Smart Libraries and Makerspaces in School and College Libraries: Innovations, Challenges, and Their Role in Empowering a Viksit Bharat 2047

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Abstract

Purpose: This study explores the current status, challenges, and transformative potential of smart libraries and makerspaces in school and college libraries, particularly within the Kolkata region, in contributing to the national vision of Viksit Bharat 2047.

Design/Method: A descriptive survey design was employed, utilizing purposive sampling, to collect data from 50 respondents, comprising librarians, teachers, IT professionals, administrators, students, and research scholars from schools and colleges. Quantitative data were gathered via a structured Google Form and supported by case studies from Atal Tinkering Lab-enabled institutions. Comparative analysis and a chi-square test were used to examine institutional differences.

Findings: The study revealed moderate smart library adoption (64% schools, 75% colleges) and limited makerspace presence (26%). No significant link was found between institution type and adoption. Key challenges included funding, staffing, and training shortages. All respondents agreed that smart infrastructure aligns with the Viksit Bharat 2047 vision.

Limitations: The sample size was limited to 50 participants within Kolkata and may not represent national trends. The study relied on self-reported data.

Practical Implementation: The findings guide institutions in planning, resource allocation, and training initiatives for future-ready learning spaces.

Originality/Value: This paper highlights grassroots-level insights into how smart libraries and makerspaces can empower students and educators to build an innovative, inclusive, and future-ready India.

Keywords: Educational Innovation, Makerspaces, School and College Libraries, Smart Libraries, Viksit Bharat 2047

1. Introduction

India's education system continues to confront entrenched inequalities, particularly along urban-rural and socio-economic divides. While metropolitan students increasingly access smart classrooms, digital libraries, and makerspaces, large segments of rural and semi-urban learners remain deprived of digital infrastructure

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and modern learning environments (Hudson, 2023). The COVID-19 pandemic further exacerbated these disparities by highlighting systemic challenges, including digital illiteracy, limited Internet connectivity, and schools lacking resources (World Economic Forum, 2020). These conditions underscore the pressing need for innovative solutions that promote equitable access and inclusion.

Smart libraries and makerspaces are transformative, redefining learning spaces. Unlike conventional libraries that primarily serve as passive repositories, smart libraries leverage technologies – including digital catalogs, cloud-based services, and artificial intelligence – to facilitate dynamic, user-centric experiences (Orji & Anyira, 2021). These libraries empower learners to access, analyze, and create knowledge interactively, fostering digital literacy and lifelong learning.

Makerspaces complement these initiatives by offering hands-on, inquiry-driven environments equipped with robotics kits, coding platforms, 3D printers, and DIY tools. These spaces help students develop 21st-century skills, such as creativity, teamwork, and problem-solving, which align with activity-based teaching methods. In India, programs such as the Atal Tinkering Lab (ATL) initiative have catalyzed the adoption of STEM education, although challenges related to infrastructure and educator preparedness persist (Smile Foundation, 2022).

National policy frameworks promote these innovations. The National Education Policy 2020 advocates transforming libraries into active learning hubs and emphasizes technology-integrated education (Smile Foundation, 2022). Concurrently, the Digital India campaign aims to enhance digital literacy and infrastructure, particularly in underserved communities. The visionary Viksit Bharat 2047 mission aspires to establish a digitally empowered knowledge society, positioning equitable education and digital literacy as foundational pillars (Kumar, 2025).

This study examines the utilization and challenges of smart libraries and makerspaces in schools and colleges within Kolkata, with a focus on institutions implementing ATL. Employing a mixed-methods approach, the research aims to provide insights and policy recommendations that contribute to India's pursuit of inclusive, technology-driven education, aligning with national goals.

2. Objectives

The study has the following objectives:

- To examine the current status and extent of implementation of smart library systems and makerspaces in school and college libraries in the Kolkata region.
- To compare the adoption, accessibility, and integration of smart technologies between school and college libraries, identifying key innovations and gaps.
- To assess the challenges, training needs, and institutional support required to effectively utilize smart libraries and makerspaces in advancing the goals of Viksit Bharat 2047.

