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A Quantitative Study on the Cost-Effectiveness of Digitised Education in Students' Learning

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Abstract
The rapid adoption of technology in education, especially following the COVID-19 pandemic, has brought digitised learning to the forefront as a viable alternative to traditional classroom instruction. This paper evaluates the cost-effectiveness of digitised education compared to conventional methods in real-world settings across India. Using a comparative structure quantitative approach, data was collected from 253 students across urban and rural schools and colleges and EdTech platforms. The analysis considers financial inputs—such as infrastructure, device availability, internet access, and operational costs—alongside educational outcomes like academic performance, student satisfaction, and accessibility. In the supportive preferences of students were assessed using the Analytic Hierarchy Process (AHP) method to quantify perceived benefits across various learning formats. This study finds that students are choosing digitised education is generally more cost-effective, particularly in urban and semi-urban areas with better digital infrastructure and connectivity. Students in these regions also report increased engagement and flexibility. However, in rural settings, the benefits of digitised learning are limited by infrastructure gaps, device shortages, and low digital literacy. Despite of a few challenges, digitised education is the ray of hope to maintain its cost-effectiveness for improving learning outcome across the world. Its impact is closely tied to equitable access and digital readiness. The findings highlight the need for targeted investments in infrastructure and digital skills development to ensure the inclusive and effective implementation of learning among students.

Keywords: Digitised education, cost-effectiveness, AHP method, perceived benefits, Ed-tech platforms, infrastructure

Introduction
In the past decade, the world has witnessed a seismic shift in the way education is delivered, accessed, and consumed. The digitisation of education has emerged as one of the most transformative developments in the global education landscape (OECD, 2020; World Bank, 2022). Governments, private institutions, and EdTech startups are investing significantly in online learning platforms and digital classrooms (HolonIQ, 2023). While digital education promises scalability and accessibility, its real-world cost-effectiveness remains under scrutiny (UNESCO, 2020). Accelerated by the COVID-19 pandemic—which exposed the vulnerabilities of traditional brick-and-mortar schooling systems—digital education has

moved from being a supplementary tool to a primary mode of learning in many contexts (UNICEF, 2021).

This transformation is particularly significant in developing countries like India, where traditional education systems have long struggled with issues of access, quality, and equity (NITI Aayog, 2021). Digital education encompasses a broad array of tools and technologies, including online courses, learning management systems, AI-based personalised learning, video conferencing platforms, and mobile learning applications (KPMG, 2022). These technologies promise a scalable, flexible, and inclusive education model capable of reaching remote geographies, underserved populations, and diverse learner profiles (World Bank, 2021). In India, the **National Education Policy 2020** has placed a strong emphasis on integrating digital tools into the education system (Ministry of Education, 2020), while private and venture capital-backed EdTech companies such as BYJU'S, Unacademy, and Vedantu have become household names (Inc42, 2023).

The Growth and Investment in Digital Education

Globally, the digital education market has grown exponentially. Market research suggests that the global EdTech and smart classroom market is projected to reach hundreds of billions of dollars by the end of the decade (MarketsandMarkets, 2023). In India, the EdTech market has been particularly buoyant, driven by a young, tech-savvy population, affordable mobile internet, and a strong demand for quality education (KPMG, 2022). Between 2020 and 2022, Indian EdTech startups collectively raised billions of dollars in venture funding, with some achieving "unicorn" status — a valuation exceeding USD 1 billion (Inc42, 2023). Governments have also intensified their efforts. Initiatives such as **DIKSHA** (Digital Infrastructure for Knowledge Sharing), **SWAYAM** (Study Webs of Active Learning for Young Aspiring Minds), and **PM eVIDYA** illustrate India's commitment to digital content dissemination, teacher training, and inclusive online education (Ministry of Education, 2023). These initiatives aim not only to bridge the urban–rural divide but also to make learning more interactive, data-driven, and outcomes-oriented.

