From Colonial Educational Inequality to the AI Divide: A Socio-Historical Analysis of Stem Education and Self-Regulated Learning in South and Southeast Asia

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Abstract
Inequalities in STEM (Science, Technology, Engineering and Mathematics) education in South and Southeast Asia are understood to be a manifestation of persistent structural educational inequalities rooted in historical educational systems and exacerbated by contemporary technological changes. This study examines the historical context of educational inequalities in STEM education in South and Southeast Asia. In particular, it focuses on the enduring impact of colonial education policies and postcolonial structural dependency. It also examines how the traditional digital divide has transformed into an emerging AI divide as a result of the increasing integration of artificial intelligence (AI) into education systems. Finally, this article analyzes how a learner-centered teaching approach called Self-Regulated Learning (SRL) can serve as an effective pedagogical approach that promotes equitable educational participation for all in AI-supported STEM educational environments. Today's STEM educational inequalities are not accidental; rather, the study argues that they have their roots in colonial educational policies that prioritized Western scientific traditions and restricted scientific knowledge to socially and economically privileged groups (Macaulay; Wood). These inequalities have persisted through the post-colonial period through continued reliance on knowledge systems, digital infrastructures, and artificial intelligence technologies developed abroad. The rapid spread of AI-based educational platforms has exacerbated these inequalities, creating a new inequality now known as the "AI Divide." This emerging AI divide reflects not only differences in access to technology; but also inequalities in the acquisition of AI literacy, the critical evaluation and application of the knowledge AI generates, and the opportunities to participate effectively in AI-supported educational environments. Through an analysis of evidence from South and Southeast Asian countries, the study shows that socially and economically advantaged learners benefit most from AI-supported STEM education environments; while students from marginalized communities continue to lag behind academically. In this context, Self-Regulated Learning (SRL) is identified as an important pedagogical approach that enhances learners' autonomy, responsibility, and learning ability and promotes equal participation in AI-supported STEM education. Finally, the study concludes that technological progress alone cannot eliminate educational inequality. To create true equity in AI-supported STEM education, educational structural reforms, inclusive teaching practices, efforts to strengthen learners' Self-Regulated Learning skills, and equitable access to technological opportunities are necessary.

Keywords: STEM Education, Artificial Intelligence in Education, Digital Divide, AI Divide, Self-Regulated Learning, Educational Inequality, South and South-East Asia.

Across South and South-East Asia, STEM education has become central to national development agendas. Governments increasingly view investment in science, technology, engineering, and mathematics as essential to participating in the global knowledge economy particularly in an era defined by artificial intelligence. Yet the policy assumption that expanding access to technology will automatically produce greater educational inclusion is dangerously simplistic. It overlooks the complex historical and structural forces that have long shaped who get to learn, and how (OECD; UNESCO).

This article argues that contemporary disparities in STEM education cannot be understood through the lens of the digital divide alone. They must be read against a broader socio-historical backdrop that includes colonial legacies, postcolonial dependency, and the uneven global distribution of technological resources. The rise of AI in education — frequently presented as a transformative equalizer — is better understood as a development that reflects and reshapes existing structures of power. Against this backdrop, the paper asks: how do historical inequalities and contemporary AI-driven transformations interact to produce disparities in STEM education across South and South-East Asia, and to what extent can Self-Regulated Learning offer a meaningful response? Previous studies have examined the Digital Divide, Artificial Intelligence in Education, and Self-Regulated Learning (SRL) separately. However, very little research has been conducted on how the legacies of colonial education, postcolonial structural dependency, and the emerging AI Divide combine to shape the inequalities in STEM education in South and Southeast Asia. Furthermore, within this broader historical and structural context, there is also very little research that has examined the role of Self-Regulated Learning (SRL) as a pedagogical approach to emerging educational inequalities. Therefore, this study aims to fill this gap by presenting an integrated analysis based on qualitative, conceptual, and socio-historical approaches.

To address this research question,the article puts forwards three key objectives. First, it examines the historical foundations of educational inequalities in STEM education across South Asia and Southeast Asia, focusing specifically on the impact of colonial educational policies and post-colonial structural dependency. Secondly among the increasing integration of AI into educational systems, the study explores how the traditional "digital divide" has evolved into an emerging "AI divide". Finally, this article analyses the significance of SRL as a learner centred pedagogical approach in fostering equitable educational participation within AI supported STEM learning environments.

This study adopts qualitative, conceptual, and socio-historical research approaches to examine the evolution of educational inequality in STEM education across South Asia and Southeast Asia. Instead of collecting primary data, this study analyzes the historical continuity between colonial educational inequality, the digital divide, and the emerging AI divide by synthesizing historical documents, theoretical literature, policy statements, and recent academic publications.

