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Physics Education and the Digital Divide: An Empirical Study of Educational Inequality in Rural and Urban Murshidabad

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Abstract:

The digital transformation of education has fundamentally altered the nature of teaching and learning, particularly in science disciplines such as physics, where conceptual understanding increasingly depends on visualisation, simulation, virtual experimentation, digital laboratories and technology-supported instructional practices. However, the benefits of digital education are not distributed equally across geographical and socioeconomic groups. This research examines the relationship between physics education and the digital divide through an empirical investigation of educational inequality between rural and urban areas of Murshidabad district, West Bengal. The study explores how disparities in internet connectivity, smartphone and computer accessibility, electricity supply, household income, parental educational background, institutional infrastructure and teachers' digital competencies influence students' participation and achievement in physics education. Particular attention is given to the differences between theoretical instruction and technology-supported experiential learning. The research conceptualises the digital divide not merely as a question of access to electronic devices but as a multidimensional educational inequality involving availability, affordability, digital literacy, quality of engagement and learning outcomes. It proposes a comparative empirical framework involving rural and urban secondary and higher-secondary institutions, students and physics teachers. The study further examines the implications of the National Education Policy 2020, Digital India, PM e-VIDYA and other educational initiatives for equitable science education. It argues that digital inclusion in physics education must become an essential component of educational justice, scientific literacy and sustainable human capital development. The paper concludes by proposing a context-sensitive framework for strengthening digital physics education in Murshidabad through institutional investment, teacher training, community-based digital learning facilities and inclusive pedagogical innovation.

Keywords: Physics Education, Digital Divide, Educational Inequality, Rural–Urban Disparity, Murshidabad, Digital Literacy, ICT in Education, Scientific Learning, Educational Inclusion.

Introduction

Education in the twenty-first century is increasingly shaped by the integration of digital technologies into instructional practices, knowledge production and academic participation. The emergence of online learning platforms, interactive simulations, virtual laboratories, digital textbooks and artificial intelligence-supported educational resources has transformed the possibilities of science education. Among the different disciplines, physics occupies a particularly important position because its conceptual structure frequently requires students to interpret abstract phenomena, understand mathematical relationships, visualise invisible processes and connect theoretical principles with observable realities. Digital technologies can strengthen these learning processes

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through animation, simulation, experimentation and interactive visualisation. For example, students can understand electromagnetic fields through graphical representations, examine projectile motion through simulations and explore the behaviour of electric circuits through virtual experiments. Nevertheless, the availability of such opportunities depends significantly on the technological and socioeconomic conditions within which students learn. The digital revolution, therefore, presents a paradox: while technology has expanded the possibilities of educational democratisation, it has simultaneously created new forms of educational exclusion.

The digital divide refers to inequalities in access to, affordability of and effective utilisation of information and communication technologies. In education, this divide becomes particularly significant when students from economically disadvantaged households cannot access the technological resources necessary for meaningful academic participation. The problem extends beyond the ownership of smartphones or computers. A student may possess a smartphone but lack reliable internet connectivity, sufficient data, a quiet learning environment or the digital literacy required to use educational applications effectively. Similarly, an educational institution may have computers but lack functional laboratory equipment, trained teachers or consistent technical support. Consequently, the distinction between digitally connected and digitally empowered learners becomes essential in understanding contemporary educational inequality.

Murshidabad provides an important geographical and educational context for examining this phenomenon. The district contains diverse rural settlements, developing urban centres, agricultural communities, commercial locations and educational institutions with varying infrastructural capacities. While urban centres such as Berhampore have comparatively greater concentrations of educational institutions, communication facilities and private educational services, many rural communities experience different levels of infrastructural and socioeconomic accessibility. These differences may influence students' exposure to digital physics education, particularly where learning depends on online resources, virtual experimentation and technology-assisted classroom activities.

Physics education in this context cannot be understood exclusively through examination results or textbook-based instruction. It must also be examined through students' opportunities to experience science as an investigative, experimental and technologically supported discipline. A student who regularly uses virtual laboratories, educational simulations and online scientific resources may encounter a substantially different learning environment from a student whose educational experience remains largely restricted to conventional classroom explanations and textbook exercises. This research consequently investigates how the digital divide shapes the opportunities, experiences and educational outcomes of rural and urban students studying physics in Murshidabad. It approaches digital inequality as a structural educational concern rather than merely a technological inconvenience.

Review of Literature

The relationship between educational technology and educational inequality has attracted considerable attention in contemporary educational research. *Warschauer (2003)* argued that digital inclusion involves much more than the physical availability of computers; it requires meaningful access to technological resources, educational content and opportunities for social participation. His perspective is particularly relevant to science education because access to technology does not automatically ensure the development of scientific understanding. Students must possess the skills and educational support necessary to transform digital information into meaningful knowledge. *Selwyn (2004)* similarly questioned the assumption that technology automatically improves

educational opportunities, emphasising that socioeconomic circumstances, institutional conditions and patterns of technology utilisation determine the actual educational benefits of digital resources.

Van Dijk (2005) conceptualised the digital divide through inequalities in material access, skills, usage and participation. This framework provides an important theoretical foundation for understanding rural–urban educational differences in Murshidabad. *Hohlfeld et al. (2008)* demonstrated that the digital divide in educational environments involves differences in technology availability, teacher preparation and the capacity of schools to integrate digital resources into classroom instruction. Their observations suggest that institutional infrastructure and pedagogical competence must be examined together.

Research on science education has also established the importance of digital simulations and interactive learning environments. *Rutten, van Joolingen and van der Veen (2012)* reviewed the effectiveness of computer simulations in science education and highlighted their potential to improve conceptual understanding when appropriately integrated with classroom teaching. *Smetana and Bell (2012)* similarly found that computer simulations can support science learning by allowing students to investigate complex phenomena and develop conceptual relationships. However, these pedagogical advantages become unequally distributed when access to technological resources varies between educational institutions and households.

In the Indian context, *the Annual Status of Education Report* has repeatedly highlighted differences in household resources, learning opportunities and educational access. *ASER 2024* provides particularly relevant evidence concerning rural digital literacy. It reported that 89.1% of surveyed children aged 14–16 had a smartphone available at home, while only 65.9% could bring a smartphone to perform digital tasks and 31.4% of those able to use a smartphone owned their own device. These figures illustrate that household availability and individual educational access are not equivalent.

The National Education Policy 2020 also recognises the transformative potential of digital education while acknowledging the importance of addressing the digital divide. Its emphasis on technology-enabled learning, virtual laboratories, teacher development and equitable educational access provides a policy foundation for the present investigation. Despite these contributions, there remains a need for district-level research examining how digital inequality specifically affects physics education, particularly in rural and urban settings within Murshidabad.

Research Gap

Existing literature has extensively examined the digital divide in general education, digital literacy, online learning and educational technology. However, relatively limited attention has been directed towards the relationship between digital inequality and discipline-specific learning experiences, especially in physics education at the district level. Physics has distinctive pedagogical requirements involving experimentation, mathematical modelling, graphical interpretation, conceptual visualisation and practical demonstrations. Consequently, digital exclusion may affect physics learning differently from subjects that rely primarily on textual resources. Furthermore, broad national and state-level statistics frequently conceal local variations between rural and urban institutions. The educational circumstances of students in Berhampore cannot automatically be considered representative of students studying in remote rural areas of Murshidabad. There is therefore a research gap concerning the relationship between household digital accessibility, institutional infrastructure, teachers' technological competencies, gender-based inequalities and students' conceptual understanding of physics. The

present study seeks to address this gap through a comparative empirical framework that connects digital accessibility with the quality, continuity and inclusiveness of physics education.

Objectives of the Study

The principal objective of this research is to investigate the relationship between digital accessibility and educational inequality in physics education across rural and urban areas of Murshidabad. It seeks to examine differences in the availability of smartphones, computers, internet connectivity and other digital learning resources among students belonging to different geographical and socioeconomic backgrounds. Another objective is to investigate the extent to which digital technologies are integrated into physics teaching practices in secondary and higher-secondary institutions. The study also aims to understand how economic conditions, parental educational backgrounds, gender differences and institutional infrastructure influence students' opportunities to participate in digital learning. Furthermore, it examines teachers' preparedness to use digital simulations, virtual laboratories, multimedia presentations and online educational platforms. Finally, the research aims to propose an inclusive framework for reducing digital educational inequality and strengthening scientific learning opportunities throughout Murshidabad.

