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The Role of Hybrid Learning in Achieving the Sustainable Development Goals

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ABSTRACT

Hybrid learning combines digital learning resources with conventional education approaches to expand educational offerings. While this approach has shown promise in addressing limitations of both online and in-person instruction, significant challenges remain in ensuring equitable access and sustainable implementation. This study examined hybrid learning's relationship with the sustainable development goals (SDGs) framework through a scoping review analyzing evidence from academic literature ($n = 80$) and reports from 36 global educational organizations. Our analysis identified 90 potential synergies (54%) and 45 challenges (26%) across social, economic, and environmental dimensions. The findings were analyzed under three main areas: (1) equity promotion through reduced geographical and socioeconomic barriers, (2) crisis response support during disruptions like pandemics and natural disasters, and (3) capacity building opportunities in workforce development. Based on these findings, we propose the SDG-Hybrid Learning Alignment Framework, including a new SDG Target 4.8 (Digital-Resilient Education) to guide hybrid learning initiatives. This framework emphasizes infrastructure standards, teaching competencies, equitable resource access, and institutional crisis continuity. Results suggest successful implementation requires integrating digital infrastructure with pedagogical approaches while considering local contexts and institutional capabilities.

1 | Introduction

The global context of education has undergone significant transformation in recent years, largely driven by rapid technological advancements. This evolution has been particularly accelerated by the COVID-19 pandemic, reshaping how knowledge is disseminated and acquired (Mayer 2023; Nerantzi 2020). The integration of technology into educational practices has led to innovative learning models, with hybrid learning (HL) emerging as a particularly promising approach (Kayi 2024).

The World Bank defines HL as an integrated approach combining in-person and online learning experiences to create more personalized and engaging educational journeys (Muñoz-Najar et al. 2021). Recent studies demonstrate how this model can combine traditional classroom efficiency and socialization opportunities with digitally enhanced learning possibilities

[Correction added on 19 February 2025, after first online publication: Affiliation 2 has been added for Flavio Martins, and affiliations have been renumbered accordingly.]

(Singh, Steele, and Singh 2021; Biancardi et al. 2023). When properly implemented, hybrid models result in dynamic and responsive educational ecosystems that provide flexibility in learning pace and schedule, accommodate diverse learning styles, enhance technological integration, create personalized learning pathways, and increase student engagement through varied modalities.

The theoretical foundation for HL's potential lies in digital inclusion research, which demonstrates how technological integration can create meaningful social change through motivation, physical access, digital skills, and usage patterns (Warschauer 2003). These elements are shaped by the distribution of temporal, material, mental, social, and cultural resources across different social groups (van Deursen and van Dijk 2019). When these considerations are properly addressed, HL offers substantial benefits, with recent cross-cultural studies demonstrating how proper implementation enhances student engagement, educational access, equity, and cost efficiency when supported by appropriate institutional frameworks (Ashraf et al. 2021; Dash et al. 2022; Martín, Alario-Hoyos, and Kloos 2022).

The implementation of HL faces a fundamental challenge: the digital divide between high- and low-income countries, which perpetuates deep inequalities in educational access (Warschauer 2003). This divide manifests in infrastructure gaps affecting teaching quality and research capacity (Chakraborty and Biswas 2020), becoming particularly evident during global disruptions where differences in institutional capacity revealed stark educational disparities between regions (Tate and Warschauer 2022). The challenge extends beyond mere access—successful implementation depends on digital inclusion, a complex web of factors including motivation, physical access, digital skills, and usage patterns, all shaped by the distribution of societal resources (van Deursen and van Dijk 2019). Viewing these challenges through a complex systems framework (Jacobson, Levin, and Kapur 2019) reveals patterns of interaction between infrastructure, institutional capabilities, and societal resources, where variations in skills and usage patterns affect group performance even when basic access is provided (Huang and Li 2022). This understanding suggests that implementation requires more than technological access alone—it demands a strategic integration of pedagogical approaches with infrastructure to develop learning experiences that reduce existing disparities (Rapanta et al. 2021; Marina and Christos 2021).

Research on HL shows both promise and complexity in its implementation. Studies demonstrate effectiveness across educational settings (Vallee et al. 2020; Müller and Mildenberger 2021) while highlighting how success depends on learner characteristics (Xiao, Sun-Lin, and Cheng 2020) and educators' ability to effectively integrate content, pedagogy, and technology (Helsa, Turmudi, and Juandi 2023). Reviews examining educational impacts across disciplines (Ashraf et al. 2021; Abu Talib, Bettayeb, and Omer 2021) and implementation experiences in diverse contexts (Sareen and Mandal 2024) have deepened our understanding of both challenges and opportunities. The widespread adoption of HL during the COVID-19 pandemic has generated substantial research on student performance (Müller and Mildenberger 2021) and implementation frameworks (Min and Yu 2023). Yet, geographical representation in research continues to vary, with some regions receiving more attention than others in leading journals (Bond et al. 2020). This suggests opportunities to examine hybrid learning's broader societal and institutional implications across diverse contexts, particularly in understanding how it might contribute to addressing educational inequalities.

