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Transforming Education in Pakistan: A Comprehensive Review of Infrastructure, Innovation, Equity, and Environmental Sustainability in 21st Century Learning Systems

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ABSTRACT

This review is a multifactor analysis of the challenges and innovations encountered in the education system of Pakistan which includes early childhood education, skill-based education, STEAM, integration, educational infrastructure and environmental sustainability. This paper is based on 52 studies carried out between 2024 and 2025 as latest studies and is aimed at analyzing such critical issues as teacher shortages, lack of infrastructure in religious seminaries (madaris), digital transformation of learning conditions, gender equity in education, and the integration of environmental awareness into the curriculum. The review identifies the new trends in innovation such as teacher-led micro-edtech economies, artificial intelligence in school administration, or grassroots entrepreneurial ecosystems. Based on comparative studies in South Asian settings, the paper determines systemic obstacles, policy implementation failures, and effective interventions that promote educational quality and accessibility. The results highlight the necessity to have combined frameworks that can align between the traditional and modern education paradigm and tackle the socio-environmental issues.

Keywords: *STEAM Education, Educational Innovation, Skill-Based Learning, Infrastructure Issues, Environmental Education, Teacher Professional Development, Educational Equity, Pakistan Education System.*

INTRODUCTION

Pakistan education systems are experiencing challenges that have not been seen before and needs a wholesome transformation in terms of pedagogical strategies, development of infrastructure and curriculum innovation. The education system in the country has a population of more than 50 million students in various forms of institutional settings such as public schools, privately operated institutions, traditional religious seminaries (Rafiq-uz-Zaman and Nadeem, 2025), but it is still typified by a number

of problems such as a shortage of teachers, inadequate facilities, lack of technology, and a high degree of gender imbalance.

This is a review paper of 52 recent studies of educational transformation in Pakistan under various dimensions that are interrelated: infrastructure and resource allocation, early childhood education issues, innovative pedagogical methods including STEAM education, skill-based learning models, technology integration, environmental education, gender equity and social inclusion, and leadership and policy implementation. The review offers evidence-based information on how educational stakeholders should navigate through the highly complicated landscape of educational reform in resource-constrained settings by analyzing these dimensions as a unified whole.

INFRASTRUCTURE PROBLEMS IN MULTICULTURAL SCHOOLS

Infrastructure Shortcomings within Religious Educational Institutions.

Religious seminaries (madaris) are an important educational aspect in Pakistan but they have gross infrastructure problems that hinder quality and student welfare (Rafiq-uz-Zaman and Nadeem, 2025). Critical examination of the situation showed acute shortages such as absence of computer facilities, poor libraries, poor sanitation and little modern education technologies. Academic needs assessments revealed serious gaps in the field of science, technology, and English teaching (Javed et al., 2025), which restrict the opportunities of students to further education and a wide range of career options.

School Safety and security Infrastructure

The study of the perceptions of school administrators also showed considerable gaps in the implementation between identified safety requirements and actual actions (Bukhari et al., 2025). The lack of resources became the major impediments to the complete security infrastructure, as the lack of boundary walls, insufficient lighting, and emergency procedures led to a significant impact on the safety and engagement of female students.

Infrastructure Environmental Health

Water sanitation and solid waste management became important infrastructure issues (Shah et al., 2025; Sutikno and Aisyahrani, 2022). Poor waste collection systems and untested groundwater supply posed health risks that had direct implications on the student attendance and health, and the gender-separated sanitation facilities had a direct effect on the female retention.

EARLY CHILDHOOD EDUCATION: PROBLEMS AND NOVELTIES

Teacher Shortage Crisis

In Punjab, early childhood care and education (ECCE) has a severe problem with teacher shortages, as many of the centers have a single teacher who has over 40 children (Otoluwa et al., 2022). These are exacerbated by low pay, lack of adequate training facilities and geographic differences, with rural centers having significantly higher percentage unqualified personnel compared to urban centers. The aftermath does not just end in quantitative measures but also in the lack of the ability to develop appropriately and high staff turnover rates.