The analysis in this study is based on an extensive review of interdisciplinary literature drawn from fields such as history, education, sociology, digital studies, and Artificial Intelligence in Education. Specifically, historical documents such as Macaulay's "Minute on Indian Education" (1835) and Wood's Despatch (1854) have been examined to understand the colonial origins of educational inequality. These historical perspectives are further elucidated through theoretical approaches such as Pierre Bourdieu's Social Reproduction Theory, Andre Gunder Frank's Dependency Theory, Amartya Sen's Capability Approach, and Edward Said's concept of epistemic inequality. The literature selected for this study has been chosen based on its direct relevance to research themes such as educational inequality, digital transformation, artificial intelligence in education, self-regulated learning, and STEM education. Furthermore, priority has been given to peer-reviewed research articles, reports from internationally recognized organizations, and key theoretical texts that provide a historical-conceptual foundation.

Colonial Foundations of Educational Inequality

The roots of contemporary STEM disparities reach back to the colonial period. Colonial educational policies were not designed to promote

universal access to knowledge; they were instruments of administrative and economic control. In British-controlled territories, Macaulay's Minute on Education (1835) institutionalized a vision of schooling that privileged Western knowledge and English-medium instruction, systematically marginalizing indigenous intellectual traditions. Wood's Despatch (1854) extended this framework by establishing a hierarchical educational structure that confined access to advanced scientific and technical knowledge to a narrow elite.

Comparable patterns took hold across South-East Asia. In Dutch-administered Indonesia, education was calibrated to serve colonial administrative functions, leaving the broader population with little access to higher-level scientific training. In French Indochina, schooling emphasized cultural assimilation into French norms while restricting entry to advanced scholarship. The cumulative effect was an educational ecosystem that excluded the majority from meaningful participation in scientific inquiry.

The significance of these interventions extends far beyond their immediate historical moment. By defining what counted as legitimate knowledge and building inequality into the architecture of educational institutions, colonial systems laid foundations that proved remarkably durable. The privileging of Western epistemologies continues to shape curricula, assessment frameworks, and educational aspirations well into the postcolonial era, marginalizing local knowledge systems and narrowing the diversity of STEM education (Zimmerman; Panadero; Frank; UNESCO).

Postcolonial Continuities and Structural Dependency

Independence did not dismantle the structures inherited from the colonial period. Many newly sovereign states adopted existing educational frameworks as vehicles for modernization, treating STEM as a key engine of national progress. Yet this expansion unfolded within a global order characterized by deep asymmetries in the production and distribution of knowledge and technology.

Dependency Theory offers a useful lens here. As Frank (1967) argues, developing regions remain structurally reliant on the technological and intellectual output of more advanced economies. In the context of STEM education, this dependency is visible in the continued use of Western curricula, textbooks, and research paradigms, and in the importation of digital tools and platforms developed elsewhere. As education has moved from its earlier analogue forms toward what is now described as Education 5.0, the platforms and AI systems driving this shift are largely products of global corporations headquartered in technologically advanced countries. Local educationinstitutions face significant challenges in adapting these technologies to their unique cultural, linguistic, and pedagogical contexts. Consequently, a persistent gap emerges between technological innovations and local educational realities. Construction upon these structural continuities, recent studies specify that this dependency has acquired a new technological dimension due to the rapid expansion of AI in the education sector. AI driven learning platforms, adaptive assessment system, and AI generate tools are predominantly developed in technologically advanced nations, consequently, they reflect the language, culture, and educational priorities of those countries. They are becoming consumers of AI based educational technologies rather than creators of them, accordingly, existing inequalities in knowledge creation and technological innovation are futher exacerbated (Homeset al.,, 2022: UNESCO, 2023; OECD 2024).

Theoretical Framework

Understanding why these inequalities persist requires theoretical grounding. Bourdieu's Social Reproduction Theory illuminates how educational systems perpetuate existing hierarchies by rewarding those who already possess cultural and social capital. In STEM contexts, students from privileged backgrounds are advantaged not only by access to resources but by their familiarity with dominant forms of knowledge and learning culture. Sen's Capability Approach adds a further dimension: access to technology is insufficient on its own; what matters is whether individuals can convert that access into meaningful learning outcomes. In an AI-enable educational environment, Sen's "Capability

Approach" is highly relevant. This is because equitable participation in education depended not merely on access to AI tech, but rather on the learners ability to use them correctly and effectively. Furthermore, factors such as digital literacy, AI literacy, support from educational institutions and socio-economic conditions significantly determine students ability to transform technological opportunities into meaningful educational outcomes. Edward Said's arguments regarding orientalism and epistemic dominance further reinforce this theoretical framework. They highlight how colonial system have historically marginalized alternative scientific traditions and indigenous scientific perspectives. Consequently, intellectual diversity within STEM education has been diminished and various knowledge traditions have been overlooked without adequate recognition.

