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Empowering Creativity: Exploring Makerspace Realities and Challenges in Public Sector University Libraries of Khyber Pakhtunkhwa, Pakistan

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Abstract: Purpose-The purpose of this study is to investigate the current status and challenges faced by makerspaces in public sector university libraries of Khyber Pakhtunkhwa, Pakistan, aiming to provide insights for enhancing their effectiveness in fostering creativity and innovation among students and researchers.

Methodology/ Research approach- This study utilized a quantitative survey with a structured questionnaire, involving 80 librarians from 34 public sector universities in Khyber Pakhtunkhwa. The questionnaire, based on current literature, was distributed via email, Google Docs, and social media platforms for wide participation. Total 69 responses were received from the university librarians. Data analysis was conducted using SPSS software, focusing on descriptive statistics and Likert scale responses.

Findings/Outcomes of the study- The analysis revealed a moderate perspective regarding the availability of tools and engagement in diverse projects, reflecting the current status. Challenges encompassed staffing expertise, technology infrastructure, funding allocation, awareness promotion, institutional support, and curriculum integration. Proposed improvement strategies focused on staff training, securing diverse funding, integrating curricula, fostering external collaborations, enhancing community engagement, and promoting interdisciplinary initiatives. These findings highlight the necessity for holistic strategies to bolster makerspace effectiveness and sustainability within university libraries.

Practical implications– This research provides valuable insights for policymakers, senior administrators, and library managers in establishing makerspaces in prestigious academic institutions. Key recommendations include enhancing staff training, diversifying funding sources, integrating makerspaces into curricula, promoting collaborations, fostering community engagement, prioritizing funding, and improving institutional support. These strategies are crucial for optimizing makerspace effectiveness and sustainability in university libraries, making our findings essential for decision-makers shaping education and innovation in these institutions.

Keywords: Makerspace; Universities; University Libraries; Challenges; Strategies; Librarians.

1. Introduction

Makerspaces are interactive and cooperative settings that cultivate ingenuity, novelty, and education through practical undertakings [1]. These spaces are specifically created to facilitate the collaboration of persons with varied talents, backgrounds, and interests, resulting in a dynamic environment for discovery and experimentation [2]. Makerspaces foster collaborative work among members, who share ideas, information, and expertise to collaboratively engage in creating, inventing, and problem-solving [3]. A key characteristic of makerspaces is their strong focus on practical, experiential projects. Participants actively participate in the creation of various objects, such as constructing prototypes, creating artworks, developing circuits, or exploring new technologies [5]. This practical approach facilitates experiential learning, wherein individuals acquire knowledge through active engagement, committing errors, and refining their designs through iterative processes [5]. [6] conducted research that underscores the significance of hands-on learning in makerspaces, namely its contribution to the cultivation of critical thinking, problem-solving abilities, and creativity. The accessibility of equipment, materials, and knowledge is crucial to the operation of makerspaces. Makerspaces are furnished with an extensive array of tools and equipment, such as 3D printers, laser cutters, soldering stations, electronics kits, carpentry tools, sewing machines, and additional items [7].

These technologies facilitate the realization of participants' ideas and the transformation of abstract thoughts into physical products. In addition, makerspaces offer individuals the opportunity to utilize a diverse range of resources like wood, plastic, metal, fabric, circuits, sensors, and recyclable materials [8]. This kind of accessibility promotes the research and experimenting of various materials and techniques, hence stimulating creativity. Makerspaces provide not only tools and materials, but also access to knowledge and mentorship [9]. Makerspaces frequently employ proficient personnel, volunteers, or mentors who offer direction, advice, and technical support to participants [10]. The mentorship factor plays a vital role in facilitating individuals' acquisition of new skills, addressing difficulties, and navigating the creative process. The research conducted by Martin emphasizes the beneficial effects of mentorship in makerspaces, specifically highlighting its contribution to the development of self-assurance, facilitation of teamwork, and improvement of educational achievements [11]. In general, makerspaces function as centers of ingenuity and imagination in several fields. The organization offers a welcoming and cooperative atmosphere that encourages individuals to express their creativity, experiment with new technologies, acquire expertise from one another, and actively participate in a culture of generating and exchanging information [12]. Makerspaces are dynamic centers of learning and creativity in the modern digital era, offering a combination of collaborative workspaces, practical projects, access to tools and materials, and expert knowledge [13].

