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Enhancing Education Quality: The Transformative Role of ICT in Modern Teaching and Learning

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ABSTRACT



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Objective: This study examines the impact of information and communication technology (ICT) adoption on the quality of education, focusing on its influence on academic performance and student engagement in different educational institutions.

Methods: Data were analysed using SPSS to explore the relationships between ICT adoption, academic performance and student engagement. A sample of 420 educational institutions in Thoothukudi, including primary, secondary and higher education levels, was selected using purposive sampling. Data were collected from institutional records, government education databases, and surveys of 35,000 students and 2,500 educators over the period 2019-2024. Regression analysis was used to assess the influence of ICT on student performance, with a focus on the effectiveness of ICT integration in modern teaching practices.

Results: The results indicate a positive correlation between ICT integration and academic performance. Schools with advanced ICT tools showed higher student engagement, especially at the secondary and tertiary levels. However, challenges related to infrastructure and teacher preparedness were identified as barriers to effective ICT use.

Novelty: This study provides new insights into how ICT adoption varies across educational levels and the specific challenges faced by different institutions, particularly in rural areas.

Theoretical and policy implications: The findings emphasise the importance of improving ICT infrastructure and teacher training. Policy makers are encouraged to focus on equitable distribution of ICT and support for educators to improve learning outcomes through technology.

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1. Introduction

The integration of Information and Communication Technology (ICT) into education systems has significantly transformed the landscape of learning and teaching worldwide. With the rapid proliferation of digital tools, ICT has become an indispensable resource for enhancing educational access, equity, and quality (Abulibdeh et al., 2024; J. Wang et al., 2022). Particularly in developing regions such as Thoothukudi, Tamil Nadu, ICT-enabled education has bridged gaps between urban and rural learners, ensuring equitable learning opportunities. Ammar et al. (2024) Gunness et al. (2023), the adoption of ICT in education fosters innovative teaching methodologies, promotes personalized learning, and improves overall student engagement. Alamri et al. (2021), Boelens et al., (2017) highlights the role of ICT in supporting blended learning models, which are increasingly recognized as effective strategies for sustainable education delivery. As nations advance toward knowledge-driven economies, investments in ICT infrastructure and teacher training programs have been prioritized to foster skilled human capital (Beynaghi et al., 2016; Gouvea et al., 2018; Mazumdar-Shaw, 2018). However, despite these strides, disparities persist, necessitating a deeper understanding of ICT's role in transforming education in underserved areas like Thoothukudi.

While ICT holds immense potential for revolutionizing education, several challenges hinder its seamless integration into the teaching-learning process (Abulibdeh et al., 2024; Oke & Fernandes, 2020). In rural regions, the digital divide remains a pressing issue, with limited access to reliable internet connectivity and modern technological tools (Salemink et al., 2017). Additionally, educators often face barriers such as inadequate training, lack of technical support, and resistance to adopting new teaching methodologies (Feng & Xiao, 2024; Watty et al., 2016). (Ferede et al., 2022; Iglesias-Pradas et al., 2021), the effectiveness of ICT in education is contingent upon its proper implementation, which includes robust policies, infrastructure, and teacher preparedness. Hong et al. (2024), Olanrewaju et al. (2021), Zhao & Chen



(2023) indicates that disparities in ICT adoption contribute to inequities in student performance, particularly between urban and rural learners. Addressing these challenges is critical to unlocking the full potential of ICT as an enabler of inclusive and equitable education.

Constructivist learning theory serves as a foundational framework for understanding the impact of ICT in education (H.-Y. Hong et al., 2019; Wu et al., 2022). This theory posits that learners construct knowledge through active engagement, collaboration, and exploration, which aligns with the capabilities of ICT tools (Wang et al., 2024; Yeh et al., 2021). ICT fosters interactive and student-centered learning environments, facilitating deeper understanding and retention of knowledge (Wu et al., 2022). Kitsantas et al. (2019). Varenina et al. (2021) demonstrate that ICT enhances cognitive development by promoting critical thinking and problem-solving skills. Additionally, MacBlain, (2021)'s concept of the Zone of Proximal Development (ZPD) underscores the significance of social interaction and scaffolding in learning, which ICT platforms effectively support through features like online collaboration and peer feedback (Cai et al., 2024; Qi & Derakhshan, 2024). These theoretical underpinnings highlight ICT's transformative role in modern educational practices (Alt, 2018; Lin et al., 2024; van den Beemt & Diepstraten, 2016).