3. Literature Review

Smart libraries signify a transformative shift through automation, personalization, and digital integration. Orji & Anyira (2021) describe the S.M.A.R.T. framework, which encompasses Service, Methods, Automation, Resources, and Technologies, covering AI assistants, kiosks, digital catalogs, and IoT systems. Despite barriers, studies (e.g., Nigeria) show improved efficiency and user satisfaction where such systems are adopted. In India, this model aligns with the Viksit Bharat 2047 mission, promoting tech-enabled, inclusive learning environments. Parallel to this is the rise of makerspaces in schools and libraries, rooted in the maker movement (Dougherty, 2012). Makerspaces foster hands-on learning with robotics, coding, and 3D printers (Halverson & Sheridan, 2014), enabling creative literacies and transforming libraries into participatory hubs. In India, initiatives like Atal Tinkering Labs demonstrate this impact, though gaps in infrastructure, educator training, and facilitation remain (Smile Foundation, 2022). Despite their promise, makerspaces in libraries remain under-researched. Kurzeja et al. (2023) caution that poor design may reinforce inequalities. Herstätter et al. (2020) emphasize the need for real-time evaluation models, while systematic tools such as PRISMA (Page et al., 2021) and MMAT (Hong et al., 2018) ensure transparency and quality in mixed-methods research.

4. Methodology

4.1 Research Design

This study employed a descriptive survey research design complemented by a mixed-method approach to examine the implementation, usage patterns, and challenges related to smart libraries and makerspaces in school and college libraries. Quantitative data were gathered through structured surveys, while qualitative insights were collected through targeted case studies.

4.2 Sampling Technique and Location

A purposive sampling method was adopted to ensure the inclusion of stakeholders with relevant expertise and experience in library services and educational technologies. The study was confined to urban and semi-urban schools and colleges in the Kolkata region, reflecting a representative blend of private and public institutions engaging in smart learning initiatives.

4.3 Sampe Size

A total of 50 respondents participated in the study, comprising 30 individuals from schools and 20 from colleges. Participants included librarians, teachers, IT professionals, administrators, students, and research scholars, all of whom were selected based on their direct involvement with or knowledge of library or makerspace functions.

4.4 Data Collection Tools

Primary data were collected using a structured Google Form questionnaire. The instrument consisted of multiple-choice and checklist-based questions covering institutional infrastructure, availability of smart technologies, curriculum integration, staff training, and external support mechanisms.

4.5 Data Analysis

The responses were subjected to descriptive statistical analysis (frequency and percentage distributions), comparative analysis (school vs. college), and chi-square testing to evaluate associations between institution type and presence of smart infrastructure. The results are presented using tables, charts, and graphs for visual clarity.

4.6 Case Study Approach

This study uses qualitative case studies from official school websites of institutions with Atal Tinkering Labs, offering insights into infrastructure, adoption, and educational integration of makerspaces within school library settings.

4.7 Limitations of the Study

The study is limited by its geographical scope (Kolkata) and sample size (n=50). The reliance on self-reported data introduces the possibility of subjective bias. Additionally, case studies were limited to institutions with visible makerspace activity, potentially overlooking under-resourced settings.

5. Data Analysis & Interpretation

This section presents a comprehensive analysis of survey responses, highlighting trends, challenges, and institutional comparisons. Data from 50 respondents were grouped into six thematic sections. A chi-square test was used for statistical interpretation.