Research Questions and Hypotheses

The study is guided by several interconnected research questions. To what extent do rural and urban students differ in their access to digital learning facilities for physics education? Does household economic background influence the frequency and quality of students' engagement with digital physics resources? How do differences in institutional infrastructure affect the integration of digital tools into classroom teaching? Does the availability of virtual laboratories and simulation-based instruction contribute to improved conceptual understanding? What role do teachers' digital competencies play in reducing educational inequality? The study also investigates whether female students and students from economically disadvantaged households experience additional barriers to digital participation.

The following hypotheses may be examined through primary data collection. First, there is a significant difference between rural and urban students in access to digital physics learning resources. Second, household socioeconomic status is positively associated with students' opportunities for digital engagement. Third, institutional internet connectivity and functional computer facilities are positively associated with the frequency of technology-supported physics instruction. Fourth, students receiving regular access to simulation-based learning demonstrate differences in conceptual understanding compared with students receiving predominantly conventional instruction. Fifth, teacher digital competency significantly influences the effective integration of educational technology into physics classrooms.

Research Methodology

The proposed study adopts a descriptive, comparative and analytical research design, combining quantitative and qualitative approaches. Its geographical focus is Murshidabad district of West Bengal, with comparative attention to urban educational centres such as Berhampore and selected rural educational locations across the district. The target population comprises secondary and higher-secondary students studying physics, physics teachers and selected institutional representatives. A proposed sample may include approximately 200 students, 40 physics

teachers and 20 educational institutions, with participants distributed between rural and urban locations. These figures represent a suggested research design rather than completed fieldwork.

A stratified sampling technique may be adopted to ensure representation of rural and urban institutions, government and private schools, and different socioeconomic groups. Primary data can be collected through structured student questionnaires, teacher interviews, institutional observation schedules and physics achievement assessments. The student questionnaire should examine household device availability, personal device ownership, internet affordability, access to educational applications, frequency of digital learning and participation in online practical activities. Teacher interviews should explore professional training, institutional technical support, use of simulations and the difficulties associated with technology-assisted instruction.

Secondary information may be collected from UDISE+, ASER reports, government educational policies, district statistical publications and relevant academic literature. Quantitative analysis may include percentages, mean scores, standard deviation, correlation coefficients, independent-sample t-tests and regression analysis, depending on the nature and distribution of the collected data. A digital accessibility index may be constructed by combining device availability, connectivity, affordability, electricity reliability, digital literacy and frequency of academic use. A separate physics learning engagement index may incorporate students' participation in simulations, virtual experiments, online problem-solving and digital instructional activities. Qualitative responses can be analysed thematically to identify the institutional and social factors underlying digital inequality. Ethical considerations should include informed consent, confidentiality, voluntary participation and responsible use of student information.

Importantly, the numerical results of the proposed survey must be obtained through actual fieldwork. National and state-level statistics discussed in this paper provide contextual evidence but cannot be treated as direct measurements of the rural–urban digital divide in Murshidabad.

Digital Infrastructure and Educational Inequality: The West Bengal Context

The digital infrastructure of educational institutions provides an important starting point for understanding inequalities in technology-supported learning. UDISE+ 2023–24 reported that only 17.5% of schools in West Bengal had internet facilities, compared with the national figure of 53.9%. The report further indicated that internet availability differed substantially by school management: 15.1% among government schools, 68.1% among government-aided schools and 36.4% among private unaided schools.

These figures reveal a significant structural challenge for technology-supported education in the state. They also indicate that the institutional capacity to provide digital learning opportunities is unevenly distributed.

The disparity has direct implications for physics education. An institution without reliable internet connectivity may find it difficult to provide continuous access to online educational platforms, digital simulations and virtual laboratory resources. Even where computers are available, their educational usefulness depends on functionality, maintenance, electricity and teachers' capacity to integrate them into classroom activities. The distinction between infrastructure availability and functional pedagogical utilisation is therefore fundamental.

It is equally important to recognise that state-level statistics cannot establish the precise digital conditions of individual schools in Murshidabad. A district-specific survey is necessary to determine whether rural government institutions experience greater barriers than urban institutions and whether differences exist between government-

aided and private educational establishments. The present research consequently uses the West Bengal figures as a broader structural indicator rather than as a substitute for district-level empirical findings.

Rural–Urban Digital Divide in Murshidabad

The rural–urban digital divide in Murshidabad must be examined through the interaction of geographical accessibility, household economic conditions and institutional resources. Berhampore, functioning as an important administrative and educational centre, has a concentration of schools, colleges, coaching institutions, libraries and commercial communication facilities. Students in urban settings may have comparatively greater opportunities to access computer centres, private educational services, broadband connections and technology-supported academic resources. However, these advantages should not be assumed to be universal, as economically disadvantaged urban households may also experience restricted access to digital devices and reliable connectivity.

Rural areas present a different set of challenges. The distance between educational institutions and technological service centres may influence students' opportunities to access digital learning resources. Household income, the affordability of mobile data, shared ownership of smartphones and limited availability of computers may affect the continuity of educational engagement. Students whose family members depend on mobile phones for occupational purposes may not have unrestricted access to devices for academic activities. Consequently, the mere presence of a smartphone within a household does not necessarily establish an adequate learning environment.

The problem becomes particularly significant at the higher-secondary level, when physics learning requires access to mathematical resources, digital demonstrations, practical simulations and supplementary instructional materials. Students in institutions with limited technological infrastructure may remain dependent on conventional teaching methods, even when advanced digital resources are available elsewhere. This produces a difference not necessarily in students' intellectual potential but in the educational opportunities available to develop that potential.

A comparative empirical investigation should therefore distinguish between rural and urban institutions rather than treating each geographical category as internally uniform. Differences in school management, household income, parental education, connectivity and teacher training must also be considered. Such an approach would provide a more accurate understanding of the relationship between geographical location and educational inequality.

The Digital Divide and the Nature of Physics Learning

Physics is a discipline in which the relationship between theoretical knowledge and observable phenomena is particularly important. Students frequently encounter difficulties understanding concepts that cannot be directly observed through ordinary sensory experience. Electromagnetic induction, wave propagation, atomic structure, gravitational fields, electric potential and quantum phenomena require abstract reasoning and scientific visualisation. Digital technologies can provide valuable assistance in overcoming these conceptual difficulties by presenting scientific processes through animation, interactive models and simulations.

For example, an interactive simulation of projectile motion enables students to explore the relationship between initial velocity, angle of projection and trajectory. Similarly, digital circuit simulations allow learners to investigate the relationship between resistance, current and voltage. Such experiences encourage students to formulate hypotheses, modify variables, observe outcomes and develop scientific explanations. The availability

of these opportunities may therefore contribute to a more exploratory and inquiry-oriented approach to physics education.

However, students who lack personal devices, reliable internet access or institutional computer facilities may experience fewer opportunities to engage with these learning environments. Their understanding may depend more heavily on textbook diagrams, teacher explanations and limited practical demonstrations. Conventional teaching is not inherently ineffective, and a well-prepared teacher can develop strong conceptual understanding without sophisticated technology. The problem arises when students are denied the opportunity to use complementary educational resources that are increasingly accessible to their better-connected peers.

Digital inequality also influences students' exposure to scientific information beyond the prescribed curriculum. Online lectures, open educational resources, scientific documentaries and interactive question banks can expand the learning environment beyond the classroom. Students with consistent digital access may develop greater familiarity with contemporary scientific developments and independent learning practices. In contrast, students with limited connectivity may experience a narrower educational environment.

Socioeconomic Dimensions of Digital Educational Inequality

Economic background is one of the important factors influencing digital participation. The purchase of smartphones, computers, tablets and internet subscriptions requires financial resources that may not be equally available across households. For students belonging to economically disadvantaged families, digital education can create recurring financial pressures involving data recharges, device maintenance and access to paid educational services. These difficulties become more significant when multiple children in a household share a single device.