Despite the extensive literature on ICT in education, several gaps and inconsistencies underscore the need for continued research. While many studies have highlighted the positive impacts of ICT, such as increased student engagement and improved academic outcomes Cakiroglu et al. (2017), Dunn & Kennedy (2019), Fernandez-Gutierrez et al. (2020). Hu et al. (2018), others have pointed out challenges like teacher burnout and technology-induced distractions (Califf & Brooks, 2020; Chen et al., 2020; Sanjeeva Kumar, 2024; Zhu et al., 2023). (Adarkwah, 2021; Safdar et al., 2022) found that ICT integration significantly boosted learning outcomes in urban schools but had minimal impact in rural settings due to infrastructural limitations. (Dong et al., 2024; Windisch, 2016) suggests that targeted ICT interventions in rural schools can yield substantial improvements in literacy and numeracy skills. This divergence in findings highlights the critical need for context-specific investigations, particularly in underrepresented regions like Thoothukudi, Tamil Nadu. Furthermore, the novelty of this study lies in its focus on the localized impact of ICT in a developing region, considering socio-economic, cultural, and infrastructural factors. Unlike previous research that primarily examines macro-level trends, this study aims to explore micro-level dynamics, providing actionable insights for policymakers and educators. By analyzing the unique challenges and opportunities of ICT in Thoothukudi's education sector, this research fills a significant gap in the existing body of knowledge, contributing to a nuanced understanding of ICT's role in shaping equitable and sustainable education systems.

The primary objective of this study is to analyze the role and impact of ICT in improving the quality of education in Thoothukudi, Tamil Nadu. The study seeks to identify the challenges and opportunities associated with ICT adoption, assess its effectiveness in bridging educational disparities, and provide recommendations for enhancing its integration into teaching and learning practices. This research aims to contribute to the development of tailored strategies for leveraging ICT to achieve inclusive, equitable, and quality education in the region.

2. Method

This research employs a mixed-method approach integrating experimental design, theoretical predictions, and statistical analysis to explore the influence of ICT integration in education in the school and higher education sector in Thoothukudi, Tamil Nadu. The methodology is tailored to ensure robust insights and originality by examining recent developments and challenges in ICT deployment in education. The study adopts a quasi-experimental design with a focus on comparing educational outcomes between institutions that have adopted ICT intensively and those with minimal ICT integration. This comparative approach enables the identification of significant patterns and relationships. The independent variables include ICT adoption level, training for educators, and resource allocation, while the dependent variables are student performance, teaching efficiency, and satisfaction levels. Based on constructivist learning theories and technology acceptance models, it is hypothesized that increased ICT adoption improves learning outcomes and teaching efficiency. Aldholay et al. (2018), Rohatgi et al. (2016), indicate a positive correlation between ICT use and academic performance, suggesting the transformative potential of technology in education.

The data collection process was structured into three distinct phases to ensure a comprehensive understanding of ICT integration in education. The preliminary survey phase involved distributing structured questionnaires to educators across 420 educational institutions. This phase aimed to evaluate the extent of ICT training provided to educators and the availability of digital resources within their institutions. The implementation observation phase involved in-class monitoring to examine the real-time application of ICT tools, capturing data on how these technologies were used to enhance teaching methodologies and address challenges such as technical issues or lack of engagement. Finally, the outcome evaluation phase measured the impact of ICT adoption on academic performance. This was achieved through standardized assessments, comparing pre- and post-ICT implementation scores. The results of these phases provided a layered understanding of ICT's role in improving teaching efficiency and learning outcomes.



Table 1: Detailed data collection across all phases

Phase	Objective	Methodology	Key Data Points Collected
Preliminary Survey	Assess ICT readiness	Questionnaires to educators	ICT training levels, resource availability
Implementation Observation	Monitor ICT usage	In-class observation	ICT tools usage patterns, challenges
Outcome Evaluation	Measure academic improvements	Standardized assessments	Pre- and post-ICT implementation scores

This study included 420 educational institutions in Thoothukudi, Tamil Nadu, encompassing primary, secondary, and higher education levels. The sample size, deliberately set at three times larger than those of previous similar studies, was designed to enhance the reliability and generalizability of findings. A purposive sampling technique was employed to select schools representing varying levels of ICT adoption, ensuring a balanced representation of institutions with diverse technological readiness. Data Sources for the study were drawn from institutional records, government education databases, and direct surveys conducted among students and teachers between 2019 and 2024. This comprehensive approach ensured data accuracy and relevance to the study's objectives. The final sample consisted of 35,000 students and 2,500 educators, capturing a wide range of socio-economic and demographic backgrounds. This diverse sample enabled a nuanced analysis of ICT's role in education across various contexts and provided insights into its impact on teaching effectiveness and student learning outcomes.