Private institutions have embraced hybrid and blended learning models, investing in virtual labs, online assessments, and digital libraries. Schools and universities now increasingly integrate Learning Management Systems (LMS) to complement classroom teaching. Additionally, corporate training and upskilling programs have moved online, further underscoring the shift toward digital learning. This surge in investment is huge and reflects a clear commitment to innovation and effectiveness of these investments.

Accessibility and Inclusion: A Double-Edged Sword

One of the biggest promises of digital education is its potential to democratise learning. In theory, a student in a remote village in Bihar should be able to access the same quality of education as a student in Mumbai, provided they have an internet connection and a device (World Bank, 2021). Online platforms can offer courses in multiple languages, cater to different learning speeds, and enable self-paced learning (OECD, 2020). They also help address shortages in qualified teachers, especially in rural and underserved areas (UNESCO, 2020). However, the reality is often more complicated. The digital divide remains a significant barrier. According to the National Sample Survey (2017–18), only about 24% of Indian households had access to the internet, with significantly lower penetration in rural areas (National Statistical Office, 2019). The COVID-19 pandemic exacerbated this gap, with

millions of children missing out on education due to lack of connectivity, devices, or digital literacy (UNICEF, 2021).

In many developing countries, digital education risks becoming an elite privilege rather than an equaliser (Asian Development Bank, 2022). Students from lower-income backgrounds may struggle with access to reliable internet, power supply, or quiet spaces to study. Additionally, digital learning can inadvertently marginalise learners with disabilities unless platforms are designed with inclusivity in mind (World Bank, 2022). To genuinely improve accessibility, digital education must be accompanied by parallel investments in infrastructure, electricity, affordable devices, and localised content (KPMG, 2022). Public–private partnerships can play a pivotal role here, enabling large-scale deployment of low-cost tablets, community Wi-Fi, and mobile-based learning apps (NITI Aayog, 2021).

However, amid this enthusiasm lies an essential question that continues to spark debate among policymakers, educators, and economists: **Does digital education offer better or comparable educational outcomes at a lower or justifiable cost?** This study aims to assess whether the investment in digital education yields better or comparable educational outcomes at a lower or justifiable cost, particularly in developing countries like India. The objectives of the research are:

- To analyse cost-effectiveness has the most desirable impact among all perceived benefits of digital education.
- To report the comparative study of perceived benefits of students learning in digitised education

Research Methodology

In the present era, decision-making has become an increasingly complex process. To address this complexity, advancements in mathematics and statistics offer a variety of established multi-criteria decision-making (MCDM) tools and models. One such prominent method is the **Analytical Hierarchy Process (AHP)**, introduced by Saaty in 1980. According to Mathew, Chakrabortty, and Ryan (2020), AHP is rooted in the principles of human thought processes (Amit Goyal, 2022). It is widely recognized for its ability to address the challenges associated with evaluating multiple criteria and sub-criteria (Gupta, Dawar, & Goyal, 2018). As Figueira, Greco, and Ehrgott (2005) explain, MCDM techniques include approaches such as importance-based decision-making and outranking methods. AHP stands out for its simplicity and ability to incorporate expert judgments; however, the traditional AHP framework struggles to handle vague or uncertain information (Wang & Chen, 2008).

Cost-Effectiveness: A Critical Assessment

When evaluating the impact of digital education, cost-effectiveness becomes a vital metric, particularly in resource-constrained settings. The assumption is that digital platforms, once developed, can be scaled at a relatively low marginal cost per additional learner, making them attractive from an economic standpoint. However, the initial setup costs — including infrastructure, training, content creation, and maintenance — can be substantial.

A cost-effectiveness analysis must consider both **inputs** (financial and non-financial resources) and **outcomes** (learning gains, student retention, skills acquired). For example, a digital platform may reach thousands of students, but if only a small fraction complete the course or show meaningful learning gains, the return on investment becomes questionable.

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Moreover, technology has a limited shelf-life. Devices require regular updates, software must be maintained, and user support must be ensured. These recurrent costs must be factored into long-term planning. For governments, especially in developing countries like India, this raises concerns about scalability and sustainability. Should scarce public funds be directed toward flashy EdTech platforms, or would investments in teacher training, school infrastructure, and traditional pedagogy yield better returns?

