EPH-International Journal of Business & Management Science

INCLUSIVE DIGITAL LEARNING FOR SUSTAINABLE DEVELOPMENT: BRIDGING THE URBAN-RURAL DIGITAL DIVIDE AND ADVANCING SDG4

Dr. Anindya Saha[1], Dr. Sougata Majumder[2], Dr. Juin Ghosh Sarkar[3], Ms. Priyanka Dhar[4], Dr. Abhishek Bhattacharjee[5]

[1]Assistant Professor, Department of Data Science, Dean-School of Science and Technology, iLead, Kolkata, Email: anindyasaha2006@gmail.com
ORCID ID: 0009-0000-4403-7209
[2]Assistant Professor, Department of Management Science, MCKV Institute of Engineering, Liluah, Email – sougata.majumder97@gmail.com
ORCID ID: 0009-0004-6941-0961
[3]Associate Professor, Department of Management Science, MCKV Institute of Engineering, Liluah, Email: juing@rediffmail.com
ORCID ID:0000-0001-6158-0975
[4]Assistant Professor, Department of Management Science, MCKV Institute of Engineering, Liluah, Email-priyanka.dhar312@gmail.com
ORCID ID:0009-0002-9019-7312
[5]Assistant Professor, Army Institute of Management, Kolkata, Email: abhishek.bhattac@gmail.com
ORCID ID:0009-0004-4227-9123
** Corresponding Author: sougata.majumder97@gmail.com*
ORCID ID:0009-0004-6941-0961

Article History
Received : *2026-07-22*
Revised : *2026-08-29*
Accepted : *2026-09-07*
Published : *2026-09-16*

Abstract
In contemporary education system, technology enhanced learning are the insurgents which immensely contributes towards the fulfilment of the universal Sustainable Development Goals. This study evaluates the mechanisms between cutting-edge digital education that aids to reach Sustainable Development Goals (SDGs), especially SDG 4—fostering inclusive and fair learning ecosystem and methodizing lifelong equitable learning opportunity across all ages. This paper deconstructs the impact of usage of digital ecosystem to augment inclusive education, equity, and viability in the Urban-Rural continuum. The research work also focuses on the ramification of technology to mark educational inequality, instilling digital competency and solidarity.
The research uses both statistical and thematic analysis techniques combined with a rigorous review of international and national literature along with primary data from structured questionnaire for surveys and interviews. The respondents of the survey comprise of people belonging from various strata in the field of education from both undergraduate and post-graduate institutes including students, academicians and administrators. Quantitative data were analyzed using statistical techniques to know about the patterns of usage, disparities in access and perceived advantages of digital learning. Qualitative data were gathered from related case studies and enquiry to stake-holders for the formulation of a context regarding the hurdles faced by digital education corresponding to different geodemographic and socio-economic strata.
The study illustrates on some major findings about the enormous contribution of digital learning platforms like Learning Management Systems (LMS), online courses and mobile learning apps in terms of the capability to access quality experiences for students in remote marginal areas. Such tools have enabled

Vol. 12 Issue 5s (September, 2026)

ISSN: 2208-2190 Pages- 15-26

DOI: https://doi.org/10.69980/s8xzsh17

learners in remote areas the privilege of flexible, affordable and independent learning – benefits which were so far considered infeasible given the infrastructural and economic constraints. Digital platforms, on the ground of their flexibility, have also accomplished in reaching out to diverse groups of learners like first generation learners, especially abled learners and women learners, through delivery in regional languages and formats.

Nevertheless, this study also provides helpful notes in the areas of long-term digital gaps which can potentially obstruct the progress of technology-based education. Regardless of the progress made till date, factors such as scarce gadget access, digital literacy levels, availability of network facility and non-existence of regulatory endorsement still acts as an obstacle in of spread of digital education.

In outskirts, lack of infrastructure and shortage of trained digital learning facilitators are important parameters to the gap between potential and actual social impact of digital education.

These constraints compelled us to intervene through several activities like state-facilitated sub-infrastructure for broadband, local community digital awareness programs, along with digital pedagogy training.

The study focuses on the need for digital learning ecosystems that are inclusive and environmentally sustainable. Institutes are experimenting with cheap digital technologies with less electricity consumption rather than upgrading to high-bandwidth-sucking technological bandwagons and are also getting aligned to open access learning resources so that they don't need to depend on commercial outfits for educational materials. In India, with the DIKSHA platform or global partnerships dedicated to ICT4D (Information and Communication Technologies for Development), establishes that digital learning may follow sustainable path if operated well-researched frameworks and participatory communities.