STEAM in Early Childhood Education

The use of STEAM in ECCE introduces creative and problem-solving methods (Masih et al., 2025). The comparative analysis of Pakistani and Indonesian systems showed that Indonesian programs were more systematic with structured professional development (Pujianti et al., 2023) showing more integration of STEAM, whereas Pakistani programs remained very traditional. Nevertheless, STEAM implementation

does not need much costly equipment to be successful when it focuses on the use of everyday resources that encourage enquiry and exploration.

STEAM EDUCATION: IMPLEMENTATION, COMPARATIVE ANALYSIS, AND EVIDENCE

STEAM Effect on Creativity and Innovation

A thorough narrative review of the effect of STEAM education (2020-2025) showed that it had a consistent positive effect on creative thinking, problem-solving skills, and innovative attitude with medium to large effects sizes being apparent especially in the divergent thinking and originality. The application of design thinking and iterative problem-solving with a focus on real-world issues with multiple solution-finding options showed particularly good outcomes in project-based STEAM learning.

Enhancing 21st Century Skills

STEAM education proves to be effective in terms of collaboration, communication, critical thinking, and self-directed learning development (Rafiq-uz-Zaman et al., 2025c). The interdisciplinary projects also help in the development of collaborative skills, multimodal communication practices, and analytical evaluation, which are all vital in the modern workplaces and societies.

Comparative Implementation: Pakistan and India

Relative analysis showed that the Indian system has a higher investment in STEAM infrastructure and teacher training, so it can be applied more, whereas the STEAM in Pakistan is only introduced in elite schools (about 45% of the total schools vs. 15% of state schools), which serves to strengthen inequality in education. Integration of curriculum strategies varied greatly with India focusing more on integrated subjects and Pakistan focusing more on STEAM as individual enrichment activities.

STEAM Professional Development of teachers

Successful professional development focuses on the long-term interaction, learning communities, and the combination of content with pedagogy (Manikutty et al., 2024). Nevertheless, institutional challenges such as overloaded curricula, disciplinary-focused assessment, restricted access to resources, and the differences in administrative support pose a severe limitation to the success of STEAM implementation.

SKILL-BASED EDUCATION: FRAMES, LOOPHOLES AND POLICY OPTIONS

The Integrated Skill-Based Education Framework (ISEF)

The ISEF describes interrelated aspects such as curriculum design, pedagogy, assessment plans, teacher training, industry relations, and quality assurance (Rafiq-uz-Zaman, 2025b). Competency-based progression supports various learning pathways, with a focus on technical skills, underpinning competencies, and transversal ones such as problem-solving and collaboration. Pedagogical methods focus on experience in the workplace via training, project learning and simulation practice.

Comparative Analysis based on SAARC Countries

The comparison of the countries revealed that those with greater education-labor market alignment, industry engagement, and quality assurance obtained higher employment results (Rashid et al., 2025). The National Vocational Qualifications Framework in Sri Lanka became a model in that it standardized competencies and made it easier to transfer credit. The skill-based education in Pakistan was fragmented, with low levels of industry coordination, thus showing low enrollment (6 percent of upper secondary students) with minimal employment benefits as compared to the general education (Rafiq-uz-Zaman, 2025).

Student Perceptions and Success Factors

A study on student perceptions showed that there are big disparities between curricular intentions and outcomes that they are experiencing (Rafiq-uz-Zaman and Nadeem, 2025). Students highlighted poor workshop equipment, instructor skills weakness, and exposure at work. Gender aspects became apparent, as the female students were challenged by the cultural limitations, insufficient facilities, and the necessity to have female role models (Rafiq-uz-Zaman and Nadeem, 2025).

Marginalized Population Skill-based Education

Investigation into the skill-based education of the transgender population (eunuchs) in South Asia found significant impediments such as institutional discrimination, insufficient facilities and mismatch between the curriculum and their needs and livelihood patterns (Rafiq-uz-Zaman, 2025c). Specific initiatives aimed at women economic empowerment were promising to improve both employment and income, but their effectiveness was dependent on being relevant to local labor markets, childcare services, and microenterprise development (Rafiq-uz-Zaman et al., 2024).

DIGITAL CHANGE AND EDUCATION TECHNOLOGY

School Management using Artificial Intelligence

The application of AI in school management systems showed a variety of applications such as attendance control, monitoring student performance, resource optimization, and early warning (Rashid et al., 2025). Implementation however needs to be successful by having strong infrastructure, thorough training of administrators, open administration where privacy issues are addressed and participatory implementation where educator and community voice is involved.

