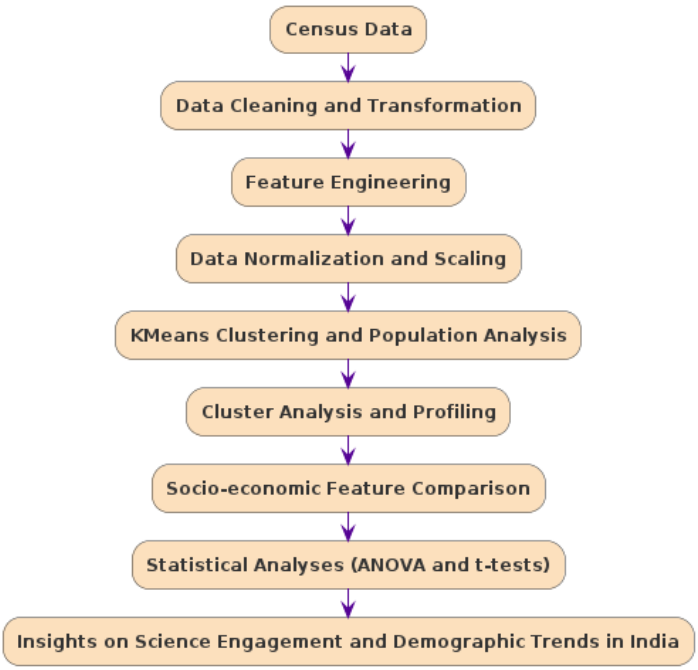

Figure 1. Data Processing and Analyzing Process

Our methodology revolves around meticulous data preprocessing, encompassing rigorous cleaning and feature selection to ensure the reliability of our analysis. Leveraging KMeans clustering, we aim to pin-point distinct population clusters showcasing varying levels of science engagement. Through cluster pro-filing, we juxtapose socio-economic features in clusters exhibiting high science engagement against those demonstrating lower engagement levels. This meticulous comparison aims to uncover nuanced patterns and disparities across demographic segments, shedding light on the intricate interplay between socio-economic factors and science engagement.

To validate our findings, we employed statistical analyses, including ANOVA (Analysis of Variance) and t-tests. These tests aim to confirm differences among the identified clusters, reaffirming the profound influence of socio-economic factors on science engagement within disparate population segments.

By employing these rigorous methodologies illustrated in Figure 1, our study seeks to present a comprehensive understanding of science engagement among diverse demographics in India. It endeavors to uncover pivotal trends in science communication, shedding light on the nuanced dynamics shaping science involvement across varied population segments.

RESULTS

Our clustering analysis revealed three distinct clusters, with Cluster 0 exhibiting the highest mean science engagement and Cluster 1 displaying the lowest as presented in Figure 2 and Figure 3. Within Cluster 0, a higher presence of attributes related to literacy, education access at various levels, better household infrastructure, urban settings, and technological amenities correlates with a stronger inclination towards science engagement. This suggests that a combination of educational access, household conditions, and technological exposure plays a vital role in fostering scientific curiosity and engagement within this cluster.

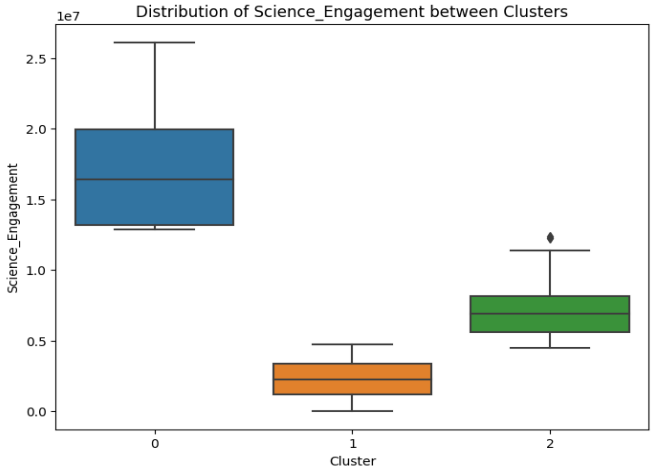

Figure 2. Distribution of Science Engagement Between Clusters

While cluster 1 shows least science engagement, potentially due to disparities in education quality, rural household prevalence, household infrastructure challenges, gender and socioeconomic disparities, and cultural influences. Addressing these issues through targeted educational improvements, infrastructural development, socio economic upliftment, and cultural inclusivity initiatives could elevate science engagement within this cluster. Correlation of attributes with science engagement in clusters 0 and 1 is shown in Figure 4.