5.1 Institutional and Demographic Profile of Respondents

Table 1: Institutional and Demographic Profile of Respondents

Variable	Category	Frequency (n=50)	Percentage (%)
Type of Institution	School	30	60%
	College	20	40%
Nature of Institution	Government	18	36%
	Private	26	52%
	Semi-Aided	6	12%
Location	Urban	38	76%
	Semi-Urban	12	24%
Years of Experience	Less than 5 Years	20	40%
	5–10 Years	18	36%
	10–20 Years	12	24%

The study surveyed a total of 50 respondents, of which 60% were from schools and 40% from colleges. In terms of institutional nature, private institutions formed the majority (52%), followed by government (36%) and semi-aided institutions (12%). The majority of participants were from urban areas (76%), while the remaining 24% represented semi-urban regions. As for experience, 40% of respondents had less than five years of experience, 36% had between five to ten years, and 24% had ten to twenty years of professional background. This distribution reflects a balanced representation across institution types, geographic locations, and levels of professional experience.

5.2 Status of Smart Library Implementation

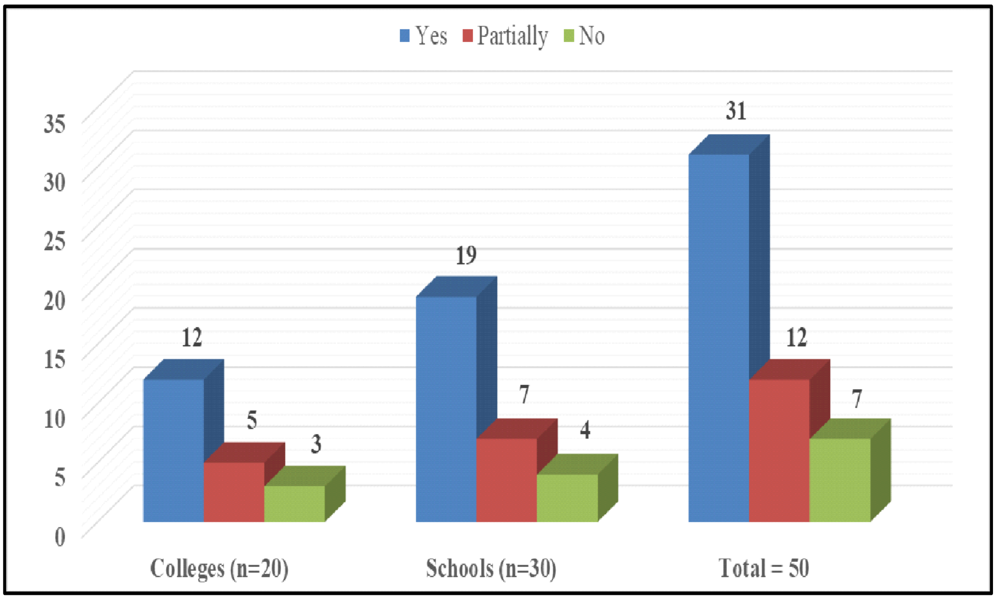

Figure 1: Status of Smart Library Implementation in Schools and Colleges

The chart in Figure 1 provides a clear visual comparison between schools (n = 30) and colleges (n = 20) regarding their adoption of smart library systems. Among schools, 19 institutions (63%) have fully implemented smart libraries, while 7 (23%) reported partial implementation, and 4 (13%) have not adopted such systems. In colleges, 12 out of 20 (60%) have fully implemented smart libraries, 5 (25%) have partial setups, and 3 (15%) do not have any smart library system. When combined, the total figures show that out of 50 institutions surveyed, 31 (62%) have fully adopted smart libraries, 12 (24%) have partial adoption, and 7 (14%) lack smart libraries entirely. This indicates a moderate level of digital library infrastructure across institutions, with slightly better adoption in schools than in colleges.