Table 3: Sample distribution

Education Level	Number of Institutions	Number of Students	Number of Educators
Primary	150	12	850
Secondary	170	15,5	1,1
Higher Education	100	7,5	550
Total	420	35	2,5

The data analysis was conducted using a combination of quantitative and qualitative methods to ensure a comprehensive understanding of ICT's impact on education in Thoothukudi. Quantitative data from standardized assessments and institutional records were analyzed using descriptive statistics, correlation, and regression analysis to identify patterns, relationships, and predictors of academic performance linked to ICT integration. The analysis focused on variations across primary, secondary, and higher education levels to provide granular insights into the differential impacts of ICT. Qualitative data, derived from surveys and interviews with educators and students, were thematically analyzed to uncover challenges, perceptions, and contextual factors influencing ICT adoption and its effectiveness in the classroom. The mixed-method approach allowed for triangulation, enhancing the validity and reliability of findings. Statistical software, including SPSS and NVivo, was used to manage and analyze the datasets. Results highlighted significant improvements in student engagement and learning outcomes in institutions with higher ICT utilization, while also identifying barriers such as limited training and resource availability. The integration of both data types enabled the study to provide actionable recommendations for optimizing ICT use in educational settings.

3. Results

The results of the study provide detailed insights into the impact of ICT adoption on academic performance across different educational levels in Thoothukudi. Data from standardized assessments, student surveys, and educator interviews were analyzed using SPSS and SmartPLS to ensure robust and comprehensive results. The analysis focused on understanding the relationship between ICT integration and educational outcomes, including student engagement, academic performance, and the challenges faced by both students and educators. The analysis revealed a significant positive relationship between the level of ICT adoption in educational institutions and students' academic performance. Institutions with higher levels of ICT integration demonstrated better performance in standardized tests, particularly in subjects such as mathematics, science, and language arts. Regression analysis using SmartPLS confirmed that ICT



adoption accounted for 25% of the variance in academic performance, with higher ICT integration leading to increased student engagement and improved learning outcomes.

Table 4: Impact of ICT Adoption on Academic Performance

Educational Level	ICT Adoption Level	Average Test Score	Student Engagement (Likert Scale)	Performance Improvement (%)
Primary School	Low	68	3.2	5%
Primary School	Medium	75	3.8	12%
Primary School	High	85	4.5	20%
Secondary School	Low	70	3.4	8%
Secondary School	Medium	78	4.1	15%
Secondary School	High	88	4.7	25%
Higher Education	Low	72	3.5	6%
Higher Education	Medium	80	4.0	14%
Higher Education	High	90	4.8	22%

The qualitative analysis revealed several barriers to effective ICT use in classrooms. Teachers expressed concerns about the lack of adequate training and support, particularly in under-resourced schools. Additionally, students in lower socio-economic areas reported limited access to ICT resources at home, which hindered their ability to fully benefit from ICT integration. The thematic analysis, conducted through SPSS and SmartPLS, indicated that while ICT adoption had a generally positive impact, its full potential was not realized due to these barriers.

Table 5: Barriers to ICT Adoption in Education

Barrier Type	Frequency (%)	Impact on ICT Use	Solutions Suggested	Percentage of Institutions Affected
Lack of Teacher Training	45%	High	Regular ICT training workshops	65%
Limited Access to Resources	39%	Medium	Increased funding for technology	58%
Internet Connectivity Issues	32%	High	Improve broadband infrastructure	50%
Student Readiness	28%	Medium	Provide supplementary online learning resources	45%
Socio-Economic Constraints	25%	Low	Government support programs	30%

In terms of student engagement, the data indicated that ICT not only improved academic outcomes but also increased students' interest in learning. A strong positive correlation was found between the use of ICT in classrooms and students' perceived motivation and enjoyment in learning activities. The data analysis using SmartPLS revealed that higher ICT usage significantly contributed to students' sense of ownership over their learning process.

Table 6: Student Engagement and Perception of ICT Use

ICT Adoption Level	Student Engagement (LScale 1-5)	Enjoyment in Learning (LScale 1-5)	Motivation Increase (%)	P A Improvement (%)
Low	3.2	3.1	5%	6%
Medium	3.8	4.0	12%	15%
High	4.5	4.3	20%	25%

The results strongly suggest that ICT adoption plays a crucial role in enhancing academic performance, student engagement, and overall educational outcomes. However, challenges such as inadequate training, resource limitations,



and socio-economic factors continue to pose significant barriers to its effective implementation. These findings underscore the need for policy changes and targeted interventions to address these barriers and ensure equitable access to ICT resources across educational institutions in Thoothukudi.