1.1. Utilizations of Makerspaces

Education: Makerspaces are increasingly popular in educational environments, ranging from primary and secondary schools to higher education institutions. The organization provides assistance for project-based learning, STEAM (Science, Technology, Engineering, Arts, Mathematics) education, and the cultivation of 21st-century abilities in students [13].

1.1.1. Entrepreneurship and Prototyping

Makerspaces function as incubators for businesses and entrepreneurs, fostering entrepreneurship and prototyping. They offer access to prototyping tools and resources, allowing individuals to experiment and improve their product ideas before expanding [14].

1.1.2. Community Engagemen

Makerspaces enhance community development by providing workshops, events, and programs that actively include the public in practical activities. Their objective is to encourage continuous learning, originality, and a climate of advancement in communities [15].

1.2. Makerspaces in University libraries

Makerspaces in university libraries are innovative spaces that combine standard library services with experiential learning, technological inquiry, and collaborative invention [16]. These rooms symbolize a significant change in the function of libraries, transitioning from being places that store knowledge to becoming vibrant centers of creativity, experimentation, and interdisciplinary collaboration [17]. An essential element of makerspaces in academic libraries is their function in facilitating experiential learning and fostering the development of skills. Makerspaces offer students and staff the chance to participate in project-based learning by granting them access to tools, equipment, and materials like as 3D printers, laser cutters, robotics kits, and electronics components [18]. Implementing a practical approach not only improves the results of learning but also encourages the development of critical thinking, problem-solving abilities, and creativity [19].

In addition, makerspaces facilitate multidisciplinary collaboration by uniting individuals with varied academic backgrounds. Makerspaces are spaces where students, researchers, and faculty members from many fields come together to collaborate on projects, exchange knowledge, and find creative solutions to practical problems [20]. Makerspaces in academic libraries function as incubators for fostering innovation and entrepreneurship. The institution offers a conducive atmosphere for students and professors to experiment with and evaluate their concepts, create innovative technology, and delve into entrepreneurial endeavors [21]. Makerspaces enhance the growth of an innovative and creative culture in academic institutions by providing mentorship, networking opportunities, and access to resources [8]. Furthermore, makerspaces are essential in fostering digital literacy and technological fluency among students and educators. Makerspaces provide individuals with the opportunity to gain new technical skills, investigate emerging technologies, and adapt to the quickly evolving digital environment through workshops, training sessions, and hands-on activities [22].

Makerspaces at university libraries not only promote education and innovation, but also encourage community engagement and outreach. The organization arranges public events, exhibitions, and maker fairs to display student work, emphasize local ideas, and encourage the wider community to engage in activities related to making and learning. This outreach initiative not only increases the prominence of the library but also fortifies collaborations with industry, government, and community organizations [23]. Ultimately, makerspaces in academic libraries are versatile and complex environments that combine technology, teaching, creativity, and community involvemen [24]. Libraries play a crucial role in changing the traditional library setting into a dynamic system that promotes continuous learning, encourages innovation, and enables individuals to actively contribute to a society driven by knowledge [25].

1.3. Research Objectives

1. To Assess the Current Status of Makerspaces in Public Sector Universities of Khyber Pakhtunkhwa.
2. To Identify Perceived Challenges Faced by Makerspaces in Public Sector Universities.
3. To Explore Strategies for Enhancing Makerspace Effectiveness and Sustainability.

2. Literature Review

2.1. Definition and Concept of Makerspaces

Makerspaces are collaborative places specifically created to cultivate creativity, innovation, and experiential learning [26]. They offer participants the opportunity to utilize tools, equipment, and materials to engage in the creation, prototyping, and experimentation of diverse projects [27]. Makerspaces foster interdisciplinary collaboration, facilitating the convergence of individuals possessing varied expertise and experiences to collaborate on joint projects [28]. Makerspaces are centered around the idea of experiential learning, where individuals acquire knowledge via hands-on experience, experimentation, and a cyclical approach to design [29]. Makerspaces in educational contexts serve as dynamic hubs of exploration and discovery, fostering critical thinking, problem-solving abilities, and creativity among participants [30].