Low Resource Teacher-Led Innovation

Micro-edtech economies led by teachers showed that the transformation of educational technology could be organized on grassroots (Connor et al., 2015). Educators designed localized online learning materials, WhatsApp learning groups, and community resource collections with open-source tools. Systemic support involves redefining the concept of professional development by incorporating the creation of technologies, creating collaborative platforms, and offering small seed funding to promising projects.

Gender Aspects of Educational Technology

It was found that there were still gender inequalities in technology accessibility, patterns of usage, confidence, and experiences of online harassment (Mahmood et al., 2024). Women students had lower access to devices, less access to home connectivity, less time on technology because of domestic obligations and more cyberbullying. The solutions to these imbalances are equal access to devices, learning design that accommodates technology, specific confidence-building, explicit anti-harassment policies, and the curriculum that discusses gender stereotypes in technology.

SUSTAINABILITY INTEGRATION AND ENVIRONMENTAL EDUCATION

Mathematics Education and Environmental Awareness

Mathematics problems with environmental contexts added involvement and perception of relevance with students (Rashdi et al., 2025; Rafiq-uz-Zaman et al., 2024). Nonetheless, obstacles were gaps in teacher confidence, the inability to find suitable situations, curriculum pressure, and assessment systems that focused on procedural skills. Responses of students were overall positive with three-quarters reporting that there was more interest in mathematics when problems were related to environmental issues and some reported frustration when environmental contexts made mathematical concepts less clear.

Environmental Education to Mitigate Smog

The school-based environmental education became an important element of overall smog reduction efforts (Lee, 2012). Some of the best strategies were offered to learn the causes and health effects of smog, adopt preventive actions, minimize the pollutant contribution, and collective advocacy. Education generates political goodwill towards regulatory action, sets environmental responsibility standards, and establishes technical capacity to develop sustainability solutions but needs to be supported by infrastructure development and policy action (Rafiq-uz-Zaman et al., 2024a).

Solid Waste Management Education

Programs that have integrated knowledge delivery and practical skills acquisition and real action showed better behavior changes (Sutikno & Aisyahrani, 2022). Nevertheless, educational interventions need to facilitate the context of the infrastructure where desirable behaviors are achievable. Trained students experienced frustration when mixed materials were put in the same cans because of insufficient municipal infrastructure, and this was why interventions to be made in education were seen to be in need of alignment with the infrastructure and policy implementation.

The Historical Approaches to the Environmental Degradation

The historical analysis showed the tendencies of a reactive, but not proactive environmental policymaking (Rafiq-uz-Zaman et al., 2024). The reason behind why the past decisions resulted in embedded infrastructure, institutions, and economic systems that supported the environmental degradation can shed light on the current issues and the students can be seen as potential change agents and not as passive consumers of the environmental issues. The historical survey shows that environmental movements have already acquired good changes, which may serve as precedents to today (Rafiq-uz-Zaman et al., 2024b).

EDUCATIONAL LEADERSHIP, POLICY AND GOVERNANCE

Leadership Styles and Effectiveness of Management

The comparison of authoritative and democratic leadership showed some specific patterns of the effect they have on teacher satisfaction, institutional climate, and management effectiveness (Haq, 2025). Democratic leadership was more effective in enhancing teacher commitment and collaborative cultures, but needed a lot of time. Gender aspects were also considered as equity issues, where female educational leaders were harassed and discriminated against and were subjected to structural disadvantages (Ullah et al., 2025). To facilitate the advancement of women in leadership in education, systemic measures must be put in place that covers the cultural mind-set and the policies of institutions and the protection of women against harassment.

Policy Implementation Gaps

It has been analyzed that there have been chronic discrepancies between the ambitious educational policies and uneven implementation (Bukhari et al., 2025). The implementation of Single National Curriculum disclosed the lack of teacher training, a lack of instructional resources, a lack of pedagogical knowledge, and a lack of monitoring of the implementation quality (Kazmi et al., 2023). Implementation gaps can only be bridged through participatory policy development, realistic implementation timelines, constant monitoring with feedback loops, sustained resources allocation and capacity building of implementation among the middle-tiers administrators.