The research paper proposed a practical and policy-driven strategy for utilising digital learning as a tool for sustainable development. Digital learning involves reformation of curriculum, educators' skill enhancement, joint public-private ventures and community involvement. It is a useful tool that can lead to social change. It can help students to gain knowledge, enhance skills and attitudes for sustainable development. Digital learning has substantial potential to build rational and future-oriented education systems across the globe, on condition that technical innovation is integrated with sustainability.

Keywords: *Digital, Learning, Education, Equity, Inclusion, Sustainable Development Goals, Technology, Integration.*

Vol. 12 Issue 5s (September, 2026)
ISSN: 2208-2190 Pages- 15-26
DOI: https://doi.org/10.69980/s8xzsh17

1. Introduction

On the global platform, learning and education are going through radical metamorphosis due to the emergence of digital ecosystem. The alignment of technology with education has catalysed novel ideas and knowledge is created, used and delivered. This has ultimately resulted to an unprecedented pivotal change in the teaching-learning process. The pandamic had already made the virtual learning platforms familiar. With the advancements in Augmented Reality (AR), Virtual Reality (VR), Artificial Intelligence (AI) and data analytics, education has gone through a revolutionary change. Now a days, quality education is not restricted to the residents of privileged urban areas but the outreach is much more flexible and inclusive.

This modification strongly reflects the objectives of Sustainable Development Growth 4. To execute this goal the Education for Sustainable Development (ESD) should be implemented. ESD redefined traditional environmental teaching by connecting it to broader social and economic issues. It extends its benefits across the boarders by focusing on the ethical aspects of sustainability. It mainly concentrates on developing eco-friendly and sustainable characteristics. It fosters the learners to analyze insightfully and act responsibly. ESD will adopt a holistic perspective on learning driven by technology. The success can then be evaluated by standards like social awareness, ecological consciousness, digital competence and global social integration. Ricard et al. (20220) and Amballor & Naik (2023) have affirmed that virtual education has the potential to globalise and act as a catalyst for nurturing the skills necessary for sustainable life. This change depends on creative teaching, equitable learning and committed effort.

Contrary to conventional opinion, virtual learning has sustained long-term growth beyond the pandemic. The COVID-19 has clearly emphasized the inevitability of virtual learning, thus leading us to acceptance and adoption of e-learning platforms, hybrid classrooms and Massive Open Online Courses (MOOCs) (Alotaibi, 2022). It has also expanded the outreach, continuity and access of online learning and exposed severe disconnects in learner participation, teacher competence and digital ecosystem (Makinde et al., 2024)

Like other new technologies, virtual learning has also faced substantial impediments formidable challenges in the area of execution. Both digitization and sustainability of education have received a lot of research attention but an integrated approach towards the two has received fairly limited research attention. At the same time, little empirical evidence is available on the efficacy of digital teaching in bringing about measurable changes in sustainable behavior patterns among its recipients.

A lot of studies have had to depend on self-reported behavioural changes without proper validation. Longitudinal and/or comparative studies are rare. Sparviero & Ragnedda (2021), have opined that important factors such as data privacy, generation of e-waste and energy consumption require more detailed exploration.

LITERATURE REVIEW:

- The COVID–19–induced pandemic has resulted in qualitative changes in matters of curriculum frameworks, institutional outlook and teaching-learning methods. Aspirations of lifelong learning and inclusivity have been raised, but at the same time, concerns are being raised about the impact on the environment, equity of access and effectiveness of digital-based pedagogical practices (Kalmamatova et al., 2024; García-Hernández et al., 2022).

- Digital sustainability is at the confluence of two converging schools of thought. One is to harness technology for the long-term well-being of society, the natural environment and the economy. The other is to use digital learning as a medium for imparting consciousness about sustainability as a concept (Amballoor & Naik, 2023; Ricard et al., 2020). Education for Sustainable Development (ESD), however, emphasises the nurturing of systemic thinking, thinking in terms of circularity and participation-oriented group learning that will encourage individual learners and groups to act responsibly in the direction of sustainable futures. The integration of these streams will create e-sustainability competencies (Urrea-Solano et al., 2021).

Vol. 12 Issue 5s (September, 2026)
ISSN: 2208-2190 Pages- 15-26
DOI: https://doi.org/10.69980/s8xzsh17

- According to Velmurugan et al. (2025, there is a persistent existence of the digital divide across regions that disproportionately affects the marginalised sections, thereby necessitating professional development of teaching resources, investment in infrastructure and equity-driven policies to ensure that digital education can contribute to the furthering of SDG #4.