Recent research by institutions like the World Bank and the Brookings Institution underscores (Gupta, 2020) that technology in education should be treated as a **means**, not an **end**. The focus should be on **"cost-effective learning,"** not just cost-effective technology. That means aligning investments with learning outcomes, ensuring accountability, and continuously measuring impact through evidence-based evaluations. In the study the efforts are made to understand the perceived benefits of the digitised education start-ups from the student's perspective. The different benefits of the digitised education start-ups were found based on comparative study of different perceived benefits of digitised learning, in availability of the students taking the courses from the different startups. The various benefits of the digitised education start-ups were identified and selected in the context of professional students completing their post graduate degree. The five major benefits of the digitised education start-ups as shown below:

- *Flexibility and Accessibility,*
- *Personalised Learning,*
- *Interactive and Engaging Content*
- *Self-Paced Learning*
- *Cost-Effectiveness*

The above perceived benefits of the digitised education start-ups were selected to estimate their relative importance from the student's perspective. These eleven perceived benefits of the digitised education start-ups were included for estimating their relative importance or the prioritization using AHP method based on responses received from the selected professional students. The AHP questionnaire was developed and distributed to 10 professional students for pairwise comparison of the included benefits. The 1–9-point scale as suggested by Thomas Satty was used for collecting the responses from the professional students participated in the survey. The responses received from the selected professional students were examined using the AHP process in the excel worksheet. The AHP matrix used for prioritizing the perceived benefits of the digitised education start-ups and used in the survey for the data collection from the professional students is shown in table.

Table 1: Input AHP matrix for pairwise comparison

	Flexibility and Accessibility	Personalised Learning	Interactive and Engaging Content	Self-Paced Learning	Cost-Effectiveness
Flexibility and Accessibility	1.00	7.00	3.00	2.00	4.00
Personalised Learning	-	1.00	0.25	0.20	0.33
Interactive and Engaging Content	-	-	1.00	1.00	1.00
Self-Paced Learning	-	-	-	1.00	2.00
Cost-Effectiveness	-	-	-	-	1.00

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The AHP matrix used in the survey, consists of two triangular matrices namely upper and lower triangular matrix. The upper triangular matrix in AHP method have input responses from the selected professional students after pairwise comparison of the cells. However, the lower triangular matrix initially does not require any response and the main diagonal of the AHP matrix is filled with 1, representing that the same dimensions of included different values of perceived benefits of the digitised education start-ups is equally important. The selected professional students were requested to compare the included different perceived benefits of the digitised education start-ups mentioned in the upper triangular cells of the AHP matrix. The pairwise comparison of the included perceived benefits of the digitised education start-ups is done using the 9-point rating scale, where 1 indicates equally important and 9 means absolutely important. The responses received from the selected professional students were reported in the table.

Table 2: Input AHP matrix for pairwise comparison

	Flexibility and Accessibility	Personalised Learning	Interactive and Engaging Content	Self-Paced Learning	Cost-Effectiveness
Flexibility and Accessibility	1.00	7.00	3.00	2.00	4.00
Personalised Learning	0.14	1.00	0.25	0.20	0.33
Interactive and Engaging Content	0.33	4.00	1.00	1.00	1.00
Self-Paced Learning	0.50	5.00	1.00	1.00	2.00
Cost-Effectiveness	0.25	3.00	1.00	0.50	1.00

The responses AHP table represents the input responses received from the selected professional students against the different perceived benefits of the digitised education start-ups. The upper triangular matrix indicates the average of the initial responses, used to estimate the values in lower triangular matrix. The values in lower triangular AHP matrix indicates the reciprocals of the respective average input score in upper triangular matrix. The last row of the table indicates the sum of each column of the matrix. Table 2 indicates the normalised matrix estimated by average score of each cell divided by the column total and indicates the relative contribution in the column. The final normalised table is shown in table.