To provide a deeper statistical understanding, multiple regression analysis was conducted to determine the extent to which ICT adoption influences academic performance, controlling for other variables such as socio-economic background and institutional resources. The analysis used SPSS and SmartPLS for structural equation modeling (SEM), which allowed for the exploration of relationships between ICT adoption, student engagement, and academic performance. The results showed a significant positive effect of ICT adoption on student engagement and performance across all educational levels. The model's fit indices (e.g., RMSEA = 0.045, CFI = 0.92, and TLI = 0.91) confirmed that the data was well-suited for the SEM model. ICT adoption explained 30% of the variance in student academic performance and 45% of the variance in student engagement.

Table 7: Regression Analysis on ICT Adoption and Academic Performance

Variable	Beta Coefficient	Standard Error	t-Value	p-Value	R ²
ICT Adoption Level (Primary)	0.35	0.04	8.75	0.000	0.30
ICT Adoption Level (Secondary)	0.42	0.05	9.10	0.000	0.31
ICT Adoption Level (Higher Ed.)	0.40	0.06	7.25	0.000	0.32
Student Engagement	0.38	0.03	11.26	0.000	0.45
Socio-Economic Status	-0.05	0.04	-1.25	0.211	
Institutional Resources	0.22	0.05	4.40	0.000	

The regression analysis clearly indicates that ICT adoption significantly improves academic performance at all educational levels, with the most notable impact at the secondary school level. Furthermore, student engagement acts as a key mediator, amplifying the effect of ICT on academic performance.

A comparative analysis was also conducted to examine how the impact of ICT integration differed between primary, secondary, and higher education institutions. The results indicated that secondary and higher education levels benefit the most from ICT integration, with substantial improvements in both student performance and engagement. Primary schools, while showing positive effects, exhibited more variability in outcomes, likely due to differences in resource availability and teacher training.

Table 7: Comparative Analysis of ICT Integration Impact by Educational Level

Educational Level	ICT Adoption Level	Average Academic Performance Improvement (%)	Average Student Engagement Increase (%)	Average ICT Resource Allocation (%)
Primary School	Low to Medium	10%	7%	20%
Secondary School	Medium to High	18%	15%	40%
Higher Education	High	22%	18%	60%

The comparative analysis highlights that higher education institutions, with better infrastructure and training, show the highest percentage improvements in both academic performance and student engagement. Secondary schools, while benefiting from ICT, still face challenges related to resource allocation, and primary schools exhibit the lowest impact, largely due to the limited access to ICT tools and teacher expertise.

Finally, a factor analysis was conducted to explore the underlying factors contributing to barriers in ICT adoption. This analysis identified key obstacles such as teacher readiness, resource limitations, and internet connectivity issues as the primary barriers to effective ICT integration. The factor loading results showed that teacher training and access to resources accounted for the largest portion of the variance in barriers to ICT adoption.

Table 8: Factor Analysis of Barriers to ICT Adoption



Factor	Eigenvalue	Factor Loading (%)	Variance Explained (%)	Reliability (Cronbach's Alpha)
Teacher Training	2.85	52.5	33%	0.89
Resource Allocation	2.12	45.3	28%	0.86
Internet Connectivity	1.87	40.1	25%	0.85
Socio-Economic Barriers	1.15	30.2	14%	0.80

The factor analysis reveals that teacher training and resource allocation are the most significant barriers to ICT adoption. These factors highlight the critical areas for policy intervention to ensure more effective ICT integration in schools across Thoothukudi. Overall, the results demonstrate that ICT adoption plays a crucial role in improving academic performance and student engagement in educational institutions across Thoothukudi. The impact is more pronounced in secondary and higher education, where better infrastructure and resources are available. However, significant challenges related to teacher training, resource allocation, and internet connectivity continue to hinder the effective use of ICT, particularly in primary schools. These findings underscore the need for targeted interventions, including comprehensive teacher training programs, improved resource allocation, and infrastructural improvements, to maximize the benefits of ICT in education.

4. Discussion

The findings of this study provide significant insights into the role of Information and Communication Technology (ICT) adoption in enhancing academic performance and student engagement in educational institutions. This section will discuss these results in relation to existing theories, the implications for educational practice, and potential avenues for future research.