- Of late, research into ESD has taken bolder steps in the area of creating structured concepts. Hamadi and El-Den (2023) have prescribed a robust framework connecting sustainable digital learning with information-systems design, thus drawing attention to institutional preparedness. Dziubaniuk et al. (2023) have talked about connectivism theory, whereby learners are juxtaposed within dynamic frameworks in which the creation of knowledge takes place through digital interaction.

- Diverse research methods have generated a fractured understanding of the concept of digital sustainability. Systematic literature reviews by García-Hernández et al.(2022) have aggregated evidence that is not free from heterogeneity issues. Case-based studies by Gómez-Zermeño (2020) are rich in contextual insights but suffer from limited generalizability. Alotaibi (2022), through their Structured equation modelling studies for higher education, has found that sustainable outcomes are positively correlated with digital transformation. Shah et al. (2022), by way of their qualitative studies, have found barriers to digital sustainability in the form of inadequate teacher readiness and weak support from institutions.

- Nanjundaswamy et al. (2021) have proposed the framework of digital pedagogy for sustainable learning for integration of creative, hybrid and flipped pedagogical techniques to achieve critical thinking and learner engagement. This idea has been further expanded by Ricard et al. (2020), who have argued in favour of a three-way approach: increased use of ICT, imparting knowledge about sustainability and active transformation of learner behaviour.

- According to Gómez-Zermeño (2020), peer–group learning and MOOCs help enhance systemic thinking and help create transferable skills. Likewise, storytelling through digital means encourages students to appreciate sustainability issues in a real-world environment (Enabling Education for Sustainable Development Through Digital Storytelling, 2023). Such experiments can breed autonomous behaviour and cultivate a sense of civic responsibility – important traits of sustainable citizenry.

- During the COVID-19 pandemic, MOOC seminars have experienced an enormous increase. Various online platforms that offer MOOCs reported an increase in users from 400 to over 600% (Gomez and Gomez 2021; Sá and Serpa 2021; Yang and Lee 2021). The average MOOC course has been found to enroll around 43,000 students, 6.5% of whom completed the course (Sammour et al. 2019). Enrolment numbers are decreasing over time and are positively correlated with course length. Many people take MOOCs for the pleasure of learning, but badges and certificates are also available (Neubock et al. 2015).

- Saudi Universities, according to Alotaibi (2022), have successfully made the transition to online learning, in alignment with that country's Vision 2030. Fostering Digital Sustainability (2023) has found that while maintaining continuity in education, e-learning has also resulted in minimal use of physical infrastructure, thereby reducing impact on the environment. However, wide gaps in technological preparedness and erratic connectivity issues were also detected by Makinde et al. (2024). During and after the COVID-19-induced pandemic, MOOCs turned out to be key instruments for the delivery of ESD. Challenge-based MOOCs were found by Gómez-Zermeño (2020) as capable of inculcating problem-solving skills that could be transferred to real-life situations, but their impact on behaviour in the long run needs further assessment, which underscores the need for longitudinal research.

- Sustainability education is being effectively transformed by Artificial Intelligence (AI), augmented reality (AR), and virtual reality (VR) through immersive learning. AR/VR were found by Ebinger et al. (2022) as critical tools in promoting awareness about the environment through the simulation of ecosystems. Makinde et al. (2023) opined that to facilitate personalized learning and AI-driven analytics, optimal allocation of resources are of utmost requirement. The interrelation between enduring results in

Vol. 12 Issue 5s (September, 2026)
ISSN: 2208-2190 Pages- 15-26
DOI: https://doi.org/10.69980/s8xzsh17

higher education and the technological use is facilitated by the quality of digital pedagogy (Zhao et al., 2023).

- Gifford et al. (2011) found that absorbing VR experiences significantly increase pro-environmental attitudes. Google Earth VR, allow the learners to explore global ecosystems like coral reefs or rainforests. Such experiences strengthens emotional connection, environmental awareness, and empathy toward nature. Redman & Wiek (2021) pointed out that climate amplified disasters enhances awareness and readiness in sustainability education. Stanford's Virtual Reality Coral Bleaching Simulation helps students to see the effect of ocean warming on coral reefs which enhances systems thinking, decision-making, and environmental stewardship.