These broader societal implications of hybrid learning align naturally with the modern concept of sustainable development. Since the landmark publication of "Our Common Future" (the Brundtland Report) in 1987, sustainable development has evolved from focusing primarily on ecological preservation to addressing interconnected societal challenges, including educational inequalities, resource distribution, and social transformation (Hajian and Kashani 2021). This evolution, driven by mounting environmental pressures and unprecedented global challenges (Sachs 2012), culminated in the 2030 Agenda and its 17 sustainable development goals (SDGs), providing 169 structured targets for social well-being, economic growth, and environmental protection (Zhang and Zhu 2020; United Nations 2024).

The SDGs can be considered mainly a policy tool and offer a broad analytical framework to systematically examine how both established sectors (Fuso Nerini et al. 2018) and emerging topics (Vinuesa et al. 2020) interact and can contribute or hinder broader societal transformation. Given that educational technology research often lacks theoretical underpinning (Bond et al. 2020), the SDGs framework offers a valuable lens for examining HL's societal impact. Our study adapts established SDGs mapping approaches and integrates digital inclusion perspectives (van Deursen and van Dijk 2019), employing a scoping review approach to systematically gather and assess evidence from both academic literature and international development organizations. Our methodology adapts Vinuesa et al.'s (2020) consensus-based expert elicitation process, originally developed for mapping AI impacts on SDGs, to evaluate how HL connects with sustainable development targets.

Building on these frameworks, we examine the central question: "What is the role of hybrid learning in achieving the Sustainable Development Goals?" This study makes three key contributions to the understanding of HL in sustainable development. First, we develop a novel analytical framework integrating digital inclusion perspectives with SDG mapping methodologies to systematically evaluate HL's societal impact. Second, we provide comprehensive empirical evidence by analyzing both academic literature and reports from 36 global educational organizations, revealing synergies and challenges across social, economic, and environmental dimensions. Third, we propose the SDG-Hybrid Learning Alignment Framework, including a new SDG Target 4.8 (Digital-Resilient Education), to guide HL initiatives toward sustainable development objectives.

Through these contributions, we aimed to inform policy and program decisions while addressing three key dimensions: equity promotion through structural barrier reduction, crisis resilience through adaptive response mechanisms, and capacity building through resource optimization. This article is structured as follows: Section 2 describes the methodology

used to assess the connections between HL and the SDGs. Section 3 presents the results from academic assessment, international development organizations, and their combined mapping. Building on these findings, Section 4 analyses HL versatility through the integrated framework. The conclusion synthesizes these insights to suggest implications and future directions for advancing HL as a contributor to sustainable development.

2 | Methods

This study employs an SDG mapping approach (Fuso Nerini et al. 2018; Vinuesa et al. 2020) that has been applied in studies across different field areas, such as sanitation (Parikh et al. 2021; Diep et al. 2021) and green energy (Martins et al. 2024). The study combines the mapping with a scoping review (Munn et al. 2022) and follows the PRISMA guidelines for the research strategy to enhance replicability and transparency (Page et al. 2021). The PRISMA checklist, adapted to our SDG mapping approach, is available in the Appendix A.

2.1 | Search Strategy and Study Selection

We conducted a two-step mapping of SDGs with HL. In the first step, we collected published evidence from academic digital libraries using a keyword query with terms related to each one of the SDGs and HL (Appendix A). We searched the following databases: ISI Web of Science, Scopus, ACM Digital Library, and IEEE Digital Library. The search was limited to studies published from 2015 onward, coinciding with the establishment of the 2030 Agenda framework.

Two reviewers independently screened titles and abstracts for relevance. Full texts of potentially eligible studies were then assessed against the inclusion and exclusion criteria outlined in Table 1. Disagreements were resolved through discussion or consultation with a third reviewer.

Our methodology was adjusted to identify connections between HL and sustainable development across three key dimensions emerging from preliminary analysis: equity promotion, crisis mitigation, and capacity building. This dimensional framework guided the documentation process, enabling evidence mapping from both academic literature and organizational reports to specific SDG targets while maintaining focus on these critical aspects of educational transformation.

2.2 | Data Extraction and SDGs Mapping

Our data analysis followed a two-phase approach inspired by previous SDG mapping methodologies (Vinuesa et al. 2020), with particular attention to evidence relating to equity promotion, crisis response capabilities, and capacity development. In the first phase, we systematically documented evidence from academic literature using a structured spreadsheet format that captured the relationships between HL and SDG targets. For each identified connection, we recorded:

TABLE 1 | Criteria for literature review with high-level questions and inclusion/exclusion parameters.