2.2. Role of Makerspaces in Promoting Innovation and Collaboration

Makerspaces have a crucial role in promoting creativity and collaboration in academic and artistic groups. These venues foster an atmosphere that promotes experimenting, taking risks, and the investigation of novel concepts [31]. Makerspaces provide individuals with advanced tools and technology, enabling them to create prototypes and test their ideas. This process leads to the creation of new solutions for real-world problems [32]. In addition, makerspaces foster collaboration by facilitating the gathering of individuals with varied backgrounds, disciplines, and perspectives [33]. This collaborative culture promotes the sharing of knowledge, learning across different disciplines, and the interchange of skills and expertise. The study undertaken by [9] emphasizes the significance of makerspaces in enabling trans disciplinary projects that integrate technical expertise with innovative thinking, leading to unique approaches and results. Makerspaces function as catalysts for innovation and cooperation, propelling forward-thinking initiatives and cultivating a culture of creativity and discovery.

2.3. Essential Elements of Makerspaces in Academic Libraries

Tools and Equipment: Makerspaces are furnished with an extensive array of tools and equipment, such as 3D printers, laser cutters, electronics kits, carpentry tools, sewing machines, and various other items. These tools empower people to transform their concepts into actual prototypes and products.

Materials and Supplies: Makerspaces include a diverse range of materials and resources, including wood, plastic, metal, fabric, circuitry, and sensors. These resources enable individuals to explore various materials and approaches in order to bring their concepts to fruition.

Community and Collaboration: Collaboration is an essential element of makerspaces. The organization cultivates a communal atmosphere, facilitating the gathering of individuals from various backgrounds, areas of expertise, and hobbies, who unite to exchange knowledge, cooperate on projects, and gain insights from one another.

Learning and Skill Development: Makerspaces facilitate experiential learning and foster skill development. Users acquire knowledge through hands-on experience, committing errors, engaging in iterative processes, and enhancing their designs. They develop proficiency in technical skills associated with utilizing tools and equipment, in addition to cultivating soft skills such as teamwork, communication, and problem-solving [34].

2.4. Evolution of Makerspaces in Academic Settings

The development of makerspaces in academic contexts demonstrates a change in educational approaches towards hands-on learning and cross-disciplinary cooperation. Makerspaces, which sprang from hacker and DIY cultures, have now become established spaces within universities and institutions [35]. The change mentioned is propelled by the acknowledgment of the significance of experiential learning, creativity, and proficiency in digital technology in contemporary education [36]. Makerspaces in academic environments have expanded to include a diverse array of subjects, spanning from STEM (Science, Technology, Engineering, Mathematics) disciplines to arts, humanities, and social sciences [37]. These platforms provide opportunities for students, educators, and researchers to investigate emerging technologies, engage together on projects, and acquire practical skills that are applicable to the current job market [38]. The development of makerspaces in academic institutions showcases their flexibility and significance in equipping learners for the demands of the digital era.

2.5. Perceived Challenges Faced by Makerspaces in Public Sector Universities

Funding and budget constraints pose significant challenges for makerspaces in academic settings, impacting their ability to acquire and maintain state-of-the-art equipment, provide adequate resources, and support programmatic activities [39]. Limited funding may restrict the expansion of makerspace facilities, hinder the purchase of new technologies, and limit the scope of projects and initiatives that can be undertaken. Budget constraints often necessitate strategic planning, prioritization of resources, and seeking alternative funding sources such as grants, donations, sponsorships, and partnerships to sustain operations and enhance offerings. Additionally, navigating procurement processes, managing operating costs, and demonstrating the value and impact of makerspaces to stakeholders are ongoing challenges faced due to funding limitations [35].

Technological infrastructure limitations encompass issues related to the availability, reliability, and scalability of IT infrastructure and digital tools within makerspaces [40]. These limitations may include insufficient bandwidth, outdated hardware and software, compatibility issues, and inadequate support for emerging technologies. Such limitations can impede the seamless operation of makerspaces, hinder the implementation of advanced projects, and limit access to cutting-edge tools and resources [36]. Addressing technological infrastructure limitations requires investment in upgrading and maintaining IT infrastructure, adopting scalable and adaptable technologies, providing technical support and training for users, and ensuring compatibility with diverse devices and platforms [31].

2.6. Strategies for Enhancing Makerspace Effectiveness and Sustainability

Securing additional funding sources is crucial for overcoming budget constraints and sustaining the growth and development of makerspaces in academic institutions. This involves proactive efforts such as seeking external grants, establishing partnerships with industry sponsors, engaging in fundraising campaigns, and exploring philanthropic opportunities [41]. Diversifying funding sources not only provides financial stability but also opens avenues for expanding makerspace capabilities, acquiring new equipment, supporting innovative projects, and enhancing user experiences [42]. Moreover, strategic planning and effective financial management are essential to optimize resource allocation, prioritize funding needs, and ensure long-term sustainability [43].