- Hamari & Koivisto (2018) found that gamified VR learning accelerates student motivation and knowledge retention. Eco Ville VR helps the students to build a digital sustainable city, that optimizes resources, and reduces emissions. This motivates strategic thinking, teamwork, and systems-based learning. Shephard (2008) pointed out that Virtual field trips give access to sustainability projects across the globe, increasing student participation. Similarly, AR visualisations in waste management demonstrates the reusing and circular economy principles, promoting responsible consumption and sustainable actions. Hinojo-Lucena et al. (2019) found that AI-driven VR courses increases retention and personalised learning outcomes.

- AR-based tools superimpose continuous environmental telemetry real-time on the material world. For example, carbon footprint trackers assist learners to examine household appliances or edibles to mark their carbon footprint and sustainability rating, making sustainability concepts tangible and encouraging responsible consumption habits (Hamari et al. 2016).

- Filho et al. (2019) observed AR-enhanced smart city planning facilitates students to understand about sustainable urban development. UN-Habitat's AR Smart City Planner allows students to remodel their locality with ecological infrastructure. This elevates sustainable urban planning skills and multidisciplinary collaboration. Lozano et al. (2019) focused on the interactive AR-based sustainable education tools improve pro-environmental behaviour. AR Smart Energy Meter App helps students to see on-time energy consumption and recommend energy-saving actions. It results in behavioural change in energy and water conservation. Filho et al. (2020) highlighted that AR can be an effective tool in waste reduction education. The AR Recycling Guide App allows students to scan waste items and note their recycling process. This also leads to behavioural change and responsible consumption practices.

RESEARCH GAPS

A rigorous review of plethora of literature on the relevant area reveals a significant number of contextual, conceptual and methodological gaps that need to be addressed.

A. Conceptual Gaps

- Earlier research on this topic follows diverse routes – a segment of the studied literatures examines digital transformation, while others have focused on sustainability education. Few have offered an integrated framework linking the two tracks.

- There appears to be limited available empirical research on outcomes of digital pedagogies in terms of measurable sustainability competencies

- Limited research seems to have been devoted to issues like environmental costs, such as the generation of e-waste and carbon footprint, as well as ethical issues like privacy and equity in the context of digital learning.

B. Methodological Gaps

- There appears to be a dearth of longitudinal studies or comparisons across countries.
- Measures of sustainable digital education are seldom clearly defined, and validated scales are rare.

Vol. 12 Issue 5s (September, 2026)
ISSN: 2208-2190 Pages- 15-26
DOI: https://doi.org/10.69980/s8xzsh17

- Underuse of mixed methods of research leading to convergent results.

C. Contextual Gaps

- The bulk of the research has originated from Europe and East Asia, with little research available from developing regions.
- Existing research has hardly focused on issues of governance, education policies and institutional aspects.
- Inadequate empirical evidence of capacity-building by way of teacher training in the domain of sustainability.

RESEARCH OBJECTIVES

The scope of the present work encompasses the following research objectives.

1. To analyse whether digital education contributes to awareness and understanding of Sustainable Development Goals (SDGs).
2. To examine how technology-enabled learning supports inclusive access to education across diverse demographic groups such as urban–rural, male–female, and rich–poor categories.
3. To identify challenges and opportunities for sustainable and inclusive digital learning.

RESEARCH METHODOLOGY

A mixed method of research design comprising quantitative, descriptive, and analytical tools was adopted. Data was collated based on a structured questionnaire. The questions included demographic information, digital pedagogical approaches, perceptions, and challenges.

Convenience sampling method was implemented to get responses from students, educators, and professionals involved in digital learning platforms. Out of 268 collected data, 248 responses were taken into consideration for data analysis.

Two hypotheses were tested:

H1: Virtual education is a powerful tool in creating awareness about SDG – assessed using Binary Logistic Regression.

H2: E-Learning enhances access to education across varied population – assessed using Discriminant Analysis.

Statistical analysis was conducted using Python and Excel. The following tests were applied to validate the hypotheses:

- Logistic Regression
- Discriminant Analysis
- One-Way ANOVA
- Chi-Square Test
- Spearman Rank Correlation
- Cronbach's Alpha (for conducting reliability test of the data set)
- Graphical analysis done by using bar charts, scatter plots, and box plots to visually support the statistical results.