Table 1. Statistical Analysis of Cluster 0 and 1

ANOVA for Science Engagement	T-Test between Clusters 0 and 1
F-Statistic: 1568.282072244985	T-Statistic: 39.601541286230066
P-Value: 1.2342467832251809e-147	P-Value: 1.2342467832253118e-147

Our statistical analyses provided substantial evidence supporting these findings. The ANOVA test indicated a highly significant difference in science engagement among these clusters, signifying distinct

science involvement patterns. The T-test conducted between Clusters 0 and 1 further emphasized this difference, displaying a considerable T-statistic value and an extremely low p-value, indicating a significant contrast in science engagement between these clusters.

We also found a stark contrast in science engagement levels between different regions. Northeastern states and islands like Lakshadweep and Andaman and Nicobar exhibit lower science engagement, while Tamil Nadu, Karnataka, Maharashtra, and Andhra Pradesh demonstrate higher engagement. This disparity emphasizes the need for targeted science communication strategies tailored to specific regional contexts. By acknowledging and addressing these regional differences, tailored outreach efforts can effectively elevate science engagement, ensuring more inclusive and effective initiatives across diverse geographical segments (Demanet & Van Houtte (2014).

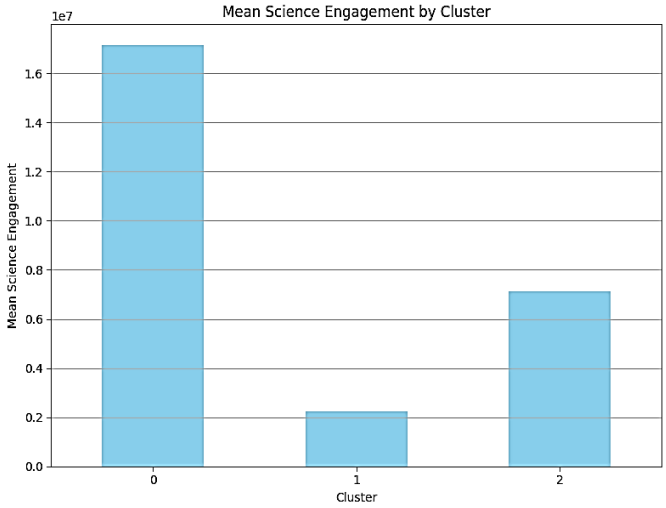

Figure 3. Mean Science Engagement by Cluster

Through our analysis, which delves into the impact of socio-demographic factors, we unveiled compelling trends that distinctly mold preferences for science communication. Our exploration has shed light on the crucial role of tailored strategies in science outreach initiatives aimed at diverse demographic groups across India. These findings spotlight the necessity for personalized approaches in science communication efforts. These customized strategies can effectively address the nuanced preferences and engagement levels observed within varying demographic segments (Grabau, 2016).

Therefore, the insights gleaned from this analysis not only substantiate the significance of socio-demographic factors but also underline the pivotal need for strategic customization in science outreach endeavors (Fredricks, Blumenfeld, & Paris (2004). This emphasis on tailored approaches holds the potential to enhance the effectiveness and resonance of science communication efforts among diverse demographic groups across India.

DISCUSSION

Our analysis reveals intriguing patterns in science engagement among diverse demographic clusters in India. These clusters, characterized by varying levels of engagement with science-related activities, highlight the intricate interplay of socio-demographic influences on individuals' interests. Notably, Cluster 0 emerges with the highest mean science engagement, indicating correlations with specific socio-demographic attributes. While Cluster 1 showed the least science engagement. The statistically significant disparities highlighted by ANOVA and T-tests between Clusters 0 and 1 reinforce the pivotal role of socio-demographic aspects in shaping science engagement. This underscores the need for efforts to tai-lor science communication strategies based on demographic considerations.

Our analysis indicates that gender-based disparities in science engagement were not prominently observed within both Cluster 0 and Cluster 1. This finding challenges the assumption of significant gender-driven differences and suggests a more inclusive approach to science outreach programs, transcending gender-specific initiatives. Individuals without access to fundamental amenities such as computers and internet connectivity exhibited notably lower levels of engagement. This observation signals a need for targeted outreach strategies aimed at bridging the digital divide, ensuring equitable access to scientific knowledge and opportunities.

It is evident that a uniform science communication approach might not yield optimal outcomes. The distinct preferences observed across different demographic segments underscore the necessity for tar-geted and culturally attuned communication initiatives. Recognizing these nuanced preferences can guide the development of strategies that resonate more effectively with diverse audiences (McCallie et al., 2009).