5.3 Makerspace/ATL/STEM Lab Implementation

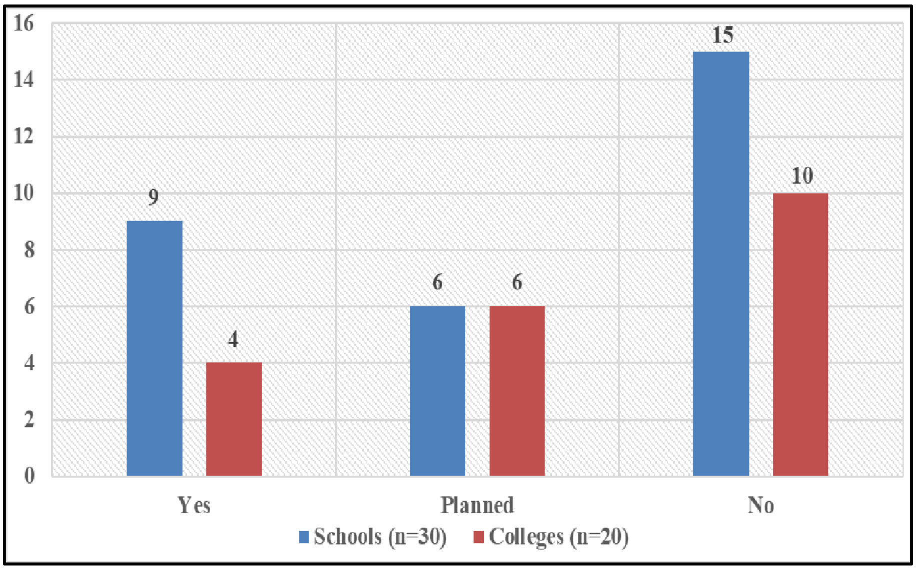

Figure 2: Status of Makerspace/ATL/STEM Lab Implementation in Schools and Colleges

As illustrated in the data, among the 30 schools surveyed, 9 (30%) reported having established a makerspace, 6 (20%) are in the planning phase, and 15 (50%) have no such facility. In contrast, of the 20 colleges surveyed, only 4 (20%) have implemented makerspaces, 6 (30%) are in the planning stage, and 10 (50%) have not taken any initiative in this direction. These findings suggest that although both schools and colleges share similar levels of non-adoption, schools are comparatively more active in planning or establishing innovation labs. This may be attributed to national initiatives such as the Atal Innovation Mission, which primarily targets school ecosystems.

In terms of available tools and technologies, science and DIY kits were the most common (47.1%), followed by coding platforms (23.5%), robotics kits (17.6%), and 3D printing tools (17.6%). These numbers indicate that while foundational hands-on resources are moderately accessible, more sophisticated and technology-driven tools, such as 3D printers and robotics kits, remain limited.

Regarding staff readiness, only 40% of institutions reported having trained teachers or librarians to manage makerspace activities. Meanwhile, 35% expressed the need for training, and 25% lacked trained personnel altogether. This highlights a critical skills gap, posing a threat to the long-term sustainability of makerspaces.

Furthermore, only 16% of respondents reported partnerships with external agencies, such as government bodies or NGOs. The lack of collaborative networks underlines the necessity for institutional alliances, targeted funding, and structured training to realize the full potential of innovation-driven learning environments.