Teacher Well-Being and Stress Management

The study found out that there are complicated connections between emotional intelligence, coping with stress, and well-being among teachers (M et al., 2023). The causes of teacher stress were excessive work, poor pay, poor professional growth, poor working conditions, high classes, and lack of administrative support. The interventions needed to support teacher well-being include the use of coordinated interventions that focus on the development of individual emotional intelligence, the leadership of the institution that supports teachers, and systemic interventions that deal with structural stressors.

Special needs and Supportive Education

Inclusive education studies showed that there were major difficulties such as poor teacher training, lack of resources and materials, poor infrastructure, and low organization in special-regular education (Javed et al., 2025). Lack of teacher preparation resulted in anxiety and resistance in approach towards diverse students. The inclusive education must be advanced with full-blown reforms that include integration of pre-service teacher education, years of in-service professional growth, co-teaching, infrastructure modification, and attitudinal barriers.

DISCUSSION: FINDINGS SYNTHESIS AND CROSS-CUTTING THEMES

Integration of Problems in the Educational Aspects

The general overview of the problem raises certain trans-cutting areas that erode the educational change:

Infrastructure and Resources shortages: The absence of resources and their uneven distribution represent systemic bottlenecks in all the discussed dimensions (Rafiq-uz-Zaman and Nadeem, 2025; Shah et al., 2025). Geographic and socioeconomic disparities still serve to perpetuate educational disparity in which the disadvantaged populations receive poor quality education at the very age during which equity-focused intervention strategies can be best provided.

Policy-Practice Mismatches: Ground-level implementation reveals the absence of teacher education, a lack of monitoring, and responsibility despite the emphasis of policies on the importance of skills development, environmental integration, and inclusive practices (Bukhari et al., 2025; Kazmi et al., 2023). This gap implies that the policy making process should be backed by a realistic implementation plan inclusive of training the teachers, resources and monitoring system provision.

Teacher Capacity and Support: Teachers become the center of all the improvements yet they are not sufficiently supported on all the dimensions (Javed et al., 2025; M et al., 2023; Otoluwa et al., 2022). Whatever the new curricula, the inclusion of the environmental content, the necessity of the inclusion of the diverse learners the teachers must have adequate preparation, professional development, manageable loads, remuneration that is competitive and institutional facilitation. The fundamental aspects influencing the quality of education are existing conditions, where understaffing, lack of training, excessive workloads, and low payment are the concomitants.

Gender Equity Across Dimensions: The reviewed articles state that the existence of gender differences can be observed in all dimensions including access to early childhood education (Otoluwa et al., 2022), attendance of skill-based education (Rafiq-uz-Zaman and Nadeem, 2025), access to technologies and harassment (Mahmood et al., 2024), and the possibility to be a leader (Ullah et al., 2025). In a bid to address gender equity, the interventions on the infrastructure, contents of the curriculum, the institution policies and cultural attitudes are those that should be addressed in totality.

CEO-led Innovative Solutions and Fast Development

However, it has certain positive shifts in innovative technologies:

Teacher-Led Innovation: Teacher-led micro-edtech economies demonstrates the way technological transformation can be caused by the grassroots initiative in resource-constrained settings (Connor et al., 2015). Enabling educators to be the producers, and not the consumers, of educational technology; scale-up and share of resources, allowing systemic collaboration; deliver long-term and scalable solutions to educational technology integration.

Integrated Skill-based Education Framework: In case of the examples of the Integrated Skill-based Education Framework (ISEF), STEAM education integration, and the environmental education approaches, it can be seen that a complete approach with lots of interacting dimensions proves to be more efficient than a standalone one. These strategies recognise that sustainable change must be achieved via concerted action about the curriculum, pedagogy, assessment, teacher development and institutional assistance.

Comparative Learning: Comparative learning with regional partners (India and Indonesia) discovered that by being more coordinated, industry better engaged and quality assured better results (Pujianti et al., 2023; Rashid et al., 2025). Pakistan can make use of regional experience and adapt to local conditions and constraints.

Community Engagement: Local interventions like learning WhatsApp groups (Connor et al., 2015) and community environmental education on local community matters demonstrates that local community-based interventions contribute to the effective interaction and behavior change in the long run.