The positive relationship between ICT adoption and academic performance, as observed in this study, aligns with several established theories in education and technology integration. According to the Technological Pedagogical Content Knowledge (TPACK) framework, the effective integration of ICT in education requires the intersection of three core components: technology, pedagogy, and content knowledge (Mishra & Koehler, 2006). Our findings suggest that when these elements are in harmony, the impact on academic performance is substantial. This supports the notion that ICT adoption in classrooms enhances the delivery of educational content and makes learning more engaging and accessible. Moreover, the Constructivist Learning Theory, which emphasizes the active role of learners in constructing knowledge, is also supported by the results of this study. ICT tools, especially interactive platforms, enable students to explore learning materials actively, fostering deeper engagement and a more personalized learning experience. This aligns with findings from Zhao et al. (2002), who noted that ICT encourages student-centered learning and enhances cognitive engagement, which leads to improved academic outcomes. The results of our study also reinforce the Social Learning Theory (Bandura, 1977), which posits that individuals learn from observing others within a social context. The use of ICT in educational settings facilitates collaborative learning and peer interactions, where students can share resources, discuss concepts, and learn from each other, further enhancing academic performance. This collaborative environment is critical for fostering critical thinking and problem-solving skills, which are essential for academic success.

The significant increase in student engagement resulting from ICT adoption is particularly noteworthy. Engagement is a key predictor of academic success, as it influences motivation, participation, and overall learning outcomes. Fredricks et al. (2004) defined engagement as the extent to which students are emotionally, behaviorally, and cognitively invested in their learning. Our study demonstrates that ICT enhances all three dimensions of engagement. Digital tools such as online discussions, multimedia presentations, and interactive simulations provide students with diverse ways to engage with the content, making the learning process more dynamic and interesting. The finding that ICT adoption increases engagement particularly in secondary and higher education institutions can be attributed to the increased availability of resources, infrastructure, and teacher training at these levels. In contrast, primary schools, which exhibit lower engagement levels, often struggle with limited access to technological tools and lack of comprehensive teacher training. This discrepancy highlights the need for targeted interventions to bridge the gap between different educational levels, ensuring equitable access to ICT resources.



The comparative analysis conducted in this study shows that ICT adoption has a more pronounced effect on secondary and higher education compared to primary education. This finding is consistent with previous research by Teo (2011), which highlighted that the impact of ICT on learning outcomes tends to be greater at higher educational levels where students have more advanced cognitive abilities and are more self-directed in their learning. Additionally, secondary and higher education institutions are generally better equipped with ICT infrastructure and more trained educators, which contribute to the more effective use of ICT tools. At the primary school level, the impact of ICT adoption on academic performance and student engagement was less significant. This may be attributed to several factors, including limited access to technology, inadequate teacher training, and the developmental stage of students, who may not yet be equipped to fully leverage ICT for learning. This underscores the importance of providing foundational ICT training for both teachers and students at early educational stages to build a solid technological base for future learning.

While the study found significant benefits associated with ICT adoption, it also identified several barriers to its effective integration. The most prominent barriers include teacher readiness, resource allocation, and internet connectivity issues. These findings are in line with the work of Ertmer (1999), who identified that teacher beliefs and attitudes towards technology are critical in determining the success of ICT integration in classrooms. Teachers who lack confidence in using technology may resist adopting it, even when it is available. As noted by Baylor & Ritchie (2002), professional development programs focused on enhancing teachers' technological skills and pedagogical approaches are essential to overcoming these barriers. Resource allocation also emerged as a significant challenge, particularly in primary schools. Venkatesh et al. (2003) emphasize that inadequate access to high-quality digital tools and learning materials limits the effective use of ICT in education. The findings suggest that investment in ICT infrastructure, including both hardware and software, is crucial to realizing the full potential of technology in enhancing academic performance. Furthermore, internet connectivity remains a major barrier in many educational institutions, especially in rural or underserved areas. As highlighted by Selwyn (2011), access to reliable and high-speed internet is a prerequisite for the effective use of many digital learning tools. Without adequate connectivity, students and teachers may be unable to fully exploit the benefits of ICT, leading to disparities in learning outcomes.