5.4 Library Integration, Student Engagement, and Institutional Challenges

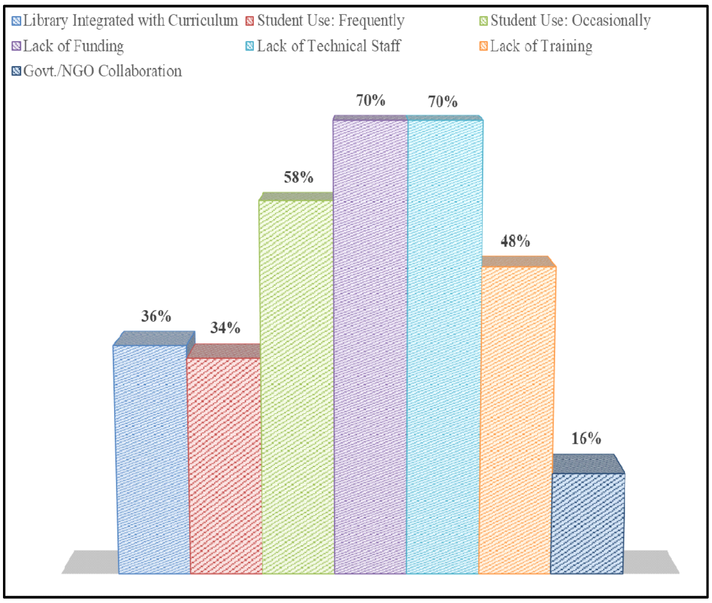

Figure 3: Status of Implementation of Smart Libraries

The chart highlights significant gaps in the implementation of smart libraries across 50 institutions. Only 36% reported full integration with subject teaching, and just 34% observed frequent student engagement with digital resources, while 58% noted only occasional use. Structural challenges dominate: 70% cited lack of funding, and an equal proportion reported insufficient technical staff. Additionally, 48% of institutions indicated inadequate staff training in smart tools. Notably, only 16% had collaborations with government or NGOs, underscoring limited external support. These findings reveal that, although smart libraries are present, their academic alignment, utilization, and sustainability are hindered by systemic barriers.

5.5 Perceptions and Institutional Needs

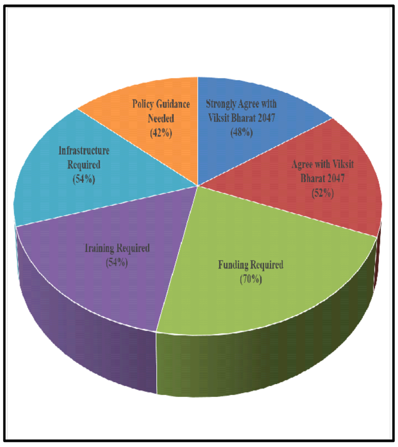

Figure 4: Institutional Perceptions on Smart Libraries and Makerspaces

The pie chart illustrates institutional perceptions regarding smart libraries and makerspaces in the context of Viksit Bharat 2047. A remarkable 100% of respondents supported their role in educational transformation – 48% strongly agreed, while 52% agreed. However, implementation gaps persist. Funding emerged as the most critical requirement (70%), followed by the need for training (54%) and infrastructure development (54%). Additionally, 42% emphasized the importance of clear policy guidelines. These findings reveal that while institutions conceptually align with the national vision, they face practical challenges. Addressing financial, infrastructural, and policy barriers is crucial to enabling effective and inclusive adoption of smart education adoption.