CONCLUSION

Pakistan education system is in a crossroad. These significant institutional problems include inappropriate infrastructure, insufficient number of teachers, policy gaps, and gender inequality which influence the quality of education and promote inequality. Nevertheless, the possibilities of change have been demonstrated by new technologies in teacher-led technology, integration of STEM, skill-based education reform, and environmental education. The synthesis of the research contained in this review demonstrates that in order to enhance education, overall and integrated strategies, giving attention to all the interlocked dimensions simultaneously rather than single interventions at a time on the dimensions should be taken.

The existing gap between high-profile policies and unfair implementation continues to stir as a feature problem that requires tactical action. The introduction of the new curriculum changes and online programmes, skill-based education cannot take place without providing sufficient preparations of the teachers, allocation of resources, institutional support and regulated accountability. The education sector in Pakistan needs not just another policy but a strategy of implementation that is realistic in terms of timelines, dedication to resources, and orderly observation of the education system to enable it to adjust to the new arising challenges.

The support of the teachers proves to be the issue of the first order in any academic progress. Nevertheless, be it the establishment of STEAM curriculums or environmental education, scaffolding of diverse students, or school leadership, educators should have adequate training, ongoing professional development, work-load, salaries and acknowledgment within the institution. The poor quality of education is caused by existing understaffing, low training, work overloads, and low wages. The most vital lever of educational change is the investment in teacher well-being, development, and support, which is the most critical as well.

Equity between sexes should be carefully regarded in all the fields of education. The prevalent gender inequality reflects the structural inequality and the cultural perspectives since the skill-based training, the use of technology, and educational leadership make the access to the early childhood education available.

These imbalances require unified efforts both in regard to infrastructure development, content of the curriculum, as well as in institutional policies and cultural norm change.

RECOMMENDATIONS

Policy and Governance Level

Create Integrated Education Transformation Commission: Have a special inter-ministerial commission to infuse education, skills training, environment and technology programs to ensure that policy is in-unison (Bukhari et al., 2025; Rafiq-uz-Zaman, 2025b).

Embracement Realistic Implementation Planning: "Lay off policy promotion and proceed to realistic implementation planning, including timelines, resource plans, teacher training plans and teacher monitoring systems. Create change agents at the middle-tier administration (Bukhari et al., 2025; Kazmi et al., 2023).

Implement Performance-Against-Plan Accountability Systems: Implement the tracking system concept where an adaptive implementation takes place through the use of a continuous monitoring system with feedback capabilities. Reclaim the compliance-based accountability model to the outcome-based model of student learning, teacher development and institutional performance (Bukhari et al., 2025).

Increase Public Investment in Education: Acutely increase the amount of money spent on education budget particularly in infrastructure development, teacher pay and teacher development. The tendency towards under-investment is prevailing and limiting the prospects of change (Otoluwa et al., 2022; Rafiq-uz-Zaman and Nadeem, 2025).

Design Gender-Responsive Education Policies: Implement explicit gender equities policies on infrastructure (separate sanitation facilities, safe learning space), curriculum (and stereotypes), institutional practice (empowering female educators and leaders), and cultural change (Mahmood et al., 2024; Ullah et al., 2025).

Teacher Development

Comprehensive Teacher Professional Development Program: Implement a sustained and practice-based professional growth of teachers on in-service based on the mode of STEAM integration, environmental education, inclusive practices, and the use of technology. Ensure that construction of professional learning communities in which the development of teachers is facilitated occurs (Javed et al., 2025; Manikutty et al., 2024).

Integrated Teacher Preparation Reform: Restructure the pre-service teacher education into a structure that integrates modern pedagogies (STEAM, project based education, environmental education, inclusive practices) across all the curricula as opposed to just one course. Build teacher proficiency in order to facilitate integrated and interdisciplinary teaching (Javed et al., 2025; Manikutty et al., 2024).

Address Teacher Stress and Well-Being: Multi-level intervention, including building of emotional intelligence, stress management programs, workload reducing programs, competitive pay systems, and school leadership support. It is important to note that teacher well-being affects the quality of education (M et al., 2023).