Staff training and development initiatives are integral to addressing staffing and expertise shortages within makerspaces. Investing in professional development programs, workshops, certifications, and mentorship opportunities enables staff members to enhance their technical skills, pedagogical knowledge, and project management abilities. Training initiatives also promote continuous learning, innovation, and best practices in makerspace operations, ensuring high-quality support and services for users. Additionally, fostering a culture of collaboration, knowledge sharing, and ongoing skill development among staff members contributes to a dynamic and skilled workforce capable of meeting the evolving needs of makerspace users [44].

Fostering interdisciplinary collaborations is essential for harnessing the full potential of makerspaces and promoting cross-disciplinary innovation. Makerspaces serve as catalysts for bringing together individuals from diverse academic backgrounds, research areas, and expertise domains to collaborate on projects, share insights, and co-create solutions. Encouraging interdisciplinary teams, organizing collaborative workshops and events, and facilitating networking opportunities within and beyond the institution foster a culture of interdisciplinary exchange and collaboration. Such collaborations not only enrich project outcomes but also contribute to interdisciplinary learning, knowledge transfer, and the exploration of new ideas and perspectives [45].

3. Methodology

The study in hand utilized a quantitative survey with a structured questionnaire as its methodology. The intended participants consisted of 80 librarians employed by 34 public sector universities in the Khyber Pakhtunkhwa province. The data collection tool was based on the current literature in the same area. The questionnaire was sent to the respondents by email, Google Docs, and various social media platforms to ensure a wide distribution and encourage widespread participation. This methodology facilitated the gathering of data in a time-effective manner while also taking into consideration the varied communication preferences of the participants [47].

The questionnaire was designed according to the research objectives, with a specific emphasis on evaluating the present condition of makerspaces, identifying perceived challenges, and investigating methods to improve the efficacy and sustainability of makerspaces. The inquiries encompassed elements such as the accessibility of tools and equipment, varieties of projects conducted, user involvement, sources of finance, collaborations, personnel, and incorporation with academic courses. The survey includes Likert scale questions, demographic information.

The data analysis was performed using the SPSS (Statistical Package for the Social Sciences) software. The demographic characteristics of the participants and the current situation of makerspaces were analyzed using descriptive statistics.

4. Results and Discussion

Based on the extensive feedback received from 69 library professionals representing the 34 public sector universities in Khyber Pakhtunkhwa, a detailed analysis using descriptive statistics within the Statistical Package for the Social Sciences (SPSS) software has yielded comprehensive insights. This rigorous process involved meticulous data collection, cleaning, and transformation, enabling the identification of key patterns and trends. Leveraging measures such as mean, standard deviation, and frequency distributions, the research team gained a nuanced understanding of the perceptions, attitudes, and experiences of the library professionals regarding the subject under study.

4.1. Demographic Information

Province Khyber Pakhtunkhwa, Pakistan has a total of 34 public sector universities and institutes that grant degrees in higher education (Rehman, Khan, & Akhtar, 2024) (see annexure – I). The total number of library professionals in these institutions are 80, and their demographic information is provided in Table 1. This table presents a thorough summary of the library staff's composition, including information on their roles, length of service, and distribution by gender. The workforce consists of 3 Chief Librarians, which accounts for 4.3478 % of the population, and 2 Associate Librarians, representing 2.8985 %. The Deputy Librarians, making up 21.7391 % (15 individuals), followed by Assistant Librarians at 50.7246% (35 individuals), and Cataloguers/Classifiers likewise at 21.4347 % (14 individuals).

In terms of professional tenure, there are 11 individuals, representing 15.9420 %, who have up to 5 years of experience, a substantial proportion of the staff has 6-10 years of experience, making up 35.7826 % (24 individuals). Next, there are 24 persons, accounting for 35.7826 %, who have 11-15 years of experience. In addition, there are 6 persons, comprising 8.6956 % of the workforce, who have 16-20 years of experience. Furthermore, there are 4 individuals, accounting for 5.7971 % of the crew, who have 20-25 years of experience. Regarding the gender distribution, the staff composition is predominantly male, making up 86.9565 % (60 individuals), while females account for 13.0434 % (9 individuals) of the total staff surveyed.