The Digital Divide and Its Structural Dimensions

The rapid expansion of digital technologies across South and South-East Asia has often been framed as a democratizing force. Yet this optimism obscures the structural inequalities that shape both access to and use of technology. The COVID-19 pandemic made these dynamics starkly visible. As institutions across the region shifted to online learning, students in rural India struggled with absent smartphones and unreliable connectivity (The Hind, 2021). In Bangladesh, learners in remote areas travelled significant distances simply to access a usable signal (UNESCO). In Indonesia, urban students in Jakarta adapted with relative ease while those on remote islands faced persistent infrastructural barriers (World Bank). In the Philippines, students without internet access fell back on printed modular materials, underscoring just how uneven the digital landscape remains (UNESCO).

These cases illustrate that the digital divide is not reducible to a question of technological availability. It is embedded in broader socio-economic conditions in access to personal devices, stable electricity, quiet study spaces, and family support. Moreover, even where access exists, the ability to navigate digital environments meaningfully varies widely. Digital literacy, pedagogical guidance, and institutional support all determine whether technology translates into learning. Without these enabling conditions, digital education risks reproducing and amplifying the very inequalities it promises to overcome.

From Digital Divide to AI Divide

The integration of artificial intelligence into education marks a qualitative shift in this landscape. Intelligent tutoring systems, adaptive learning platforms, and learning analytics tools offer genuine potential for personalized, responsive education at scale. Yet this integration does not occur in neutral conditions. The structural inequalities that have historically shaped access to knowledge continue to operate, recent scholars emphasize that the AI divide is not merely a gap in technological access. Instead, it reflects disparities in opportunities to acquire AI literacy, the ability to critically understand AI generated knowledge, and the capacity to participate meaningfully in AI supported educational environments. Therefore, inequalities in AI supported STEM education are not determined only by access to technology, rather they are largely sharped by learners' digital competencies, the preparedness of educational institutions, and broader socio- economic conditions.

In India, private institutions have increasingly adopted AI-based learning platforms, while many government schools continue to struggle with basic digital infrastructure. In Malaysia and Singapore, relatively high levels of investment in educational technology have enabled more sophisticated AI-driven learning environments, highlighting how regional inequalities within South-East Asia itself are being reconfigured rather than resolved (OECD). Singapore's active integration of adaptive platforms positions it as a regional leader, while reports from India's public education sector point to persistent gaps in both resources and technological literacy (The Straits Times; The Hindu).Collectively, tese examples reveal that the proliferation of AI technologies is further reinforcing existing educational hierarchies and inequalities, rather than eliminating the disparities that have long existed in education. Counties with robust tech infrastructure adequate institutional investment and AI readiness are reaping significant benefits form AI supported STEM education. Therefore, education system with

limited resources face the risk of an even widening AI divide.

Crucially, the development and control of AI systems remain concentrated in a small number of technologically advanced countries. These systems are trained on datasets that carry particular cultural and epistemological assumptions, which shape the content and structure of the educational materials they generate. From the perspective of epistemic inequality, this raises a fundamental question about whose knowledge is encoded in AI-driven education and whose is rendered invisible. In this sense, contemporary AI dependency echoes the epistemic hierarchies first established under colonialism (Said).

Self-Regulated Learning as a Mediating Framework

Within this complex landscape, Self-Regulated Learning emerges as a critical conceptual and practical resource. Unlike models that position learners as passive recipients of instruction, SRL emphasizes learner agency: the capacity to set goals, monitor progress, adapt strategies, and reflect critically on outcomes (Zimmerman). These competencies are particularly relevant to STEM education, which demands sustained engagement, iterative problem-solving, and the ability to transfer knowledge across contexts.

AI technologies, in principle, can scaffold self-regulated learning. Adaptive systems can deliver personalized feedback, helping students identify weaknesses and adjust their approaches. Learning analytics can make progress visible in real time, supporting both learners and teachers in responding to emerging needs. Yet the effectiveness of these tools is not evenly distributed. Students who already possess strong self-regulatory skills are better placed to interpret AI-generated feedback and use it productively. Those with limited experience in self-directed learning may find these systems difficult to navigate, deepening rather than narrowing existing divides (Panadero).