Generalizability of Findings

Given the diversity of socio-economic landscapes within India, the generalizability of our findings hinges on several factors:

Similar Socio-Economic Profiles: If other regions or countries exhibit socio-economic profiles like those observed in the demographic clusters analyzed in our study, there's a greater likelihood that the findings can be generalized.

Meta-Analyses and Comparative Studies: Synthesizing findings from multiple studies across different regions or countries can provide a broader understanding of science engagement dynamics.

Cross-Cultural Validity: While cultural nuances influence science engagement, certain broad patterns may transcend cultural boundaries. If the socio-demographic factors identified as influential in our study, such as access to technology or educational attainment, are salient across diverse cultural contexts, these findings may have broader applicability.

By considering these factors and conducting further research that explores science engagement dynamics in diverse socio-economic contexts, we can enhance the generalizability of our findings and contribute to the development of effective science communication strategies on a broader scale.

Recommendations for Enhancing Science Engagement

Policymakers, educators, and stakeholders can utilize the insights from this analysis to enhance science literacy and foster a more inclusive scientific culture in India through several specific recommendations:

Tailored Outreach Programs: Develop science outreach programs that are tailored to the socio-economic characteristics and regional disparities identified in the analysis. For example, focusing on improving access to fundamental amenities like computers and internet connectivity in regions with lower engagement levels can help bridge the digital divide and enhance science participation. For instance, The Prime Minister's Special Scholarship Scheme (PMSSS) aims to build up capacities in the youth of Jammu & Kashmir by providing educational opportunities and empowering them to compete in the mainstream (Government of India, 2024). Similar schemes can be provided to larger demographic people.

Targeted Communication Initiatives: Recognize the diverse preferences observed across different demographic segments and regions. Implement targeted and culturally attuned communication initiatives to effectively engage various population segments in science activities. This might involve utilizing local languages, incorporating culturally relevant examples, and collaborating with community leaders to in-crease outreach effectiveness.

Investment in Education Infrastructure: Prioritize investments in education infrastructure, particularly in regions with lower science engagement levels. This could include improving school facilities, increasing access to quality education, and providing resources for hands-on science learning experiences.

Support for Science Education: Support for science education should encompass programs and initiatives spanning all educational levels, from primary to higher education. This approach includes promoting STEM education, facilitating teacher training programs, and creating opportunities for hands-on learning experiences in science. Existing schemes like the Sir C V Raman Scholarship, designed to encourage and support meritorious students pursuing science education at the undergraduate level, offer a platform for expansion. By increasing outreach efforts, policymakers can ensure that students from all socio-economic backgrounds have equal opportunities to pursue their academic aspirations in science (Karnataka Government, 2019).