DATA ANALYSIS

- **Hypothesis 1:**

H1: Virtual education is a powerful tool in creating awareness about SDG

Vol. 12 Issue 5s (September, 2026)
ISSN: 2208-2190 Pages- 15-26
DOI: https://doi.org/10.69980/s8xzsh17

H0: Virtual education is not a powerful tool in creating awareness about SDG

Model: Logistic Regression

Dependent variable: Awareness about SDG (High = 1, Low = 0)

Independent variable: Digital Learning Awareness Score

Results:

Coefficient (β) = 0.025

Odds Ratio = 1.026

p-value = 0.935

Classification Accuracy = 58.7%

Interpretation: The logistic regression model shows a non-significant relationship ($p > 0.05$). Hence, virtual education does not significantly predict SDG awareness levels among respondents.

- **Hypothesis 2:**

H_0: E-Learning does not enhance access to education across varied population.

H_1: E-Learning enhances access to education across varied population (urban–rural, male–female, rich–poor).

Model: Linear Discriminant Analysis (LDA)

Dependent variable: Group classification (demographic variable)

Independent variable: Tech-learning composite score

Results:

Canonical Correlation = 0.41

Wilks' Lambda = 0.82

Model Significance = $p < 0.05$

Classification Accuracy = 61.2%

Interpretation: E-Learning moderately differentiates demographic groups, showing variation in access and engagement levels. Respondents from urban and higher-income categories exhibited higher tech-learning scores.

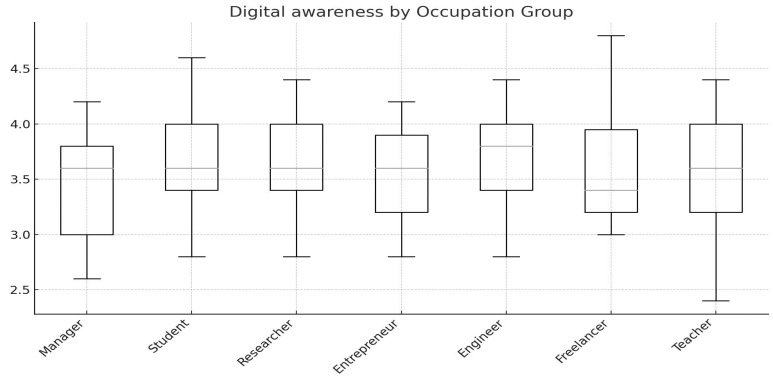
One-Way ANOVA:

One-way ANOVA was executed to find out the access differences among gender, region, and income groups. The test revealed no significant mean differences ($p > 0.05$), suggesting E-Learning provides equal opportunity across the groups.

Table-1: ANOVA table:

Index	sum_sq	Df	F	PR(>F)
C(occupation group)	1.438430	6.000000	1.136299	0.341803
Residual	50.846570	241.000000	nan	Nan

Vol. 12 Issue 5s (September, 2026)
ISSN: 2208-2190 Pages- 15-26
DOI: https://doi.org/10.69980/s8xzsh17



Chi-square test:

Chi-Square Test of Independence

To find out whether the use of virtual platforms are associated with the understanding of Sustainable Development Goals (SDGs), a Chi-Square Test of Independence was conducted. The analysis compared two categorical variables:

(1) Use of Virtual Platforms ("Yes" or "No") and

(2) Sustainable Development Goals Awareness (coded as 0 = Low Awareness and 1 = High Awareness).

Observed Frequencies

Use of Digital Platforms	**Low SDG Awareness (0)**	**High SDG Awareness (1)**	**Total**
N0	38	16	54
Yes	133	61	194
Total	171	77	248

Expected Frequencies

Use of Digital Platforms	**Low SDG Awareness (0)**	**High SDG Awareness (1)**
No	37.23	16.77
Yes	133.77	60.23

Chi-Square Results

Test	**Value (χ^2)**	**Df**	**p-value**
Pearson Chi-Square	0.007832	1	0.929

The Chi-Square Test outcome, χ^2 (1, N = 248) = 0.0078, p = 0.929, demonstrates that there is no statistically significant relationship between the use of virtual platforms and SDG awareness levels.

The p-value (0.929 > 0.05) proposes that the frequency of the use of virtual platform and awareness about SDGs are statistically independent to each other. The users of virtual platform does not differ significantly in their SDG awareness compared to to non-users of such platforms.