This uneven distribution of SRL competencies is itself a product of structural inequality. Students from more advantaged backgrounds typically encounter educational environments that cultivate metacognition, independence, and reflective practice from an early age. Meaningful efforts to embed SRL within AI-driven education must therefore be accompanied by targeted pedagogical interventions particularly for learners whose prior schooling has not equipped them with these capabilities. So, education policies must prioritize not only the expansion of AI infrastructure but also the systematic development of learners' self regulatory capacities through inclusice pedagogical practices and teacher support programmes.

Key Findings and Discussion

The analysis conducted in this study reveals several significant findings regarding the evolution of educational inequalities in STEM education across South Asia and Southeast Asia. Firstly, this study highlights that the inequalities observed in STEM education today did not arise solely from recent advancements in digital technologies. Instead, they are rooted in colonial educational policies that prioritized Western systems of knowledge and restricted scientific education to the socially and economically privileged. Structural inequalities persisted even after political independence, and they remain deeply embedded in the structures of educational institutions to this day.

Secondly, this study emphasizes that post-colonial education systems continue to experience structural dependency through their reliance on curricula, technological platforms, and Artificial Intelligence (AI) applications developed abroad. Consequently, rather than eliminating educational inequalities, technological modernization has, in many instances, further reinforced them.

Thirdly, the study's findings indicate that the traditional digital divide has now transformed into an emerging AI divide. Educational inequality is no longer determined solely by access to digital devices or internet connectivity; it is also shaped by disparities in AI literacy, digital skills, the preparedness of educational institutions, and the ability to critically understand and utilize knowledge generated by AI. These differences are most clearly reflected in South Asian and Southeast Asian countries, where significant disparities exist in technological infrastructure and investment in education.

Finally, this study highlights that Self-Regulated Learning (SRL) serves as a crucial pedagogical approach for enhancing learner agency within AI-supported STEM educational environments. However, SRL alone cannot fully eliminate structural educational inequalities. Its effectiveness depends heavily on equitable education policies, inclusive pedagogical practices, teacher preparedness, and sustained institutional support. Overall, the findings of this study confirm that the 'AI divide' is not an entirely new educational phenomenon; rather, it is a new form of long-standing, historically rooted educational inequality. Therefore, technological advancement alone is not sufficient to tackle these challenges; it is essential to complement it with educational reforms grounded in a historical understanding.

Conclusion

Technological innovation alone cannot resolve the inequalities that define STEM education across South and South-East Asia. The disparities visible today are historically produced, structurally sustained, and epistemically reinforced. The emergence of AI in education has not dissolved these dynamics; it has given them new form. The analysis in this article highlights that the shift from the traditional digital divide to emerging AI divide is not an entirely new educational challenge; rather it is a continuation of long standing, historically rooted educational inequalities. Although AI holds significant potential to enhance STEM education, its benefits can be fully realized only when technological advancement is coupled with equitable educational policies, learner cantered pedagogical practices, and inclusive learning approaches. Bridging the AI divide will require more than infrastructure investment. It demands structural reform, culturally responsive pedagogy, and a genuine commitment to developing SRL and learner agency so that technology becomes a tool of inclusion rather than another mechanism through which existing inequalities are reproduced. This study adopts a qualitative, conceptual, and socio-historical approach based on historical documents, theoretical literature, policy statements, and secondary sources. This study does not include primary empirical data or quantitative analyses. Therefore, the results of this study should only be understood as a conceptual explanation of educational inequality in AI-supported STEM education; they should not be considered as an empirical assessment based on empirical data. Future empirical studies in different educational contexts will help to further confirm and expand the arguments presented in this study.

Suggestions

Policy Recommendations

To ensure equitable participation in AI-enabled STEM education, education policies should not only focus on improving digital infrastructure, but also on creating equal educational opportunities for all. Governments should invest in AI literacy; strengthen technological infrastructure and take measures to reduce educational disparities between urban and rural educational institutions. Educational institutions should integrate Self-Regulated Learning (SRL) methods into STEM curricula through learner-centred teaching approaches. At the same time, teachers should be provided with professional training to use AI effectively and ethically. Furthermore, policymakers and curriculum designers should encourage the development of AI tools that are adapted to local social, linguistic and cultural contexts, and enhance regional cooperation among South Asian and Southeast Asian countries. This will enable us to create an AI-supported educational environment that is inclusive, adaptive, and equitable.

Suggestions for Future Research

Future studies should empirically examine the impact of AI on STEM learning in diverse socio-economic contexts in South Asia and Southeast Asia. Studies that examine AI literacy, institutional preparedness, and self-regulated learning (SRL) can provide deeper insights into reducing educational inequality. Similarly, further studies on AI technologies that are adapted to local social, linguistic, and cultural contexts can make a significant contribution to creating an inclusive and equitable AI-supported educational environment.

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