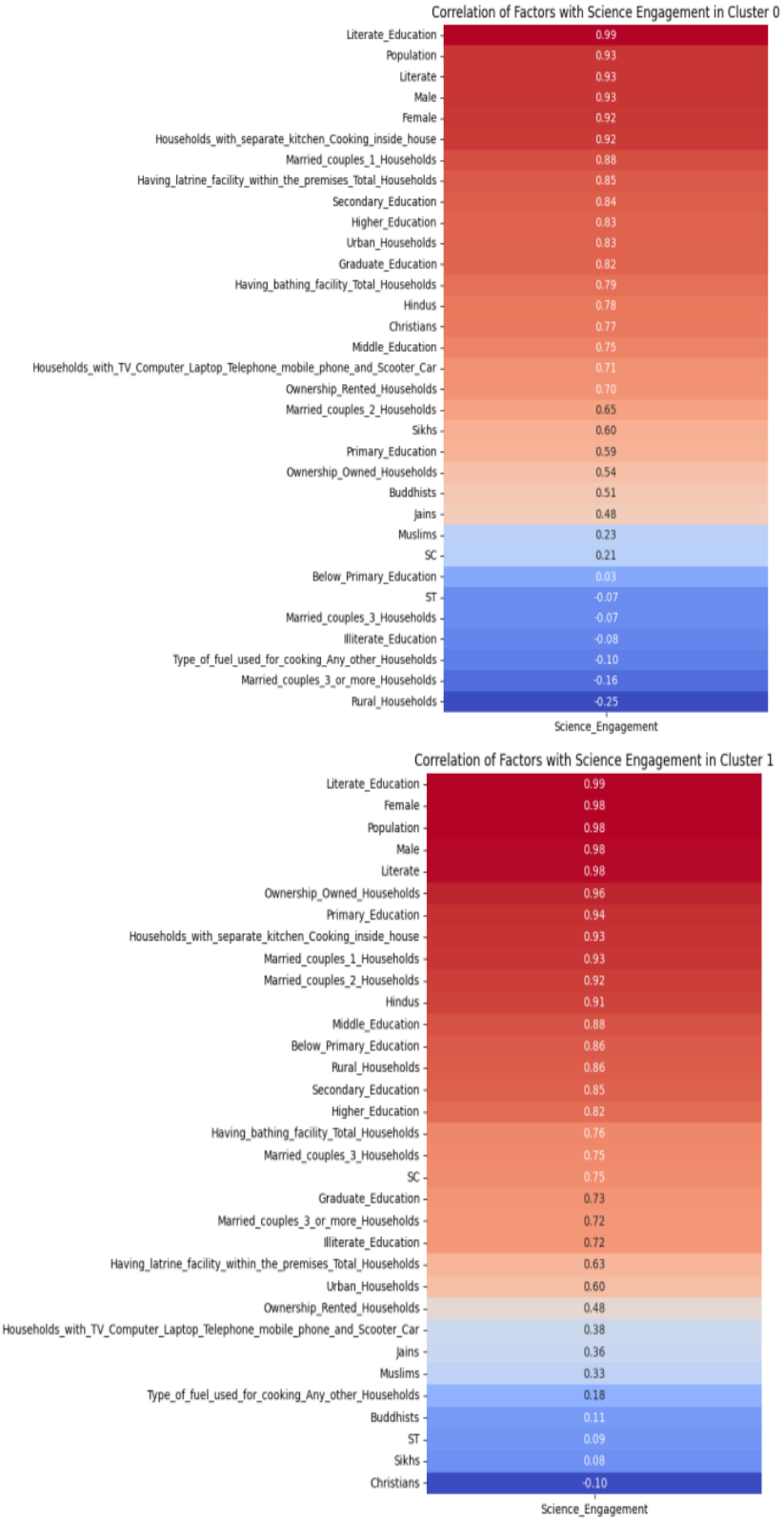

Figure 4. Correlation of attributes with science engagement in clusters 0 and 1

Regional Development Initiatives: Implement targeted regional development initiatives to address disparities in science engagement. This could involve promoting scientific research and innovation hubs

in underrepresented regions, incentivizing scientific institutions to establish branches in these areas, and fostering collaborations between academia, industry, and government to promote scientific development.

By implementing these recommendations, policymakers, educators, and stakeholders can work towards building a more inclusive and equitable scientific culture in India, ultimately contributing to the nation's socio-economic development and global competitiveness in the field of science and technology.

Limitations and Constraints

Despite our efforts, there are limitations and constraints inherent in our analysis that warrant consideration:

Data Age: The dataset utilized in this study is derived from the 2011 India census. While it provides a comprehensive snapshot of socio-economic indicators at that time, the socio-economic landscape may have evolved since then. This temporal gap could affect the current applicability of our findings and their relevance to present-day science engagement trends.

Limitations in Socio-Economic Indicators: While the census dataset covers a broad range of socio-economic indicators, there may be other relevant factors influencing science engagement that were not captured in the dataset. For instance, cultural attitudes towards education and science, access to science communication platforms, and regional variations in science infrastructure could play significant roles but might not be adequately represented.

Sampling Bias: The census data represents a large-scale population sample, but it's essential to recognize the possibility of sampling bias inherent in any large-scale survey. Certain demographic groups or regions may be overrepresented or underrepresented in the dataset, potentially skewing the analysis results

CONCLUSION

Our comprehensive analysis of science engagement across diverse demographic clusters in India reveals the nuanced impact of socio-demographic factors on individuals' interest in science-related activities. Notably, infrastructure facilities and urban settings significantly correlate with heightened science engagement, particularly within Cluster 0. These findings emphasize the need for tailored, contextually sensitive science communication strategies that resonate with specific demographic profiles. The statistical significance highlighted between clusters underscores the crucial role of socio-demographic considerations in shaping science engagement levels. Moving forward, further exploration of underlying mechanisms and additional socio-demographic variables will deepen our understanding. In advocating for tailored, culturally sensitive science communication strategies, our study resonates with the imperative of fostering widespread engagement and enduring interest in scientific pursuits

across the multifaceted landscape of India. Such nuanced approaches hold the potential to bridge disparities, amplify inclusivity, and ignite enduring curiosity for science among diverse demographic profiles. As we stride forward, continued exploration and fine-grained analyses will refine our strategies, nurturing a vibrant scientific eco-system for all.

Computational Details

All computations and analyses were conducted using the Python programming language, utilizing libraries such as Pandas for data manipulation, Scikit-learn for machine learning and clustering, and Matplotlib/Seaborn for data visualization. The computational tasks were executed on a standard computational environment capable of efficiently managing the substantial volume of census data and facilitating the clustering process.

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