Parental educational background also influences the educational utilisation of digital resources. Parents with greater familiarity with technology may be better positioned to assist students in identifying appropriate learning materials, accessing online educational platforms and managing academic activities. Conversely, parents with limited digital literacy may experience difficulty supporting technology-based learning, even when devices are available at home. This creates an intergenerational dimension of educational inequality.

Gender is another important dimension requiring investigation. In some households, differences in device ownership, access time and expectations regarding technology use may affect girls' opportunities for independent digital learning. ASER 2024 reported that among rural children aged 14–16, 70.2% of boys could bring a smartphone to perform digital tasks, compared with 62.2% of girls. The corresponding figures for smartphone use were 85.5% and 79.4%, respectively.

Although these are national rural estimates rather than Murshidabad-specific statistics, they demonstrate why gender-sensitive analysis is necessary.

Educational inequality therefore emerges through the cumulative interaction of economic resources, household conditions, gender, geographical location and institutional capacity. Addressing the digital divide requires attention to these interconnected factors rather than a narrow focus on the distribution of electronic devices.

Institutional Infrastructure and the Role of Physics Teachers

Educational institutions play a decisive role in determining whether digital technologies become meaningful instruments of scientific learning. The availability of computers, projectors, internet connectivity, digital boards

and functional science laboratories creates the basic conditions for technology-supported instruction. However, the presence of infrastructure does not automatically ensure its effective utilisation. Institutions require regular maintenance, technical support, appropriate educational content and trained teachers who can connect digital resources with curriculum objectives.

In physics education, teachers perform an especially important mediating role between technological resources and conceptual understanding. A teacher who possesses adequate digital competencies can use simulations to explain abstract concepts, demonstrate scientific relationships through animations and encourage students to investigate physical phenomena independently. Conversely, insufficient professional training may result in technology being used merely for displaying presentations rather than facilitating meaningful scientific inquiry. Teacher preparedness should therefore be considered an essential dimension of digital inclusion.

The professional development of physics teachers in Murshidabad should incorporate practical training in digital pedagogy, virtual laboratory applications, simulation-based instruction, educational video production and online assessment. Teacher education institutions can contribute by organising workshops and developing collaborative digital teaching resources. Such initiatives would help teachers move beyond the conventional transmission of information towards a more interactive and learner-centred approach.

An additional institutional challenge concerns the relationship between virtual laboratories and physical experimentation. Virtual laboratories provide opportunities to repeat experiments, manipulate variables and understand theoretical relationships. Nevertheless, they cannot entirely replace direct laboratory experiences involving actual scientific instruments, measurement procedures and experimental uncertainty. An equitable physics education system must therefore integrate digital simulations with practical laboratory work instead of treating them as competing alternatives.

Digital Educational Policies and Their Implementation

India has introduced several educational initiatives intended to expand digital learning opportunities and reduce educational inequality. The National Education Policy 2020 recognises technology as an important instrument for improving educational access, quality and institutional efficiency. It emphasises the development of digital infrastructure, educational platforms, virtual laboratories, teacher training and technology-supported pedagogical practices. Its approach is particularly relevant to physics education because it encourages the use of simulations, digital resources and experiential learning environments.

The PM e-VIDYA initiative, introduced in 2020, aims to provide multimodal educational access through digital platforms, television, radio and other communication channels. DIKSHA provides digital educational resources for students and teachers, while SWAYAM and SWAYAM PRABHA extend access to educational content through online and broadcast-based systems. The Ministry of Education identifies these initiatives as mechanisms for promoting equitable learning opportunities and addressing the digital divide.

The availability of virtual laboratories through the DIKSHA ecosystem also creates opportunities for science education. These resources can support the visualisation of scientific concepts and provide additional experimental learning experiences. The official virtual laboratory framework recognises their potential to supplement conventional practical instruction while acknowledging that virtual experiences cannot entirely replace physical laboratory work.

Digital Infrastructure for Knowledge Sharing (DIKSHA)

Nevertheless, policy implementation involves challenges that cannot be resolved through the creation of digital platforms alone. Students require devices, affordable connectivity, electricity and adequate digital literacy to benefit from these initiatives. Similarly, teachers need training and institutions require functional infrastructure. The gap between policy intention and educational experience becomes particularly important in rural areas, where the availability of digital resources may not correspond to the actual capacity to use them. The central question is therefore not simply whether digital educational initiatives exist, but whether their benefits reach students across different socioeconomic and geographical conditions.

Comparative Analysis: Rural and Urban Physics Education

The rural–urban comparison in Murshidabad can be understood through several interconnected dimensions. The first is the availability of technological infrastructure. Urban institutions may have comparatively greater opportunities to access computers, broadband facilities and digital learning centres, whereas rural institutions may depend more heavily on mobile internet and shared technological facilities. The second dimension concerns the nature of household access. Urban students may encounter a wider range of private digital learning services, while rural students may experience greater dependence on household smartphones and school-provided resources. These differences require verification through institutional surveys rather than generalisation based on geographical location alone.

The third dimension involves the pedagogical use of technology. In institutions with functional digital facilities and trained teachers, students may participate in multimedia demonstrations, online assessments and simulation-based experiments. In institutions with limited facilities, physics teaching may remain predominantly dependent on textbooks, blackboards and conventional laboratory demonstrations. Although both approaches can produce meaningful learning, unequal access to supplementary resources can create differences in students' exposure to scientific investigation.

The fourth dimension relates to academic participation and independent learning. Students with reliable internet access can revisit difficult concepts through educational videos, access digital question banks and engage with additional scientific materials. Students with restricted access may have fewer opportunities for continuous learning outside classroom hours. This difference may become particularly important during examination preparation and when students need additional explanations of complex physics concepts.

The fifth dimension concerns the distribution of educational opportunities across gender and socioeconomic categories. A rural–urban comparison that ignores differences within households may overlook students who are digitally disadvantaged despite living in technologically developed urban environments. Similarly, a student from a relatively affluent rural household may have greater digital access than a student from a low-income urban household. Therefore, geographical location should be examined alongside household income, parental education, gender and institutional management.

Proposed Empirical Framework for Measuring Digital Inequality

To understand the multidimensional character of digital inequality, the present study proposes a Digital Physics Education Equity Framework (DPEEF). This framework considers digital accessibility as a combination of six interrelated dimensions: infrastructural accessibility, household affordability, digital literacy, institutional preparedness, pedagogical integration and educational outcomes. Each dimension represents a different stage in the process through which technological resources are transformed into meaningful learning opportunities.

Infrastructural accessibility measures the availability of electricity, computers, smartphones and internet connectivity. Household affordability examines the economic capacity to purchase devices and maintain internet subscriptions. Digital literacy evaluates students' and teachers' ability to use educational technologies effectively. Institutional preparedness considers the availability of functional computer laboratories, technical support and teacher training. Pedagogical integration examines the frequency and quality of digital technologies used in physics instruction. Finally, educational outcomes consider conceptual understanding, scientific reasoning, practical engagement and academic participation.

The framework proposes that these dimensions should be measured independently before being combined into an overall digital physics education equity index. A suggested weighting system may assign equal importance to all six dimensions during the initial exploratory stage. However, the final weights should be validated through expert consultation, statistical analysis and field evidence. This would prevent the research from assuming that device availability alone determines educational quality.

Case Studies and Critical Analysis Based on Murshidabad District

Case Study 1: Digital Transformation of Government Secondary Schools in Murshidabad – The Smart Classroom Initiative

One significant example of technology-supported educational development in Murshidabad is the smart classroom initiative introduced by the district administration in 2022. According to a report published on 15 December 2022, the administration selected 30 government high schools for the introduction of audio-visual classroom facilities. The district reportedly had more than 280 government high schools at that time. The initiative included projectors, computers and speaker systems across classrooms from Classes VIII to XII. Digital educational materials, including subject-specific videos, diagrams and instructional content, were organised for classroom use. The initiative was designed to address the limitations of conventional classroom instruction and improve communication between teachers and students.