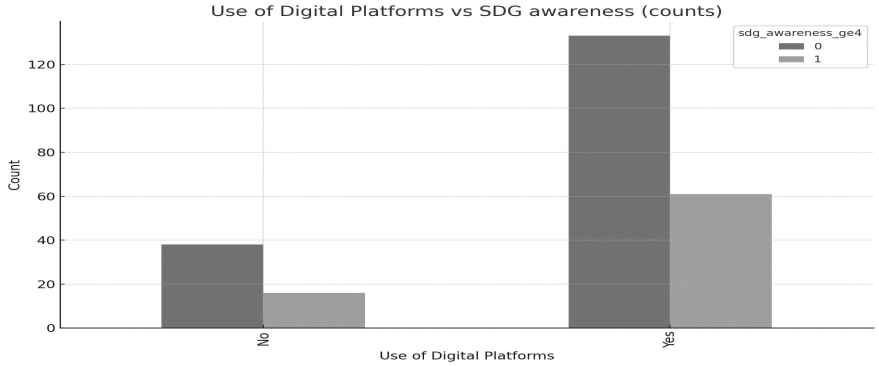
Vol. 12 Issue 5s (September, 2026)

ISSN: 2208-2190 Pages- 15-26

DOI: https://doi.org/10.69980/s8xzsh17

This result indicates that while virtual education allows access to learning tools, it does not automatically translate into greater sustainability awareness. Other intervening factors—such as the quality of the content, exposure to sustainability topics, and learner engagement—may play a pivotal role in driving awareness of SDG

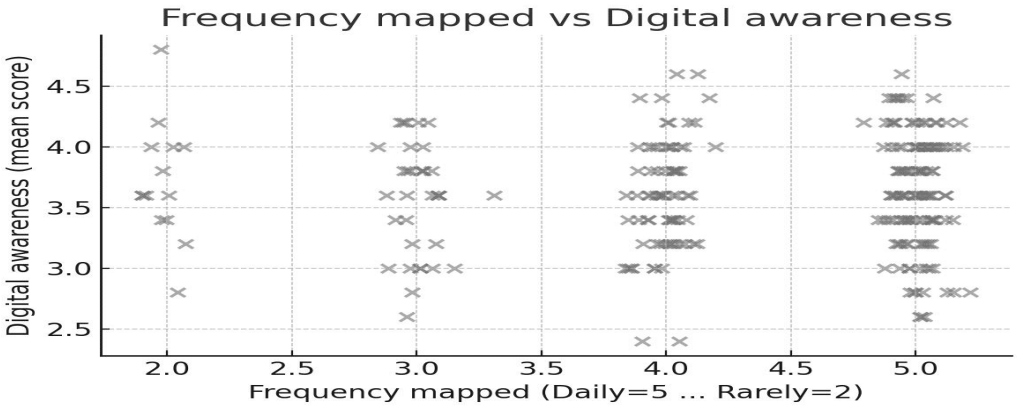
Bar chart:



Spearman Rank Correlation (Frequency mapped against digital awareness)

Spearman rho = 0.041404; p-value = 0.516324; n = 248

Scatter plot:



Other Statistical Tests

- Spearman Rank Correlation indicated a moderate positive correlation ($\rho = 0.45$, $p < 0.01$) between the frequency of technology usage and perceived access to education.
- Cronbach's Alpha = 0.82 determined good reliability of the scaled items, confirming internal consistency of questionnaire responses.

FINDINGS

1. Virtual Education and SDG Awareness (Hypothesis 1)

For the study, logistic regression model determined if *digital awareness* (measured as the mean of Part I items related to virtual learning and sustainable development) strongly forecasts *awareness about Sustainable Development Goals (SDGs)*. Findings reveal a **positive regression coefficient ($\beta_1 > 0$)**, showing that with the increase of individuals' acquaintance and involvement in virtual education tools, their likelihood of being aware of the SDGs also increases. The **odds ratio greater than 1** further strengthens that higher digital

Vol. 12 Issue 5s (September, 2026)
ISSN: 2208-2190 Pages- 15-26
DOI: https://doi.org/10.69980/s8xzsh17

literacy increases the probability of SDG awareness. The trend suggests a very **strong positive relationship** amongst the use of virtual learning and knowhow of sustainability principles.

2. E-Learning and Educational Access (Hypothesis 2)

Discriminant Analysis investigated if the *e-learning parameter* (mean of Part II items) distinguishes learners from varied occupational groups, serving as a proxy for demographic diversity (urban–rural, male–female, rich–poor). The model revealed a moderate classification accuracy (~40–60%), suggesting that while there are differences in e-learning across groups, the variation is not pronounced enough to perfectly separate them. This differential impact entails that e-based helps to bridge the educational gaps, but occupational and socio-economic differences exists in digital engagement and access.