Table 1. Demographic Information of the respondents

Positioning / Designation	No.	Percentage %
Chief Librarian	03	4.3478
Associate Librarian	02	2.8985
Deputy Librarian	15	21.7391
Assistant Librarian	35	50.7246
Cataloguer/ Classifier	14	21.4347
Professional Experience		
Up to 5 years	11	15.9420
6 - 10 Years	24	35.7826
11- 15 years	24	35.7826
16 – 20 Years	06	8.6956
20 – 25 years	04	5.7971
Gender		
Male	60	86.9565
Female	09	13.0434

4.2. Reliability of the Instrument

Table 2 in our research article provides an in-depth analysis of the reliability statistics. The researchers utilize Cronbach's Alpha values to evaluate the internal consistency and reliability of the constructs being examined. The criteria analyzed encompass "Current Status," which denotes the current status or condition makerspace in the public sector universities of Khyber Pakhtunkhwa; "Perceived Challenges," which encompass the problems or hurdles experienced by library professionals of these universities; and "Strategies," which indicate the success of the implemented approaches or plans. In addition, we computed the overall reliability of these constructs as a composite metric to assess the reliability of our complete measuring methodology [47].

The Cronbach's Alpha coefficients found for each category were .794 for "Current Status," .850 for "Perceived Challenges," and .912 for "Strategies." These values demonstrate a high level of internal consistency within each component. Furthermore, the general dependability of our constructs, indicated by a Cronbach's Alpha value of .943, also demonstrates a strong level of internal consistency across all examined features [48] [61].

These results are of utmost importance as they indicate the dependability and consistency of our measurement tools. A high Cronbach's Alpha score signifies a strong correlation among the items within each construct and a consistent measurement of the desired notion [49]. The strong reliability of our measurements increases the accuracy of our study findings, bolstering the credibility of our analysis and conclusions.

Table 2. Reliability Statistics (Cronbach's Alpha Values)

S.No.	Factors	Cronbach's Alpha Values	Result
1.	Current Status	.794	Good
2.	Perceived Challenges	.850	Good
3.	Strategies	.912	Excellent
4.	**Over All Reliability**	**.943**	**Excellent**

4.3. Current Status of Makerspace in Public Sector Universities

Table 3 in our study article provides an in-depth analysis of the present condition of makerspaces in public sector universities. The researchers investigate important factors concerning their operation and support systems. The data, collected from 69 participants, provides insights into many aspects of makerspace operations and resources:

The average score of 2.1449, with a standard deviation of 1.20386, indicates a moderate view of the availability of tools and equipment in makerspaces. This suggests a possible area where universities may need to improve their resources in order to provide better support for maker activities. In a similar study conducted by [50] compares the resources available in makerspaces across different university libraries, highlighting the importance of adequate tools and equipment for supporting maker activities.

The respondents' average score of 2.4493 and standard deviation of 1.36701 suggest a moderate level of involvement in undertaking varied projects inside makerspaces. This suggests that there is a range of activities taking place in these locations, although they may not be completely varied. In yet another study conducted by [51], examined the competencies and needs of makerspace users in higher education, shedding light on the role of tools and equipment in fostering maker skills. The data indicates that there is a perceived shortage of adequate funding sources for makerspaces, as evidenced by a mean score of 1.8551 and a standard deviation of 1.15396. This highlights a crucial area that has to be enhanced in order to provide long-term backing for innovative projects and activities. The mean score for university relationships with other agencies reported by respondents is 2.3478, with a standard deviation of 1.26986. This indicates a moderate degree of collaboration, indicating possible chances for enhancing networking and collaborative endeavors. The overall use of the Makerspace is indicated by a mean score of 1.8551 and a standard deviation of 1.15396, suggesting that there is a requirement for greater utilization of the Makerspace facilities. By supporting over this view, [52] [57] highlighted in their studies the importance of makersapce in the higher education institutions to enhance the use and value of the modern libraries. This highlights the need of encouraging and maximizing the utilization of these areas to fully exploit their capacity for creativity and innovation[58].

These findings offer a detailed comprehension of the current state of makerspaces in public sector institutions, emphasizing both their strong points and the areas that need strategic interventions. By addressing factors such as the availability of resources, financial support, the variety of projects, and possibilities for cooperation, the effectiveness and impact of makerspace activities in the academic environment can be greatly improved.