From the perspective of physics education, this initiative offers considerable pedagogical possibilities. Physics involves abstract scientific concepts that frequently require visual interpretation. Topics such as electromagnetic induction, wave motion, reflection, refraction, force and energy can become more comprehensible through animations, demonstrations and graphical representations. A smart classroom can therefore provide an environment in which students observe scientific phenomena through visual resources before connecting them with mathematical explanations and practical experiments.

However, the initiative also raises an important question concerning the geographical distribution of technological opportunities. If digital facilities are concentrated in a limited number of selected institutions, students attending schools outside the programme may experience fewer opportunities for technology-supported learning. The distinction between digitally equipped and less-equipped institutions can create an institutional digital divide within the same district.

Critical analysis: The smart classroom initiative demonstrates the potential of district-level educational intervention, but its long-term effectiveness depends on the regular use of technology, teacher training, equipment maintenance and equitable expansion. For physics education, the next stage should involve integrating interactive simulations, virtual experiments and digital assessment into ordinary classroom instruction. The initiative should also be evaluated according to its actual educational impact rather than the number of projectors installed.



Case Study 2: Ghorapakhia Primary School, Suti – Community Participation in Digital Education

A particularly interesting example of grassroots digital educational development comes from Ghorapakhia Primary School in Suti, Murshidabad. According to an *Anandabazar Patrika* report published on 18 September 2023, the school introduced digital classroom facilities using four smart televisions, supported by Wi-Fi connectivity. The school reportedly had 182 students and six teachers. The initiative was made possible through institutional resource management and financial contributions from teachers and parents, in addition to the school's available funds. The report stated that student attendance increased by approximately 18% within five days of introducing digital classes, according to the school authorities.

This case is particularly important because it demonstrates that digital educational transformation does not always depend exclusively on large-scale government investment. Local participation, community awareness and institutional initiative can also contribute to technological development. The school illustrates how digital resources can make classroom instruction more engaging through visual presentations and multimedia materials.

The implications for physics education are substantial. Similar facilities could be used to demonstrate the movement of objects, the working of simple machines, the formation of shadows, the behaviour of light and the principles of electricity. Students who have limited opportunities to perform certain experiments can initially observe digital demonstrations and subsequently connect them with practical classroom activities.

Critical analysis: The Ghorapakhia example demonstrates the importance of community-supported digital inclusion. However, the reported increase in attendance should not automatically be interpreted as an improvement in academic achievement or scientific understanding. A separate investigation would be required to examine whether digital instruction improves conceptual comprehension, practical engagement and long-term learning outcomes. The case also highlights the need for sustainable financial support so that digital education does not depend entirely on voluntary contributions from teachers and parents.



Case Study 3: Andiran Primary School, Beldanga – Household Device Inequality and the Failure of Uniform Online Education

The experience of Andiran Primary School in the Beldanga area of Murshidabad during the COVID-19 pandemic provides a particularly significant example of household-level digital inequality. A Hindustan Times report published on 31 July 2020 documented that the school initially attempted to conduct online classes but discovered that parents of only 15 out of 162 students possessed smartphones. This meant that only a small proportion of the school's households had the device required to participate in the proposed online learning arrangement. To address the problem, teachers began visiting neighbourhoods and conducting lessons in open courtyards for small groups of students.

This case reveals a fundamental contradiction in technology-dependent education. Although online instruction was introduced as a mechanism for maintaining educational continuity, the assumption that every student possessed a smartphone proved unrealistic. The digital divide was therefore not simply a matter of internet speed or the quality of educational applications; it was a question of basic technological availability.

The implications for physics education are especially important. During periods when students cannot attend physical classrooms, digital resources can provide access to recorded lectures, experimental demonstrations and conceptual explanations. However, students without smartphones or household connectivity cannot benefit from these resources. They may miss opportunities to revise difficult concepts, watch scientific demonstrations or receive continuous academic support.

The teachers' decision to conduct neighbourhood-based classes demonstrates an alternative model of educational inclusion. It suggests that technological interventions should be accompanied by community-based teaching arrangements, printed learning materials and accessible educational facilities.

Critical analysis: The Andiran case provides strong evidence that digital education cannot be implemented through a uniform technological model without considering household realities. It also demonstrates the importance of teachers as agents of educational resilience. For Murshidabad, the lesson is that digital physics education must incorporate offline resources, school-based device access and community learning arrangements.

The case is particularly relevant to understanding how household poverty and technological exclusion can interrupt continuity in science education.



Case Study 4: Raghunathganj II – Community-Based Digital Literacy and Scientific Learning Opportunities

An additional example of digital inclusion can be identified through the digital literacy initiative at Krishnasail Education Center in Raghunathganj II block of Murshidabad. A report by the ST Foundation describes the provision of tablet-based learning opportunities and an Informatics and Computer Basics programme for children aged 14 and above. The initiative seeks to develop basic computer knowledge and digital competencies among children who may otherwise have limited opportunities to use technological resources independently.

This initiative is significant because it addresses a dimension of the digital divide that is often neglected: the difference between having access to a device and possessing the ability to use it effectively. Students may have access to smartphones but remain unfamiliar with educational applications, online research, digital information management and independent technology-supported learning.

For physics education, basic digital literacy is an important prerequisite for accessing scientific knowledge. Students who understand how to navigate educational platforms can explore physics lectures, digital textbooks, simulations and instructional videos. They can also develop familiarity with scientific graphs, interactive learning materials and digital problem-solving resources.

The initiative can be extended through specialised science learning modules involving motion, electricity, optics, energy and environmental physics. For example, students could use educational software to explore the relationship between distance and time or examine how changes in electrical resistance affect current.

Critical analysis: The Raghunathganj II example highlights the importance of community-based digital skill development. However, basic computer literacy and scientific digital literacy are not identical. Students require subject-specific guidance to transform technological skills into scientific understanding. Therefore, community digital centres should collaborate with school physics teachers and nearby higher educational institutions to provide discipline-specific learning opportunities.



Case Study 5: Institutional Educational Inequality in Murshidabad – The Relationship Between School Infrastructure and Social Disadvantage

A significant academic perspective on educational inequality in Murshidabad is provided by *Arijit Das (2016), whose research examined disparities in the provision of schooling facilities in Muslim-majority and non-Muslim-majority areas of West Bengal, using Murshidabad as the study region. The study constructed an Educational Development Index using eleven socioeconomic indicators and principal component analysis. Its findings indicated that blocks with a higher proportion of Muslim populations registered comparatively lower levels of educational development and that deprived schools were concentrated in disadvantaged areas.*

This research is relevant to the present investigation because it demonstrates that educational inequality in Murshidabad has a wider structural and geographical dimension. Differences in educational opportunities cannot be understood exclusively through the presence or absence of digital devices. Institutional infrastructure, socioeconomic conditions and the distribution of educational resources also influence the quality of learning.

The district administration's demographic information indicates that 80.22% of Murshidabad's population lived in rural areas and 19.78% in urban areas according to Census 2011. The district's geographical and demographic structure therefore makes rural educational access an important dimension of development planning.

For physics education, institutional inequality can influence access to functional laboratories, scientific instruments, electricity, computers and trained subject teachers. Students attending institutions with limited laboratory resources may have fewer opportunities to develop experimental skills. Similarly, the absence of digital facilities may restrict their exposure to simulations and supplementary scientific materials.

Critical analysis: The findings of *Das (2016)* provide a useful foundation for understanding the geographical and socioeconomic dimensions of educational deprivation. Nevertheless, they should not be interpreted as direct evidence of contemporary digital inequality or physics achievement. The present research extends this discussion by investigating whether similar institutional disadvantages are reflected in digital accessibility, physics laboratory facilities and technology-supported scientific learning.