5.6 Awareness and Training Preferences for Smart Library and Makerspace Tools

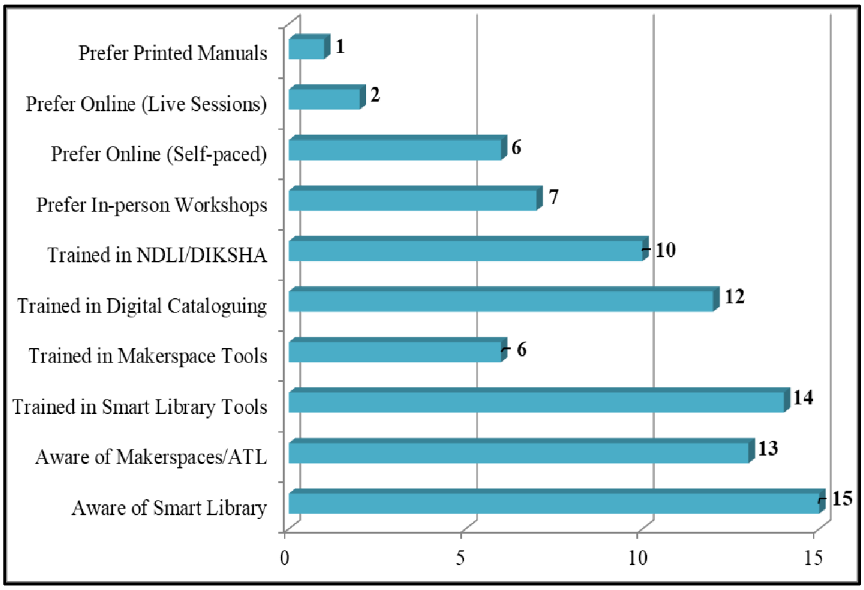

Figure 5: Awareness of Smart Libraries and Makerspaces

The chart illustrates respondents' awareness of smart libraries and makerspaces, their training backgrounds, and preferences for future capacity-building. Nearly 90% of participants reported awareness of "Smart Library" concepts, with slightly fewer familiar with Makerspaces/ATLs – likely influenced by recent educational policy pushes. Despite this awareness, significant training gaps exist. While some had experience with systems like Koha, OPAC, and cataloging tools, most lacked formal training in makerspace technologies and national digital platforms such as NDLI and DIKSHA. This highlights a disparity between awareness of digital systems and practical, hands-on competence. Respondents strongly supported the need for structured capacity-building, with most recommending mandatory training for library and educational staff operating in smart environments. Preferences for training modes varied: in-person workshops remained popular, though many showed growing interest in online, self-paced modules and live virtual sessions. These findings underscore the urgent need for flexible, blended learning models that deliver ongoing technical training tailored to diverse institutional roles and staff schedules.

6. Chi-Square Test of Independence: Association between Institution Type and Facility Implementation

6.1 Objective

To determine whether there is a statistically significant association between the type of institution and the implementation status of:

- Smart Library Systems
- Makerspace/ATL Facilities

6.2 Variables

- Independent Variable: Institution Type (School, College)
- Dependent Variable: Implementation Status (Yes, Partially, No)

6.3 Hypotheses

For both Smart Library and Makerspace implementation:

(H_0) Null Hypothesis: There is no association between institution type and implementation status (they are independent).
(H_1) Alternative Hypothesis: There is a significant association between institution type and implementation status.

Formula: $\chi 2 = \underline{\sum E\ (O - E)2}$
$\qquad\qquad E$

Where:
O = Observed frequency
E = Expected frequency under H_0
Summation is done across all cells in the contingency table

Table 2: Contingency Table for Smart Library Implementation

Institution Type	Yes	Partially	No	Total
School (n=30)	19	7	4	30
College (n=20)	12	5	3	20
Total	31	12	7	50

Using the formula above and calculating expected values:

$\chi 2 = 0.059$

Degrees of freedom (df) = (2 - 1) × (3 - 1) = 2

p-value = 0.971

Since, $p > 0.05$, we failed to reject Ho . There is no statistically significant association between institution type and the status of smart library implementation.

Table 3: Contingency Table for Makerspace/ATL Implementation

Institution Type	Yes	Planned	No	Total
School (n=30)	9	6	15	30
College (n=20)	4	6	10	20
Total	13	12	25	50

$\chi2 = 0.962$

Degrees of freedom (df) = 2

p-value = 0.618

Again, with > 0.05, we failed to reject H€ . The type of institution and the status of makerspace implementation are not significantly associated.

6.4 Test Summary

The Chi-square test results revealed no statistically significant association between institution type and the adoption of smart libraries ($p = 0.971$) or the availability of makerspaces/ATLs ($p = 0.618$). This indicates that both schools and colleges face similar levels of implementation, suggesting that infrastructural and resource-related barriers are uniformly distributed. The findings highlight the need for systemic, policy-level interventions rather than institution-specific approaches to advance smart education in alignment with the Viksit Bharat 2047 vision.