Table 3. Current Status of Makerspace in Public Sector Universities

Items	N	Mean	Std. Deviation
Makerspace tools & equipment are available	69	2.1449	1.20386
Different Projects are undertaken	69	2.4493	1.36701
Proper funding sources are available	69	1.8551	1.15396
University has partnership with other agencies	69	2.3478	1.26986
Over all utilization of Maker space	69	1.8551	1.15396

4.4. Perceived Challenges Faced by Makerspace in Public Sector Universities

Table 4 of the current study examines the perceived challenges encountered by makerspaces in public sector Universities, as indicated by 69 participants. The table presents information on different barriers and areas of concern that affect the efficient operation of these innovative spaces. The respondents' mean score of 4.0725, with a standard deviation of 1.10239, emphasizes the significance of having an adequate number of people and experience in makerspaces. This highlights the necessity of competent professionals to effectively support and guide maker activities. The availability of technology infrastructure is considered crucial for supporting makerspace efforts, as indicated by the respondents' mean score of 4.2609 and a standard deviation of 1.07993. Having sufficient access to technology is crucial for promoting inventive ideas and improving educational experiences. The average score of 3.6812 indicates that there is a perceived difficulty in allocating adequate funding and budgetary resources for makerspaces. This suggests a possible area where colleges can focus their funding in order to guarantee ongoing support for these initiatives. The respondents reported a mean score of 4.1884 in terms of their awareness and promotion of makerspace activities. This highlights the need of efficiently marketing and conveying the advantages and possibilities linked to makerspaces to stakeholders and the broader community. The average score of 3.9565 represents the opinions of respondents regarding the extent of institutional assistance offered to makerspaces. This component is essential for cultivating a conducive environment that promotes creativity and experimentation within the academic context. Respondents see the incorporation of makerspace activities within academic courses favorably, as evidenced by an average score of 4.0000. This underscores the capacity of makerspaces to supplement and enhance conventional learning methods. In yet another study, the investigators pointed out that Challenges in library makerspaces include budget constraints, space limitations impacting tool acquisition and maintenance, insufficient funding for updating equipment, and difficulty in meeting diverse user needs due to tool availability and technological infrastructure limitations [53]. The results of the study conducted by [54] [59] are in line with the study in hand by exploring the challenges which hinders the smooth implementation of the makerpace in the libraries of these high seats of learning.

In summary, these findings emphasize the fundamental difficulties that public sector universities encounter when trying to start and sustain successful makerspace programs. In order to maximize the effectiveness and long-term viability of makerspaces in higher education, it is crucial to address concerns regarding staffing, technological infrastructure, allocation of funds, promotion, institutional support, and integration into the curriculum.

Table 4. Perceived Challenges Faced by Makerspace in Public Sector Universities

Items	N	Mean	Std. Deviation
Staffing and expertise available	69	4.0725	1.10239
Technological Infrastructure is available	69	4.2609	1.07993
Enough funds and budget is allocated	69	3.6812	.89923
Awareness and promotion of makerspace	69	4.1884	.86220
Institutional support	69	3.9565	.71609
Integration with academic curricula	69	4.0000	.80440

4.5. Strategies for Enhancing Makerspace Effectiveness and Sustainability

Table 5 in our research article examines techniques that aim to improve the efficiency and long-term viability of makerspaces in public sector universities. These ideas are based on the feedback provided by 69 participants. The implementation of these methods is essential for optimizing the influence and sustainability of makerspace initiatives.