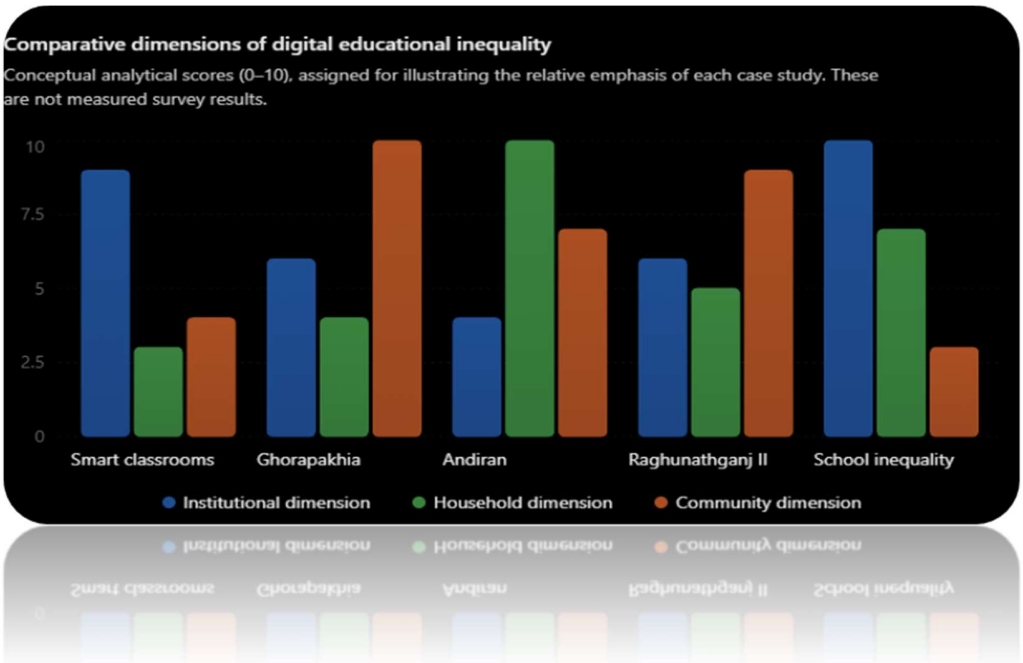


Comparative analytical interpretation

Comparative dimensions of digital educational inequality

Conceptual analytical scores (0–10), assigned for illustrating the relative emphasis of each case study. These are not measured survey results.

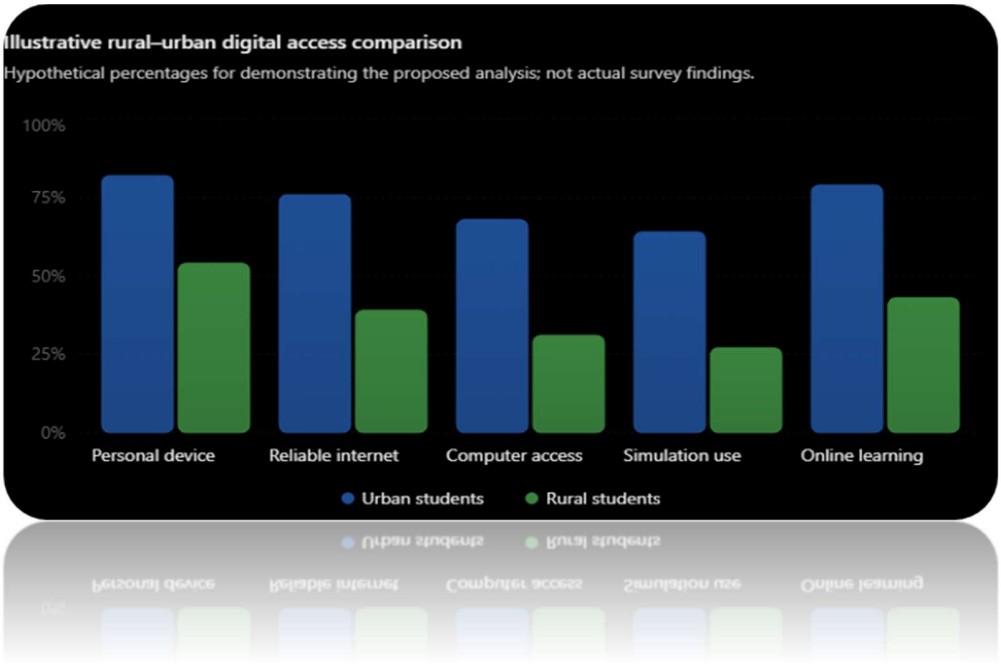
The comparative analysis indicates that digital inequality cannot be reduced to a single infrastructural problem. It emerges through the interaction of household resources, institutional capacity, community participation and students' technological competencies. The Andiran experience particularly demonstrates that online educational opportunities can become inaccessible when household device ownership is extremely limited. In contrast, Ghorapakhia demonstrates how local institutional initiatives and community participation can create alternative pathways for digital inclusion. These examples suggest that educational interventions must be designed according to local requirements rather than implemented through a uniform model.



Illustrative rural–urban digital access comparison

Hypothetical percentages for demonstrating the proposed analysis; not actual survey findings.

The hypothetical comparison suggests how differences across digital access indicators could be examined. In actual research, the percentages should be calculated from responses collected from the selected institutions and households. The analysis should also control for socioeconomic background to distinguish geographical effects from income-related effects.



Overall Critical Discussion

The Murshidabad case studies reveal an important contradiction in the contemporary transformation of education. Digital technology is increasingly regarded as an instrument for democratising knowledge, yet the opportunities created by technological advancement remain dependent on existing socioeconomic and institutional conditions. The smart classroom initiative demonstrates the potential of institutional investment, while the Ghorapakhia example highlights the importance of community participation. However, the Andiran experience demonstrates that technological interventions can exclude students when basic household resources are unavailable. The Raghunathganj II initiative further establishes the importance of developing digital competencies alongside technological access. These cases collectively suggest that digital inequality is not merely a geographical distinction between rural and urban communities but a multidimensional phenomenon involving institutional capacity, household resources, social participation and educational preparedness.

The implications are particularly significant for physics education. Unlike purely text-oriented learning, physics requires students to develop the ability to visualise scientific processes, interpret mathematical relationships, observe experimental phenomena and connect theoretical principles with practical experiences. Unequal access to digital simulations and virtual laboratories may therefore create differences in the quality of scientific exposure available to students. A student studying in a well-equipped institution may receive opportunities to investigate scientific relationships through interactive demonstrations, while another student may remain dependent on

conventional explanations. Such differences do not indicate differences in intellectual ability; they reflect unequal educational opportunities.

The geographical context of Murshidabad makes this issue particularly relevant. With a predominantly rural population and considerable socioeconomic diversity, the district requires a context-sensitive model of digital educational development. The central policy challenge is to ensure that the advantages of digital education are not restricted to a small number of technologically advanced institutions. Instead, educational planning should prioritise equitable access, teacher development, functional science laboratories, community-based digital learning and affordable technological resources.

Research Argument

The case studies demonstrate that the digital divide in Murshidabad is simultaneously an infrastructural, economic, institutional and pedagogical challenge. The transition towards digitally supported physics education cannot be considered successful merely through the introduction of smart classrooms or online platforms. Its success must be evaluated through the extent to which students from different geographical and socioeconomic backgrounds receive comparable opportunities to participate in scientific learning. The experiences of Suti, Beldanga, Raghunathganj II and the district-level smart classroom initiative provide important starting points for understanding this relationship. The study consequently argues that digital inclusion should become an integral component of scientific educational justice. A genuinely equitable physics education system must ensure that geographical location, household income and institutional limitations do not determine a student's opportunity to develop scientific knowledge, experimental competence and technological awareness.

Critical Analysis: The Gap Between Digital Policy and Educational Reality

A critical examination of digital education reveals that technological expansion and educational democratisation are not necessarily identical processes. Educational policies frequently emphasise digital platforms, online content and technology-supported instruction as mechanisms for improving learning outcomes. However, the actual educational experience of students depends on the social, economic and institutional conditions within which these technologies operate. The availability of educational applications cannot compensate for the absence of a suitable device, uninterrupted connectivity or a supportive learning environment.