7. Case Studies

Table 4: Comparative Overview of Innovation Infrastructure in Selected Schools in Kolkata

Name of Institution	Location	Initiatives Implemented	Tools & Technologies Mentioned
Lakshmipat Singhania Academy	Alipore	STEM, Robotics, Innovation Lab	LEGO Robotics, Arduino Kits, 3D Printing, Design Thinking
South City International School	Jadavpur	STEM, Makerspace	Coding Kits, Science & Robotics Lab, Tinkering Tools
Delhi Public School Ruby Park	Kasba	ATL, Makerspace	3D Printers, DIY Robotics Kits, STEM Challenge Modules
IEM Public School	Salt Lake	ATL, Robotics Club	Microcontrollers, IoT Kits, AI & ML Tools
The Future Foundation School	Regent Park	ATL, STEM Integration	Arduino, Raspberry Pi, Science Kits
Delhi Public School Newtown	Newtown	ATL, Robotics	AI Tools, DIY Science Kits, Raspberry Pi
The Heritage School	Anandapur	STEM, Innovation Center	Coding Platforms, IoT Projects, 3D Design Tools
Birla High School	Moira Street	ATL, Robotics Club	DIY Robotics, ATL Modules, AI Projects
Garden High International School	Kasba	Innovation Lab, STEM activities	Scratch, Python Coding, 3D Prototyping

8. Findings

The study concludes with the following findings:

- 62% of institutions have fully implemented smart libraries, with colleges slightly ahead, although the difference is not statistically significant.
- Only 26% have established makerspaces/ATLs, while 24% plan future implementation.
- 35.3% of respondents expressed the need for training in operating smart tools, especially in makerspaces.
- 36% reported full integration of the library with the academic curriculum, while 64% reported only partial integration.
- Only 16% of institutions have partnerships with government or NGOs for support, indicating missed collaboration opportunities.

- Major barriers include a lack of funding and technical staff (both at 70.6%), as well as outdated infrastructure and inadequate training.
- 100% of respondents agreed that smart libraries and makerspaces are essential to realizing the Viksit Bharat 2047 vision.

9. Recommendations and Future Research,

- Mandate and fund makerspace setups through UGC, AICTE, and NITI Aayog support.
- Institutionalize regular training for librarians and educators in STEM and digital tools.
- Promote public-private partnerships for infrastructure, training, and resource sharing.
- Develop best-practice models to integrate smart libraries into academic curricula.
- Conduct longitudinal and comparative studies to evaluate the impact and stakeholder perceptions.

10. Implications for Stakeholders

This study offers important implications for multiple stakeholders. For students, smart libraries and makerspaces enhance digital literacy, creativity, and experiential learning, preparing them for future-ready careers. For faculty, they support innovative pedagogy, research, and interdisciplinary collaboration. For librarians, the findings highlight the need to shift from custodians of collections to facilitators of technology-driven, user-centered services. For institutional leaders and policymakers, the study emphasizes the urgency of sustainable funding, infrastructure, and staff training to scale these initiatives. Collectively, these implications reaffirm the role of libraries as inclusive, innovative hubs aligned with the national vision of Viksit Bharat 2047.

11. Conclusion

This study found that while smart libraries are moderately adopted (62%) and makerspaces remain limited (26%), both schools and colleges face similar infrastructural and resource challenges, with no significant institutional differences. Funding shortages, a lack of technical staff, and limited training emerged as the most critical barriers, echoing earlier findings by Halverson & Sheridan (2014) and Orji & Anyira (2021), which suggest that sustainable digital learning requires both infrastructure and skilled facilitators. Despite these gaps, all respondents affirmed the transformative potential of smart libraries and makerspaces in achieving the Viksit Bharat 2047 vision.

The findings extend existing scholarship by situating smart libraries and makerspaces in the Indian context, showing that while adoption is growing, institutional leadership often underprioritizes libraries as innovation hubs. This mirror concerns raised by Kurzeja et al. (2022) that poor design or lack of support can deepen inequalities. Therefore, consistent with prior research, this study highlights the urgent need for systemic investment, policy support, and capacity-building to reposition libraries as central to 21st-century education.

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