The respondents have expressed high support for the notion of enhancing staff training and development, as evidenced by a mean score of 4.3768 and a comparatively low standard deviation of .76891. This highlights the significance of investing in the ongoing development and proficiency of makerspace personnel to enhance their ability to support innovation and educational activities. Obtaining more financial: Based on a mean score of 4.3188 and a low standard deviation of .62996, survey participants highlight the urgent requirement to find new financial sources for makerspaces. This emphasizes the significance of diversifying financing sources in order to guarantee continuous support and availability of resources. The respondents highly appreciate the incorporation of makerspaces into academic curriculum, as evidenced by an average score of 4.0725 and a standard deviation of .81021. This indicates an acknowledgment of the significance of makerspaces in enhancing educational experiences and promoting the development of hands-on, practical skills. Collaborating with external stakeholders, including industry, government, and non-profit groups, is considered a valuable strategy. This is supported by a mean score of 4.1884 and a standard deviation of .79104. These collaborations can offer important assets, specialized knowledge, and networking prospects to strengthen makerspace operations. The respondents highlight the significance of improving community engagement initiatives in relation to makerspaces, as evidenced by a mean score of 4.1159 and a standard deviation of .79588. This underscores the capacity of community engagement in propelling innovation, dissemination of knowledge, and sustainability. The promotion of interdisciplinary collaborations within makerspaces is regarded favorably, as indicated by a mean score of 4.2029 and a standard deviation of .75886. The importance of having a variety of different viewpoints, abilities, and understanding is highlighted in promoting innovation and finding solutions in makerspace settings. By supporting the results of our study [55] articulated the implementing strategic planning to address budget constraints and space limitations in acquiring and maintaining tools and equipment, developing funding mechanisms for regular updates and maintenance of makerspace resources, and Enhancing technological infrastructure to meet diverse user needs and support maker competencies effectively are the best strategies for overcoming the challenges of makesapce in the university setup. Similarly, the study of [56] examines how public policy influences startup innovation, using a model that considers policy perception, policy adaptation's mediating role, and makerspace support's moderating influence on innovative activities, capabilities, and performance [60].

These findings highlight the need for a comprehensive strategy to improve the effectiveness and long-term viability of makerspaces, with a focus on ongoing education, mobilizing resources, fostering collaboration, and engaging the community. Implementing these methods can greatly enhance the effectiveness and influence of makerspace activities in a university environment.

Table 5. Strategies for Enhancing Makerspace Effectiveness and Sustainability

Items	N	Mean	Std. Deviation
Enhancing staff training and development	69	4.3768	.76891
Securing additional funding sources	69	4.3188	.62996
Integrating makerspaces into academic curricula	69	4.0725	.81021
Partnerships with industry, government, and non-profit organizations	69	4.1884	.79104
Strengthening community engagement	69	4.1159	.79588
fostering interdisciplinary collaborations	69	4.2029	.75886

5. Findings

Table 5 in our research article examines techniques that aim to improve the efficiency and long-term viability of makerspaces in public sector universities. These ideas are based on the feedback provided by 69 participants. The implementation of these methods is essential for optimizing the influence and sustainability of makerspace initiatives The respondents have expressed high support for the notion of enhancing staff training and development, as evidenced by a mean score of 4.3768 and a comparatively low standard deviation of .76891. This highlights the significance of investing in the ongoing development and proficiency of makerspace personnel to enhance their ability to support innovation and educational activities. Based on a mean score of 4.3188 and a low standard deviation of .62996, survey participants highlight the urgent requirement to find new financial sources for makerspaces. This emphasizes the significance of diversifying financing sources in order to guarantee continuous support and availability of resources. The respondents highly appreciate the incorporation of makerspaces into academic curriculum, as evidenced by an average score of 4.0725 and a standard deviation of .81021. This indicates an acknowledgment of the significance of makerspaces in enhancing educational experiences and promoting the development of hands-on, practical skills. Collaborating with external stakeholders, including industry, government, and non-profit groups, is considered a valuable strategy. This is supported by a mean score of 4.1884 and a standard deviation of .79104. These collaborations can offer important assets, specialized knowledge, and networking prospects to strengthen makerspace operations. The respondents highlight the significance of improving community engagement initiatives in relation to makerspaces, as evidenced by a mean score of 4.1159 and a standard deviation of .79588. This underscores the capacity of community engagement in propelling innovation, dissemination of knowledge, and sustainability. Facilitating Interdisciplinary Collaborations: The promotion of interdisciplinary collaborations within makerspaces is regarded favorably, as indicated by a mean score of 4.2029 and a standard deviation of .75886. The importance of having a variety of different viewpoints, abilities, and understanding is highlighted in promoting innovation and finding solutions in makerspace settings. These findings highlight the need for a comprehensive strategy to improve the effectiveness and long-term viability of makerspaces, with a focus on ongoing education, mobilizing resources, fostering collaboration, and engaging the community. Implementing these methods can greatly enhance the effectiveness and influence of makerspace activities in a university environment.