The problem becomes more complex when digital education is treated as a substitute for conventional educational infrastructure. Schools require qualified teachers, functional laboratories, libraries and adequate classroom facilities irrespective of technological advancement. An excessive emphasis on online learning may unintentionally disadvantage students who cannot participate consistently in technology-based instruction. In physics education, this may result in unequal exposure to simulations, practical demonstrations and contemporary scientific resources.

Another critical issue concerns the commercialisation of digital learning. Students with sufficient financial resources may access private coaching applications, paid educational content and personalised online instruction, while economically disadvantaged students may remain dependent on freely available resources with varying levels of accessibility. Such differences can transform digital technology into a new mechanism of educational stratification.

Furthermore, digital learning should not be measured solely through the number of devices distributed or the number of institutions connected to the internet. The quality of educational engagement is equally important. A

computer laboratory that remains unused, a digital board without appropriate instructional content or an online platform that students cannot access independently does not represent meaningful digital inclusion. The success of digital physics education must therefore be assessed through actual student participation, teacher preparedness, conceptual understanding and equitable learning opportunities.

For Murshidabad, the central challenge is to establish a balance between technological modernisation and educational justice. Digital development must strengthen existing educational institutions rather than create additional distinctions between privileged and disadvantaged learners.

Major Findings Expected from the Proposed Investigation

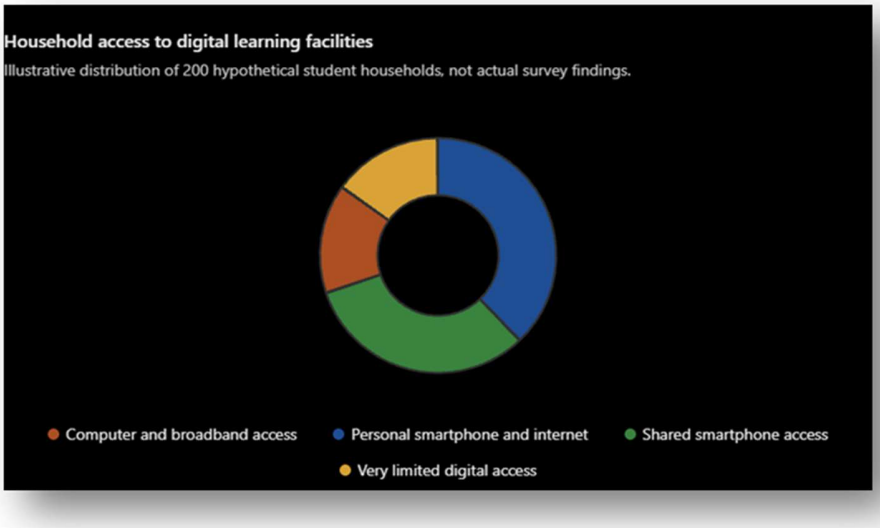
Since the proposed district-level primary survey has not yet been conducted, the following are analytical propositions to be investigated rather than established empirical findings. The study anticipates that differences may exist between rural and urban institutions in terms of internet connectivity, availability of functional computers and access to technology-supported physics instruction. It also proposes that household income, parental education and device-sharing arrangements may influence the frequency of students' engagement with digital educational resources. Another area requiring investigation is whether teacher training and institutional technical support are associated with more effective use of physics simulations and virtual laboratory activities.

The research also expects to examine whether digital accessibility contributes to differences in students' independent learning practices, scientific visualisation and participation in practical activities. It is important to recognise that these relationships may be influenced by additional factors, including teachers' instructional methods, students' prior academic preparation, language accessibility and the quality of physical laboratory facilities. Consequently, the investigation should avoid assuming that digital access alone determines academic achievement.

Figure 1. Pie Chart – Household Digital Accessibility

Household access to digital learning facilities

Illustrative distribution of 200 hypothetical student households, not actual survey findings.

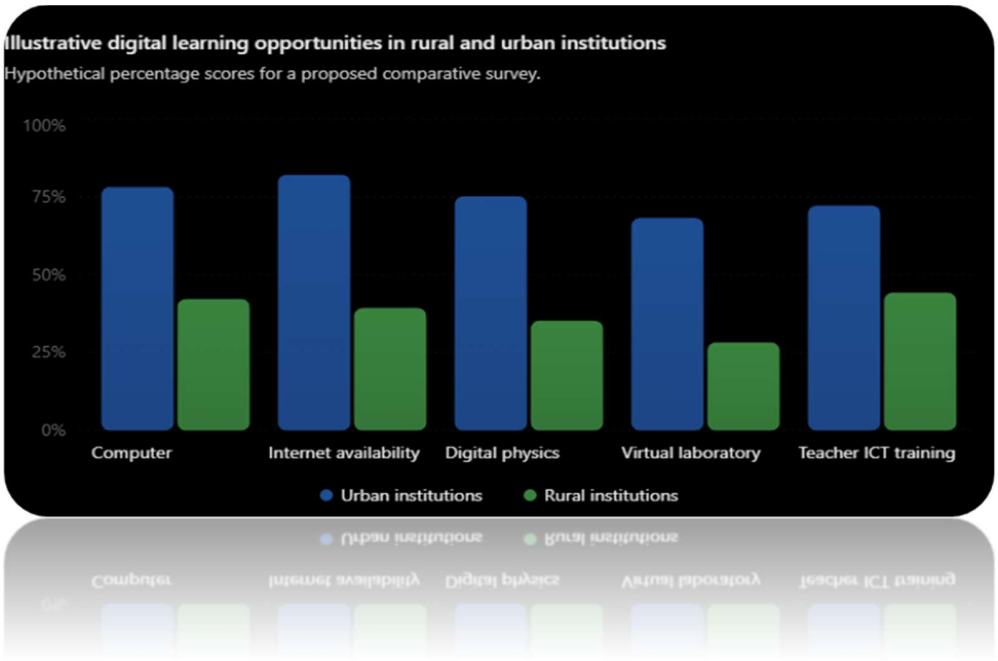


Analysis: The illustrative distribution highlights the distinction between personal device ownership, shared access and more comprehensive computer-based connectivity. The Andiran Primary School case demonstrates why this distinction matters: only 15 of 162 students reportedly had parents with smartphones when online classes were attempted. The findings suggest that digital inclusion should be measured through independent student access rather than household device availability alone.

Figure 2. Bar Graph – Digital Infrastructure and Physics Learning

Illustrative digital learning opportunities in rural and urban institutions

Hypothetical percentage scores for a proposed comparative survey.



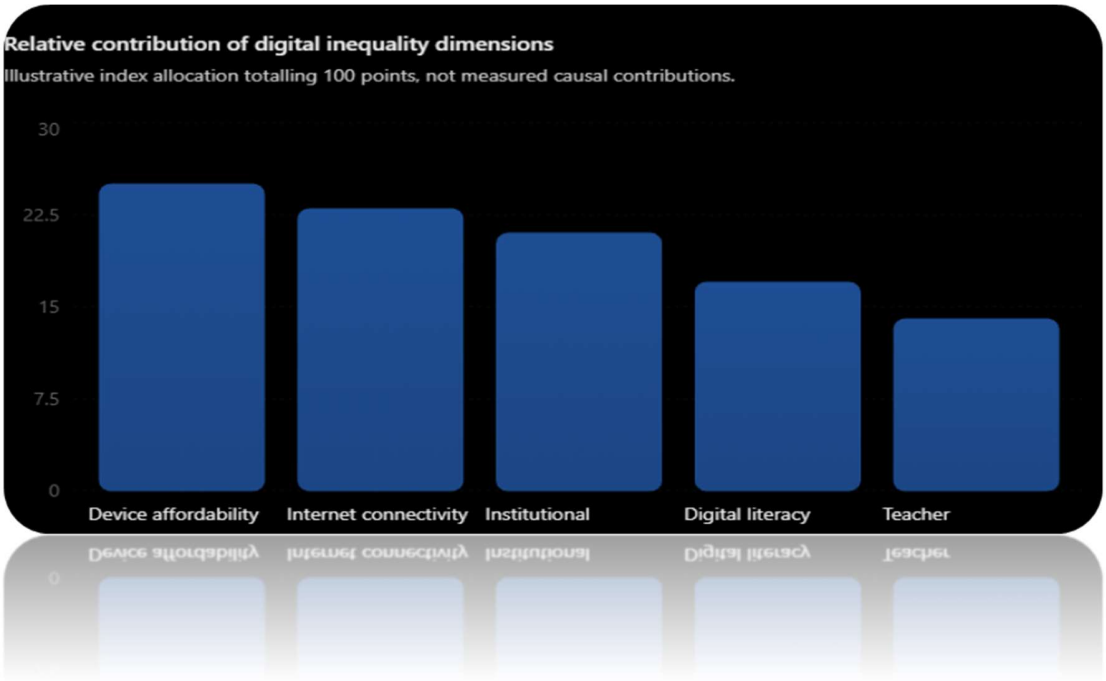
Analysis: The graph illustrates how differences in technological infrastructure may influence students' opportunities to experience digital physics education. The largest illustrative disparity occurs in virtual laboratory exposure. This is particularly relevant to the Andiran and Raghunathganj II cases, where household accessibility and digital competencies are important considerations.