Grow Teacher Supply: Urgent supply of teachers to the early childhood learning field and specialization in recruitment, training and incentives. The geographical distribution of the teachers should be aware of the inequity and equalized (Otoluwa et al., 2022).

Infrastructure and Allocation of Resources

Infrastructure Investment Priority: Invest in infrastructure in the underprivileged institutions including madaris, schools in the rural areas, and under-invested urban areas. These investments should be associated with the aspects of physical learning, water and sanitation, waste management, and technological accessibility (Rafiq-uz-Zaman and Nadeem, 2025; Shah et al., 2025; Sutikno and Aisyahrani, 2022).

Gender-Responsive Infrastructure: Ensure that the infrastructure facilities are in a gender-segregated, safe, and armed manner accessible to both normal and disabled students and equally, gender-specific technology (Mahmood et al., 2024).

Support Teacher-Led Innovation: Institute systems that support teacher-led technology innovation include small-scale seed funding, resource-sharing platforms, incentive system and recognition, and technology development professional development (Connor et al., 2015).

Pedagogical and Curriculum Innovation

Systematic integration of STEAM into education: Systematize the idea of STEAM education at the K-12 education level, not only in the elite private schools, to make as many learners as possible available to innovative pedagogy. Dwelling on the project-based learning, veritable problem solving, and interdisciplinary interwovenness (Rafiq-uz-Zaman, 2025a; Rafiq-uz-Zaman and Nadeem, 2025).

Inclusion of Environmental Education: Core to curriculum Incorporate environmental education at the core of the curriculum, including mathematics, science, and social studies, and provide concrete opportunities of environmental action and altering the infrastructure that facilitates sustainability activities (Lee, 2012; Rashdi et al., 2025).

Skill-based Education Framework: Adopt Structured Skill-based Education Framework(ISEF) which ensures a consistency in the curriculum design, pedagogy, assessment, teacher education and industry relations. Strengthen the systems of educational coordination and quality assurance in the industry (Rafiq-uz-Zaman, 2025b; Rashid et al., 2025).

Inclusive Education Practices: Phase in step by step manner offer inclusive education practices in order to ensure that the students with varied abilities are in a position to access mainstream classrooms with all the support required. In addition to the good intentions to comprehensive infrastructures, education of teachers, collaboration, and institutional investments (Javed et al., 2025).

Online Equity and Technology Fusion

Equal Opportunity in Technology: Equitably offer access to technology on the basis of socioeconomic and gender realities through institutional device lending programs, linking support, and learning design to the support of various access conditions (Mahmood et al., 2024).

Artificial Intelligence and Ethical Oversight: When there is the use of artificial intelligence in the management of the school, come up with a powerful governing board that encompasses privacy, algorithmic discrimination, transparency as well as fair implementation. Ensure that AI does not consist of the professional judgment of educators (Rashid et al., 2025).

Digital Literacy Development: Establish all-encompassing digital literacy programs among students and educators which encompass information literacy, online safety, online citizenship and online critical analysis (Mahmood et al., 2024).

Social Inclusion and Equity of Gender

Specific Gender Equity Programs: Gunpowder other programs (gender equity) that involve not only revision of its curricular content with regards to stereotyping, but also its recruitment and empowerment of its female educators, the provision of infrastructure to allow female learners to feel safe and comfortable as well as cultural transformation programs (Mahmood et al., 2024; Ullah et al., 2025).

Inclusive Programming of Marginalized Groups: K-12 Develop customized skills and vocational education and job training initiatives of marginalized communities such as transgender individuals and economically disadvantaged youngsters and do this with community engagement taking into account individual obstacles and requirements (Rafiq-uz-Zaman et al., 2024; Rafiq-uz-Zaman, 2025c).

Monitoring and Evaluation

Establish Excellent Surveillance Systems: Have well-developed surveillance of education outcomes including educational results, growth of skills, labor market results, teacher quality and equity indicator. Ensure that disaggregated data cross gender, socioeconomic and geographical patterns to keep track of inequality reduction (Bukhari et al., 2025).

Research and Evidence Generation: Proficiency on the action research and the intensive examination of teaching activity which generates indications on the efficient processes in the Pakistani contexts. Established research capability in educational institutions which can be used to continuously improve (Rafiq-uz-Zaman, 2025a; Rashid et al., 2025).

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