The implications of this study for educational practice are multifaceted. First, the positive relationship between ICT adoption and academic performance suggests that policymakers and educational leaders should prioritize the integration of technology in classrooms. This could involve increasing investment in ICT infrastructure, such as providing tablets, computers, and reliable internet access to schools, especially at the primary level. Second, teacher training programs should be expanded to ensure educators are equipped with the necessary skills to effectively integrate ICT into their teaching. This includes not only technical skills but also pedagogical strategies that leverage technology to enhance learning. The study emphasizes the need for continuous professional development to ensure that teachers remain up-to-date with emerging technologies and pedagogical practices. Finally, the findings highlight the need for tailored approaches to ICT adoption based on the educational level and institutional context. Secondary and higher education institutions, which are already more equipped with ICT resources, should focus on further enhancing the use of technology to promote higher-order thinking skills, collaboration, and digital literacy. Primary schools, on the other hand, may require targeted interventions to address resource gaps and teacher training deficits.

Future research should further explore the specific mechanisms through which ICT adoption influences student engagement and performance. This could involve examining the role of different ICT tools and platforms (e.g., online learning management systems, educational apps) in fostering different types of engagement (emotional, cognitive, behavioral). Additionally, longitudinal studies could provide deeper insights into the long-term impact of ICT on academic outcomes. Research could also explore the cultural and contextual factors that influence ICT adoption, particularly in rural or underserved areas. Understanding these factors would help to design more inclusive and context-specific strategies for ICT integration.

5. Conclusion

This study investigated the impact of Information and Communication Technology (ICT) adoption on academic performance and student engagement across educational institutions in Thoothukudi, offering key insights into the role of ICT in modern education. The findings highlight several crucial conclusions: Firstly, there is a significant positive relationship between ICT adoption and academic performance. Institutions that effectively integrated ICT into teaching practices demonstrated improved academic outcomes, indicating that ICT tools enhance the learning experience by providing diverse resources and interactive platforms. Secondly, the study revealed that ICT adoption significantly boosts student engagement. Both behavioral and cognitive engagement levels were notably higher in institutions that incorporated ICT, as it encouraged active participation, increased interest, and critical thinking among students, which subsequently contributed to enhanced academic performance.



However, the impact of ICT varied across educational levels. The study found that secondary and higher education institutions experienced a more pronounced effect from ICT adoption, likely due to better infrastructure, resources, and teacher training compared to primary schools. This underscores the need for early-stage ICT integration in primary education to ensure that foundational skills are developed from the outset. Additionally, the study identified several barriers to ICT adoption, including inadequate teacher readiness, insufficient resources, and unreliable internet connectivity, especially in rural areas. These challenges must be addressed to ensure equitable access to ICT benefits across all educational institutions.

Based on these findings, several recommendations can be made: increasing investment in ICT infrastructure, particularly in primary schools, where resource availability is often limited; expanding teacher training programs to equip educators with the necessary skills to use ICT effectively in the classroom; and tailoring ICT adoption strategies to meet the specific needs of each educational level. Additionally, ongoing support for teachers, both in terms of technical skills and pedagogical strategies, is essential to ensure that ICT is used to its full potential.

Lastly, future research should explore the specific ICT tools and platforms that have the most significant impact on student engagement and performance, focusing on the long-term benefits of ICT in education. Longitudinal studies could offer deeper insights into how ICT influences learning over time, and further research is needed to understand the factors that impact ICT adoption, particularly in rural areas. In conclusion, while ICT adoption holds great promise for enhancing academic outcomes and student engagement, addressing the barriers to its widespread use is crucial. Overcoming these challenges will create more dynamic and effective learning environments, benefiting both students and educators.

Limitation

The limitations of this study are based on purposive sampling, which may challenge generalizability to other regions beyond Thoothukudi. Moreover, despite using regression analysis to examine the impact of ICT adoption, confounding variables such as socio-economic differences, language barriers, and cultural factors that could also play a role in academic performance and engagement, were not included in the analysis. Additionally, the reliance on quantitative data may miss the more nuanced qualitative data about teacher and student integration of ICT in their teaching and learning.

Author Contribution

Ragukumar K: Study conception, data analysis, manuscript writing.

Introduced the research framework, facilitated access to international datasets, and reviewed the policy implications section.

Jothye A, Elenna : Had the technical expertise in ICT, developed the analytical models, and reviewed the methods and results section. All authors have read and approved the final manuscript.

Conflicts of Interest

The authors declare no conflict of interest related to the publication of this study.

Data Availability Statement

Data supporting the findings of this study can be found from institutional records, government education data bases, and survey results. However, access to these data is limited to ensure the privacy of students and educators. Data access requests should be addressed to the corresponding author and will be considered upon approval by the respective institutions.

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