Figure 3. Stacked Bar Graph – Sources of Digital Educational Inequality

Relative contribution of digital inequality dimensions

Illustrative index allocation totalling 100 points, not measured causal contributions.

Analysis: Device affordability and internet connectivity receive the highest illustrative index weights, followed by institutional infrastructure. This conceptual prioritisation reflects the problems identified in the Andiran case and the institutional challenges highlighted by the smart classroom initiative. The weights should ultimately be determined through expert consultation or empirical statistical analysis.



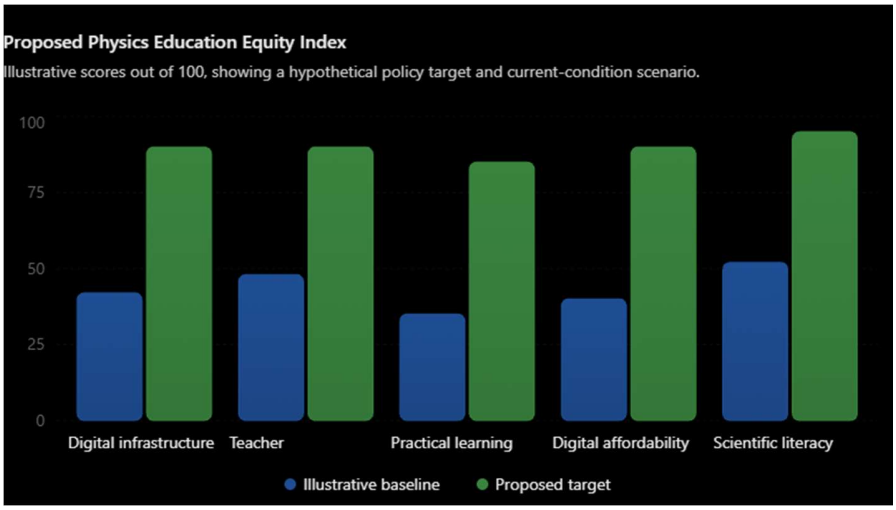
Policy Recommendations and Educational Interventions

Reducing digital inequality in physics education requires a comprehensive approach that connects infrastructural investment with pedagogical development and social inclusion. The first priority should be strengthening digital infrastructure in rural educational institutions. Government and aided schools should receive adequate support for establishing functional computer laboratories, reliable internet connectivity, electricity backup and appropriate projection facilities. Infrastructure programmes should include maintenance provisions and periodic evaluation so that technological equipment remains operational.

Physics Education Equity Index – Policy Gap

Proposed Physics Education Equity Index

Illustrative scores out of 100, showing a hypothetical policy target and current-condition scenario.



Explanation: This figure can connect the district-level problem to policy planning. The distance between the illustrative baseline and proposed target represents the scale of improvement that future interventions should seek to achieve.

The second priority should be the establishment of community-based digital learning centres in geographically underserved areas. Schools, libraries, colleges and local educational institutions can collaborate to provide students with supervised access to computers, internet facilities and digital learning resources. Such centres would be particu//////larly useful for students who do not have individual devices at home. Their operation should be designed around accessible timings and inclusive participation.

The third intervention should focus on teacher professional development. Physics teachers require continuous training in digital simulations, virtual experiments, interactive instructional design and technology-supported assessment. Teacher education institutions and universities in the region can organise workshops and collaborative resource-development programmes. These initiatives should emphasise the pedagogical integration of technology rather than merely teaching teachers how to operate digital devices.

The fourth recommendation concerns the development of low-bandwidth and offline educational resources. Physics animations, recorded demonstrations, interactive worksheets and simulation-based activities should be made available in formats that can function with limited internet connectivity. Educational resources should also be accessible in Bengali and other relevant instructional languages to strengthen comprehension among students from diverse linguistic backgrounds.

The fifth recommendation involves gender-sensitive digital inclusion. Institutions should ensure that girls and boys have equal opportunities to access school-based digital resources, participate in technology-supported activities and receive digital literacy training. Community awareness programmes can encourage families to recognise the educational importance of equitable device access.

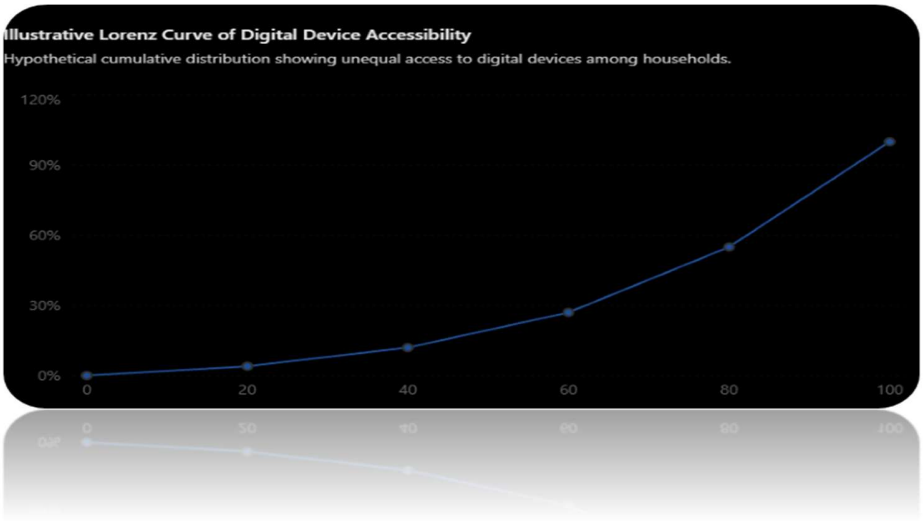
The sixth recommendation is the integration of digital and physical laboratories. Schools should develop instructional models in which students first explore a scientific concept through simulation and subsequently investigate it through actual experiments wherever appropriate. This approach can improve conceptual understanding while preserving the importance of practical scientific investigation.

Finally, a district-level digital education monitoring system should be developed to identify inequalities in infrastructure, teacher preparedness and student access. The system should collect information periodically and distinguish between the presence of digital equipment and its functional educational use. Educational planning should be based on evidence from individual institutions and local communities rather than relying exclusively on broad state-level averages.

Figure 4. Digital Accessibility Inequality – Lorenz Curve

Illustrative Lorenz Curve of Digital Device Accessibility

Hypothetical cumulative distribution showing unequal access to digital devices among households.



Explanation: The Lorenz curve can demonstrate how digital resources are distributed unequally across households. A greater deviation from the line of equality indicates a stronger concentration of digital resources among a smaller proportion of households.

Figure 5. Box Plot – Rural and Urban Physics Achievement

Illustrative mean physics achievement scores

Hypothetical average scores out of 100; a bar graph is used here because actual student-level distributions are unavailable.

Analysis: The illustrative mean-score difference demonstrates how a future empirical investigation could examine associations between digital learning opportunities and physics achievement. Actual box plots require individual student scores, including the median, quartiles and outliers. The difference shown here must not be interpreted as a measured rural–urban achievement gap.