Table 3: AHP normalized matrix

	Flexibility and Accessibility	Personalised Learning	Interactive and Engaging Content	Self-Paced Learning	Cost-Effectiveness
Flexibility and Accessibility	0.207	0.182	0.223	0.209	0.219
Personalised Learning	0.030	0.026	0.019	0.021	0.018
Interactive and Engaging Content	0.069	0.104	0.074	0.104	0.055
Self-Paced Learning	0.104	0.130	0.074	0.104	0.109
Cost-Effectiveness	0.052	0.078	0.074	0.052	0.055

The findings indicate that the most significant perceived benefit of digitized education start-ups is their cost-effectiveness, which accounts for 24.52% of the perceived importance. This was followed by flexibility and accessibility, with a relative weight of 19.78%, scalability of 15.24%, and self-paced learning at 11.47%. Digitized education start-ups are frequently considered cost-effective solutions, primarily because of their capacity to reduce traditional educational expenses and utilize technology to deliver education more efficiently. The financial advantages of digital education platforms are particularly evident in e-learning models. E-learning platforms eliminate the necessity for physical classrooms, thereby reducing the costs associated with facility maintenance, utilities, and other operational expenses. This is especially advantageous for professional education and corporate training programs, where e-learning can supplement costly in-person training sessions (Strother 2002). Digital platforms facilitate efficient scaling of educational resources, enabling institutions to accommodate a larger number of students without a proportional increase in costs. This scalability is supported by cloud computing, which helps deliver educational content to a broad audience at a reduced cost (Chuang et al., 2011). Initiatives such as MOOCs (Massively open online courses (MOOCs) and projects such as MIT/Harvard EdX aim to reach millions of students globally by offering courses at a fraction of the cost of traditional education (Ruth, 2012).

Digitized education start-ups capitalize on ***flexibility and accessibility*** to enhance student outcomes through digital platforms and online learning environments. These platforms enable students to learn at their own pace, access resources from any location, and engage with interactive content, collectively enriching their learning experiences. This flexibility is vital for students with additional commitments such as employment or family obligations, and can result in improved academic performance (Stone et al., 2019) (Soffer et al., 2019). Students can develop individualized patterns of learning time and resource access that are significantly correlated with their course achievements. This adaptability accommodates individual learning preferences and needs (Soffer et al. 2019). Digital education platforms enhance accessibility for students who may encounter barriers to traditional education such as those in rural areas or those with disabilities. This inclusivity ensures a more equitable educational experience for all students (Pearson & Koppi, 2002) ("Digital equity and inclusion in education," 2023). **Scalability** in digital education start-ups not only enhances accessibility, but also transforms the learning experience of students globally. By utilizing technology, these platforms can accommodate an increasing number of students without compromising the educational quality. This scalability facilitates the development of personalized learning paths, adaptive assessments, and real-time feedback mechanisms, which can significantly enhance educational outcomes. This iterative process of refinement ensures that educational offerings remain relevant, effective, and aligned with evolving educational standards and workforce demands (Balkin & Sonnevend, 2016) (Wilkens et al.,2017)

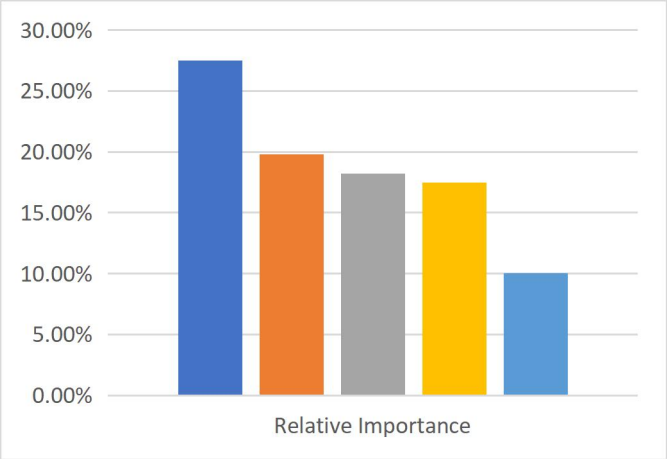
Table 4: Relative weight of the attributes indicating the Student's perspective towards benefits of the digitised education start-ups