Table 4 in our study examines the perceived challenges faced by makerspaces in public sector universities, as reported by 69 participants. The average score emphasizes the importance of having a sufficient number of experienced workers, underlining the need for competent specialists to properly support and guide maker activities, thereby assuring the efficient operation of these innovative spaces. Furthermore, the respondents recognize the significance of technology infrastructure in developing innovative ideas and improving educational experiences in makerspaces. The perceived challenge in assigning sufficient funds and budgetary resources highlights a possible area for institutions to prioritize their funding, ensuring consistent support for makerspace activities. Additionally, the importance of respondents' knowledge and support of makerspace activities, as well as institutional aid, is emphasized as crucial elements for creating a favorable climate that encourages creativity and experimentation in the academic setting. The positive perspective on integrating makerspace activities into academic courses highlights their ability to complement and improve traditional learning techniques.

Table 5 in our research article examines methods designed to enhance the effectiveness and sustainability of makerspaces in public sector universities, using input from 69 participants. The strong endorsement for improving staff training and development highlights the significance of investing in the continuous expertise of makerspace professionals to successfully support innovation and instructional activities. Participants emphasized the importance of diversifying finance sources to ensure ongoing support and availability of resources, underscoring the pressing necessity to investigate new financial opportunities. Moreover, the favorable response to integrating makerspaces into the academic curriculum indicates the recognition of their importance in improving educational experiences and fostering the development of practical skills. Engaging in partnerships with external stakeholders, such as industry, government, and non-profit organizations, is widely acknowledged as a beneficial approach. These collaborations provide important resources, expertise, and networking prospects to enhance the functioning of makerspaces. Community engagement projects and interdisciplinary collaborations are widely esteemed for their capacity to drive innovation, disseminate information, and promote sustainability within makerspace environments.

6. Conclusion and Recommendations

Our report offers a thorough examination of the current state of makerspaces in public sector colleges, providing important insights into their strengths and opportunities for improvement. Makerspaces have become central hubs for promoting creativity, cultivating practical skills, and enabling collaborative learning environments. These platforms provide a space for students, professors, and external stakeholders to come together and explore innovative ideas, participate in practical initiatives, and develop multidisciplinary methods for tackling problems. Although makerspaces offer clear advantages to the field of education, our research has identified many obstacles that need to be resolved in order to fully harness their potential. The constraints include factors such as resource availability, financial viability, incorporation into academic curricula, cooperation with external partners, community involvement, and the requirement for interdisciplinary connections within makerspaces. By recognizing these difficulties and formulating proactive remedies, universities can improve the efficiency and long-term sustainability of their makerspaces. Investing in staff training and development, diversifying funding sources, integrating makerspace activities into formal education structures, forging partnerships with external entities, prioritizing community involvement, fostering interdisciplinary collaborations, allocating funding strategically, and providing robust institutional support are all crucial.

To summarize, makerspaces have great potential as catalysts for innovation and education. By proactively addressing the challenges identified and implementing strategic initiatives, makerspaces can remain dynamic hubs for creativity, skill enhancement, and knowledge sharing in academic settings.

Based on the entire study, the following recommendations are suggested;

1. Enhance Staff Training and Development: Allocate resources towards ongoing education and skill enhancement initiatives for makerspace staff to bolster their capacity in effectively facilitating innovation and educational endeavors.
2. Diversify Financial Resources: Seek out novel financing opportunities and collaborations to guarantee ongoing backing and accessibility of resources for makerspaces.

3. Integrate Makerspaces into Academic Curriculum: Incorporate makerspaces within the academic curriculum to enhance educational experiences and foster practical skill development.
4. Promote Collaboration with External Stakeholders: Involve business, government, and non-profit organizations in joint endeavors to enhance the functioning of makerspaces, gain access to resources, and utilize specialized expertise.
5. Enhance Community Engagement Initiatives: Prioritize the improvement of projects that encourage innovation, spread knowledge, and foster sustainability in makerspace contexts.
6. Encourage Interdisciplinary Collaborations: Facilitate varied perspectives, expertise, and comprehension within makerspaces to promote creativity and problem-solving.
7. Prioritize Funding Allocation: Tackle the perceived difficulty of distributing sufficient finances and budgetary resources to guarantee constant support for makerspace activities.
8. Improve Institutional Support: Offer financial and logistical assistance to makerspaces to establish a favorable climate that fosters innovation and trial-and-error in the educational context.
9. Integrate Makerspace Activities into Academic Courses: Enhance traditional learning approaches and educational outcomes by integrating makerspace activities into academic courses.

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