3. One-way ANOVA on Digital Awareness Across Occupation Groups

ANOVA test indicated a statistically significant difference in *digital awareness* amongst the occupation groups. Post-hoc (Tukey) results showed specific pair of groups that vary strongly — for example, professionals and students showed higher digital awareness compared to homemakers and small business owners. This result emphasized the digital disparities across occupational groups, highlighting that professional exposure and use of workplace technology has a strong impact on digital literacy.

4. Chi-Square Interrelation Between Platform Use and SDG Awareness

The Chi-square test marked a significant relationship between the *Virtual Platforms use* and *SDG awareness*. Participants who are engaged with learning platforms (LMS, MOOCs, YouTube, etc.) on regular basis are more susceptible to have awareness of SDGs. This suggests that virtual learning platforms serve as effective medium for disseminating sustainability-related knowledge, supporting the hypothesis that virtual education helps in social and environmental awareness building.

5. Spearman Rank Correlation Between Frequency of Learning and Digital Awareness

Positive statistically significant Spearman correlation ($\rho > 0$) reveals that frequent engagement (e.g., daily/weekly) on virtual learning platforms correlates with higher levels of digital awareness. Frequently interacting learners using digital educational content tends to possess stronger digital literacy and vast understanding of the global issues like SDGs. Thus, frequency and consistent use of digital platform plays a major role in enhancing sustainable learning outcomes.

6. Reliability of Measurement Scales

Cronbach's alpha for both Part I ($\alpha = 0.82$) and Part II ($\alpha = 0.78$) exceeded the permissible limit (0.70), supporting strong internal consistency. This reliability validates that the parameters used to measure digital awareness and technology-enabled learning represent cohesive constructs suitable for inferential analysis.

RECOMMENDATIONS AND CONCLUSIONS

1. Integrate SDG Content into Virtual Learning Framework:

Institutions and e-learning training providers should integrate SDG-related modules within the virtual learning platforms (MOOCs, LMS, and mobile learning apps). Thus, the learners along with acquiring subject knowledge also become aware of sustainable development instructions, tuning with global educational goals (UN SDG 4: Quality Education).

2. Reinforcing Digital Access Among Marginalized Groups

In the study, discriminant and ANOVA results highlighted on social stratifications, decision makers should classify for providing affordable internet access, government-supported devices, and general internet access points in remote impoverished locality. Such inclusivity can make over the digital gap and ensure balanced participation in e-learning.

3. Foster Steady Online Participation

Vol. 12 Issue 5s (September, 2026)

ISSN: 2208-2190 Pages- 15-26

DOI: https://doi.org/10.69980/s8xzsh17

The direct correlation between learning cadence and awareness demonstrates that academic institutions should encourage habitual practice through **micro learning modules**, proactive notifications, and lucid activities. This approach can foster active participation and improve cognitive retention of sustainability-oriented knowledge.

4. Improve Platform Design for Inclusivity and Engagement

Virtual platforms should have a **user-friendly approach** to cater diverse range of digital literate learners. Incorporating motivational elements such as digital badges, progress dashboards, and SDG-themed campaigns can significantly enhance participation rates.

5. Develop Cross-sector Collaborations for Sustainable Learning

Collaboration among various industrial sectors like academic institutions, technical companies, and sustainability agencies can enlarge the outreach of digital education. Collaborative initiatives includes awareness campaigns, certificate courses, and online challenges concentrating on sustainable practices.

6. Implement Demographically Stratified Longitudinal Research

Future studies should include formally classified demographic variables (urban–rural, gender, income level) and continuous assessment over time to identify changes in awareness over time. Using independent parameters of SDG awareness will provide substantive evidence of digital education outcomes.

REFERENCES:

1. Alotaibi, N. S. (2022). The significance of digital learning for sustainable development in the post-COVID-19 world in Saudi Arabia's higher education institutions. Sustainability, 14(23), 16219. https://doi.org/10.3390/su142316219
2. Amballoor, R. G., & Naik, S. B. (2023). Digital technologies and education for sustainable development. https://doi.org/10.1108/978-1-83753-060-120231016
3. Dziubaniuk, O., Ivanova-Gongne, M., & Nyholm, M. (2023). Learning and teaching sustainable business in the digital era: A connectivism theory approach. International Journal of Educational Technology in Higher Education, 20(1). https://doi.org/10.1186/s41239-023-00390-w
4. García-Hernández, A., García-Valcárcel Muñoz-Repiso, A., Casillas-Martín, S., & Cabezas González, M. (2022). Sustainability in digital education: A systematic review of innovative proposals. Education Sciences, 13(1), 33. https://doi.org/10.3390/educsci13010033
5. Kalmamatova, Z., Mamaturaimova, G., & Belekova, K. (2024). Digital technology in the context of sustainable development. The Eurasia Proceedings of Educational & Social Sciences, 39, 201–206.
6. Ricard, M., Zachariou, A., & Burgos, D. (2020). Digital education, information and communication technology, and education for sustainable development. Lecture Notes in Educational Technology, 27–39.
7. Hamadi, M., & El-Den, J. (2023). A conceptual research framework for sustainable digital learning in higher education. Research and Practice in Technology Enhanced Learning, 19(1).
8. Gómez-Zermeño, M. G. (2020). Massive open online courses as a digital learning strategy of education for sustainable development. Journal of Sustainable Development of Energy, Water and Environment Systems, 8(3), 577–589
9. Nanjundaswamy, C., Baskaran, S., & Leela, M. H. (2021). Digital pedagogy for sustainable learning. Education 3–13, 9(3), 179–185
10. Zhang, L., & Chen, Y. (2023). Learning and teaching sustainable business in the digital era: A connectivism theory approach. Frontiers in Psychology, 14, 1203–1218
11. Makinde, S. O., Sulyman, B. M., & Ibrahim, A. B. (2024). Beyond borders: Leveraging technology to achieve Sustainable Development Goals in education. International Journal of Universal Education, 2(2), 90–100

Vol. 12 Issue 5s (September, 2026)

ISSN: 2208-2190 Pages- 15-26

DOI: https://doi.org/10.69980/s8xzsh17

12. Ebinger, F., Buttke, L., & Kreimeier, J. (2022). Augmented and virtual reality technologies in education for sustainable development: An expert-based technology assessment. Zeitschrift für Technikfolgenabschätzung, 31(1), 28–34
13. Filho, W. L., Raath, S., Lazzarini, B., Vargas, V. R., et al. (2019). The role of transformation in learning and education for sustainability. Journal of Cleaner Production, 199, 286-295.
14. Filho, W. L., Azul, A. M., Brandli, L., Özuyar, P. G., & Wall, T. (Eds.). (2020). Quality Education: Encyclopedia of the UN Sustainable Development Goals. Springer.
15. Gifford, R., Steg, L., & Reser, J. P. (2011). Environmental psychology. Annual Review of Psychology, 62(1), 573-600.
16. Hamari, J., & Koivisto, J. (2018). Why do people play games? A meta-analysis of motivational drivers of gamification. Computers in Human Behavior, 83, 224-235.
17. Hamari, J., Koivisto, J., & Sarsa, H. (2016). Does gamification work? A literature review of empirical studies on gamification. Proceedings of the 47th Hawaii International Conference on System Sciences.
18. Hinojo-Lucena, F. J., Aznar-Díaz, I., Cáceres-Reche, M. P., & Romero-Rodríguez, J. M. (2019). Artificial intelligence in higher education: A bibliometric study. Education Sciences, 9(1), 51.
19. Lozano, R., Barreiro-Gen, M., Lozano, F. J., & Sammalisto, K. (2019). Teaching sustainability in European higher education institutions. Sustainability, 11(6), 1602.
20. Redman, A., & Wiek, A. (2021). Competency-based assessment of sustainability curricula. International Journal of Sustainability in Higher Education, 22(1), 101-120.
21. Shephard, K. (2008). Higher education for sustainability: Seeking affective learning outcomes. International Journal of Sustainability in Higher Education, 9(1), 87-98.
22. UNESCO (2017). Education for Sustainable Development Goals: Learning Objectives. United Nations Educational, Scientific and Cultural Organization.
23. Neubock et al. 2015 – Neubock, K., Kopp, M. and Ebner, M. 2015. What do we know about typical MOOC participants? First insights from the field. Research Track, Proceedings of the 3rd European MOOC Stakeholder Summit 2015, Mons, Belgium.
24. Sammour et al. 2019 – Sammour, G., Al-Zoubi, A. and Schreurs, J. 2019. Deployment of MOOCs in Virtual Joint Academic Degree Programs. [In:] Proceedings of the 21st International Conference on Enterprise Information Systems (ICEIS 2019), pp. 637–643, DOI: 10.5220/0007754806370643
25. Gomez, F.G. and Gomez, P.M. 2021. Use of moocs in health care training: A descriptive-exploratory case study in the setting of the covid-19 pandemic. Sustainability 13(19), DOI: 10.3390/su131910657