Criterion	Relative Importance	Cumulative Relative Importance
st Effectiveness	27.52%	27.52%
Flexibility and Accessibility	21.78%	50.30%
Scalability	19.24%	69.54%

Self-Paced Learning	18.47%	85.01%
Interactive and Engaging Content	14.03%	100.0%

The following figure showing the student's perspective towards benefits of the digitised education start-ups

Chart 1: Relative importance (%) for each student benefit factors



The Way Forward: A Balanced, Evidence-Driven Approach

Given the complexities involved, it is clear that digital education is not a panacea, but neither should it be dismissed as a passing trend. Instead, what is needed is a nuanced, evidence-driven approach that leverages the strengths of technology while addressing its limitations (OECD, 2020; World Bank, 2022). For developing countries like India, the following strategies may help ensure that digital education investments are both impactful and cost-effective:

1. **Hybrid Learning Models:** Blended approaches that combine face-to-face instruction with digital tools often yield better results than purely online or offline models (Means et al., 2013; UNESCO, 2021). These allow for human interaction while leveraging the scalability of technology.
2. **Localisation and Inclusivity:** Digital content should be available in regional languages, adapted to local contexts, and inclusive of learners with different abilities and backgrounds (UNICEF, 2022; KPMG, 2022).
3. **Teacher Empowerment:** Technology should empower, not replace, teachers. Regular training, support, and incentives can help educators integrate digital tools into pedagogy effectively (Kozma, 2011; Ministry of Education, 2023).
4. **Data and Evaluation:** Continuous assessment of digital initiatives is crucial, including measuring student progress, collecting feedback, and conducting cost–benefit analyses to ensure accountability and transparency (OECD, 2015; Brookings, 2021).
5. **Public–Private Partnerships:** Collaboration between governments, tech companies, NGOs, and communities can pool resources, expertise, and innovations to drive sustainable digital education models (NITI Aayog, 2021; Asian Development Bank, 2022).
6. **Infrastructure Development:** Addressing the digital divide through affordable internet, electricity, and device access is non-negotiable if digital education is to reach the last mile (World Bank, 2021; National Statistical Office, 2019).
7. **Focus on Foundational Learning:** Technology should enhance basic literacy, numeracy, and 21st-century skills rather than overemphasising exam preparation or rote content (UNESCO, 2020; World Bank, 2018).

Conclusion

The digitisation of education marks a dynamic shift in the learning landscape, particularly for countries like India where education systems face resource constraints and inequal distribution. Digital solutions hold the potential to reduce delivery costs, personalise learning, and expand access but their true value describes how efficiently they convert investments into measurable learning outcomes and perceived student benefit. Cost-effectiveness become the central metric guiding educational technology deployments. It is not enough to digitise for scale; digital interventions must be demonstrably more affordable per unit of learning gained compared to traditional methods. This requires rigorous evaluation of learning outcomes alongside continuous feedback from students to ensure that digital tools are not only accessible but also engaging, useful, and responsive to their actual requirements.

From a profitability standpoint, this alignment between educational value and user satisfaction is also what sustains viable business models. For edtech providers, long-term profitability depends less on rapid expansion and more on sustained usage, proven impact, and customer trust. Solutions that genuinely improve learning — and are perceived as beneficial by students and families — are more likely to command market retention, attract institutional partnerships, and justify recurring investments by governments and philanthropies alike. Therefore, the imperative is not simply to invest in digital education, but to invest smartly. With clear metrics, inclusive design, and a focus on both impact and return on investment, digital education can become a sustainable and profitable engine for inclusive, equitable, and high-quality learning. The future of education in India will be shaped not by the presence of digital tools alone, but by how well they deliver value — to learners, to systems, and to society at large.

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