Implications for Sustainable Development and Scientific Human Capital

The digital divide in physics education has implications that extend beyond school-level academic performance. Physics provides the conceptual foundation for technological innovation, engineering, renewable energy, electronics, communication systems, medical instrumentation and several emerging scientific fields. Unequal access to quality physics education can therefore influence students' future opportunities to participate in higher education, scientific research and technology-oriented employment.

From the perspective of the Sustainable Development Goals, the issue is closely connected with SDG 4, which emphasises inclusive and equitable quality education and lifelong learning opportunities. It is also related to SDG 5 through gender equality in educational participation, SDG 9 through technological and infrastructural development, and SDG 10 through the reduction of inequalities. Ensuring equitable digital physics education would therefore contribute to broader developmental objectives.

In Murshidabad, the expansion of digital science education could support students from diverse geographical and socioeconomic backgrounds in developing scientific curiosity, technological awareness and problem-solving capabilities. It could also strengthen the relationship between school education, higher education and emerging scientific opportunities. However, the benefits of technological development will remain uneven unless digital resources become accessible, affordable and educationally meaningful for all students.

The long-term objective should not simply be to create digitally connected classrooms but to develop scientifically empowered learners. Digital inclusion must enable students to ask questions, investigate phenomena, interpret evidence and participate confidently in the knowledge economy.

Conclusion

Physics education in the contemporary digital era represents more than the transmission of scientific principles; it embodies the promise of equal intellectual opportunities, scientific curiosity and participation in an increasingly technology-driven society. However, the digital divide between rural and urban educational institutions in Murshidabad reveals that the journey towards scientific empowerment is not experienced equally by every learner. While digital technologies open new windows into the invisible world of atoms, electromagnetic fields, cosmic phenomena and computational simulations, unequal access to devices, reliable connectivity, modern laboratories and digitally prepared teachers may prevent many rural students from experiencing these possibilities to their fullest extent. The disparity, therefore, is not simply between those who possess technology and those who do not, but between those who can meaningfully participate in the evolving culture of scientific knowledge and those who remain at its margins.

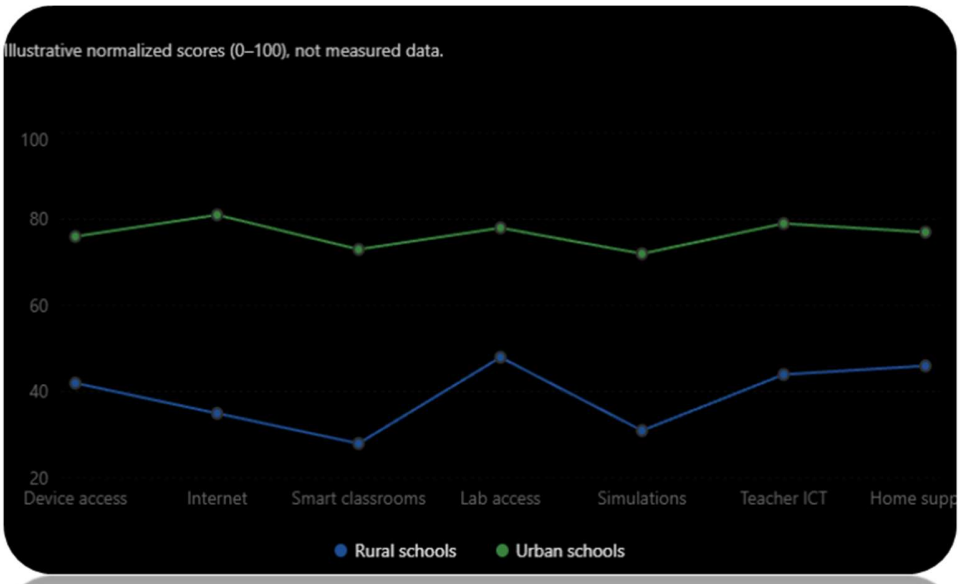
Ultimately, the democratisation of physics education must begin with the recognition that scientific imagination should never be restricted by geographical location or socio-economic circumstances. The educational landscape of Murshidabad offers an important opportunity to rethink digital inclusion through equitable infrastructure, contextualised pedagogy, accessible virtual laboratories and sustained teacher development. Technology must become a bridge between curiosity and discovery rather than another instrument of educational segregation. A truly inclusive physics education system will emerge when a student in a remote rural classroom has the same opportunity to explore scientific phenomena, experiment with ideas and develop analytical thinking as a student in an urban institution. The real measure of digital transformation, therefore, lies not in how rapidly educational institutions adopt technology, but in how effectively technology expands the horizons of every learner, irrespective of where they are born, live or study.

The relationship between physics education and the digital divide reveals an important dimension of contemporary educational inequality. Digital technologies have created unprecedented opportunities for scientific learning through simulations, virtual laboratories, interactive demonstrations and online educational resources. However, these opportunities remain unevenly distributed across geographical, socioeconomic and institutional contexts. The rural–urban educational landscape of Murshidabad provides a valuable context for examining how technological accessibility influences students' experiences of physics education. The problem is not simply that some students possess computers while others do not; it is that students experience different levels of educational opportunity, scientific exposure and technological participation.

For West Bengal, the democratisation of physics education must become an integral component of its broader developmental aspirations. The educational experiences of students in rural Murshidabad, the tea-garden regions of North Bengal, the forest-fringe settlements of western districts and the island communities of the Sundarbans should receive equal consideration in the state's digital education strategy. Strengthening school connectivity, establishing functional physics laboratories, developing Bengali-supported digital learning resources, promoting virtual experiments and continuously empowering teachers with technological competencies can help transform digital access into meaningful scientific participation. Ultimately, the vision of an educationally progressive West Bengal should not be measured solely by the number of smart classrooms or digital devices introduced, but by the extent to which scientific knowledge becomes accessible to every learner. The true success of digital education will be realised when the geographical distance between a village classroom and an urban institution no longer determines the intellectual distance between their students and the world of scientific discovery.

Rural–Urban Digital Physics Education Radar

A Multidimensional Comparative Assessment of Digital Physics Education in Rural and Urban Schools of Murshidabad District



Comparative Radar Representation of Digital Infrastructure, Pedagogical Readiness and Learning Support in Rural and Urban Physics Education in Murshidabad District. Source: Illustrative analytical framework developed by the researcher; values are hypothetical and require validation through primary field investigation.

The radar chart illustrates the multidimensional differences in digital educational infrastructure and physics learning opportunities between rural and urban schools in Murshidabad district. It considers seven major indicators: device access, internet connectivity, smart classroom facilities, physics laboratory access, simulation-based learning, teachers' ICT competencies and home learning support. The illustrative scores indicate that urban schools have comparatively higher levels of digital accessibility across all seven dimensions. The most prominent differences appear in internet reliability and smart classroom infrastructure, suggesting that geographical disparities may influence students' opportunities to engage with technology-supported physics education.

The central argument of this research is that digital inclusion must be recognised as an essential component of educational equity. Rural students should not be educationally disadvantaged because of geographical isolation, household economic limitations or inadequate institutional infrastructure. Similarly, economically disadvantaged urban students must receive appropriate support to participate meaningfully in digital learning. The proposed Digital Physics Education Equity Framework offers a multidimensional approach to understanding these inequalities by connecting infrastructural accessibility, affordability, digital literacy, institutional preparedness, pedagogical integration and educational outcomes.

Ultimately, the transformation of physics education in Murshidabad requires more than technological distribution. It demands an educational environment in which every student, irrespective of geographical location or socioeconomic background, has the opportunity to explore scientific phenomena, participate in experimental learning and develop technological competence. Digital technology should become an instrument of educational democratisation rather than another source of academic stratification. The success of digital physics education should therefore be measured not by how many institutions possess computers, but by how effectively every learner is empowered to participate in the scientific and technological future of society.

"The digital divide in physics education should be conceptualised as a multidimensional educational inequality rather than a simple disparity in technological ownership. The intersection of geographical location, household socio-economic conditions, institutional infrastructure, teacher preparedness and access to technology-mediated scientific experiences determines the extent to which students can participate in contemporary physics learning."

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