High-level question (HLQ)	"What is the role of hybrid learning in achieving the Sustainable Development Goals?"
Exclusion criteria	(EC1) Study is published before 2015[a] (EC2) Duplicates from the four bases sourced (ISI Web of Science, Scopus, ACM Digital Library, and IEEE Digital Library) (i.e., hybrid machine learning) (EC3) Articles not fully available or not in the English language (EC4) The article is a review study (EC5) The article does not present empirical evidence
Inclusion criteria	(IC1) The study shows opportunities or challenges linked to outcomes of hybrid learning (IC2) The study describes specific evidence of hybrid learning connection with at least one of 169 SDG targets
Categorization criteria	(CC1) The is evidence connected to a specific SDG target (CC2) The evidence portrays the target as a synergy or a barrier

[a]Establishment of the 2030 Agenda framework.

- The specific SDG target number
- Whether HL acted as an enabler or barrier
- Supporting evidence from the literature
- Reference information.

The evidence was systematically organized in spreadsheets that allowed examination of connections across targets. We considered a connection valid when at least one piece of published evidence demonstrated a clear link between HL and a specific SDG target.

In the second phase, we expanded our analysis to include evidence from international development organizations. Following the same structured documentation process used for academic literature, we recorded evidence from organizational reports while maintaining consistent categorization criteria. A panel of subject matter experts, who were co-authors of this study, validated the categorization of both academic and organizational evidence, ensuring the robustness of our classification process. This allowed us to build a mapping that incorporated both academic and institutional perspectives on HL's role in sustainable development. The full categorization process is available on the Supporting Information.

2.3 | Limitations

Several key limitations warrant consideration when interpreting our findings. Our analysis faces geographical representation challenges, as academic literature historically underrepresents research from developing regions (Bond et al. 2020), a disparity that persists despite our inclusion of international development organization reports. Additionally, our reliance on secondary sources without primary empirical data necessitates careful contextual interpretation, while the timing of our review during the COVID-19 pandemic may have overemphasized implementation barriers rather than the long-term impacts of HL (Reimers 2022). Furthermore, while expert validation strengthens our methodology, the diverse disciplinary backgrounds of validating specialists may have introduced contextual biases in categorization. These constraints should be considered alongside the inherent limitations of the SDG framework itself when interpreting study outcomes.

3 | Results

Building on our scoping review of academic literature and organizational documentation, we now turn to examining how HL intersects with SDGs. Our analysis revealed multiple patterns of interaction across educational contexts and implementation approaches, which we present in three complementary stages. This section is divided into two distinct subsections, comprehensively presenting the outcomes derived from the two-step methodology. First, the evidence collected from the literature review is presented, followed by evidence gathered from the international development organizations. Finally, the SDGs mapping is summarized by combining the findings from both methodology steps. Figure 1 describes the research flow steps, following adapted PRISMA reporting guidelines.

3.1 | Extracting Evidence

From the 17 SDG goals perspective, we found at least one synergy between HL and goals 1, 2, 3, 4, 5, 6, 8, 10, 11, and 15 and at least one barrier linkage with goals 3, 4, 5, 8, 9, and 10. No linkages were identified in academic published evidence for goals 7, 12, 13, 14, 16, and 17. Our analysis of 80 academic articles revealed connections to 30 synergies and 15 barriers across the 169 SDGs targets (Figure 2). A particularly strong connection emerged between HL and health dimensions of SDG 3 in resource-constrained environments, such as refugee camps (Al-Husban and Shorman 2020; Dridi et al. 2020) and crisis scenarios including COVID-19 and postdisaster situations (Manurung et al. 2020). These findings highlighted important synergies between education (SDG 4), health (SDG 3), and support for vulnerable populations/communities (SDGs 1, 5, 10, and 11). For detailed analysis of these connections, see the Supporting Information.

Following the academic data extraction, we examined documents from 36 international development organizations, categorized into five main groups:

- Multilateral institutions (UNICEF, UNESCO, World Bank, IDB)
- Regional cooperation agencies (including Arab Bureau for Education in Gulf States, Asia Pacific Program of Educational Innovation for Development)
- Bilateral development assistance organizations (such as DFID, GiZ, JICA)
- International NGOs (including Oxfam, Save the Children)
- Contractors and foundations (including Gates Foundation, Qatar Foundation)

Analysis of organizational documents revealed broader impacts than the academic literature alone. We identified synergies across all SDG goals, though specific connections to goals 6, 14, 15, and 17 remained limited. We observed terminology variations in organizational documentation—for example, UNESCO's database returned 75 documents for "blended learning" versus 25 for "hybrid learning," though both terms addressed similar concepts. This analysis revealed how HL's role in global education has evolved alongside the 2030 agenda, demonstrating its growing importance in achieving SDGs. Table 2 presents some examples of initiatives from international development organizations that indicate various intersections between HL and SDGs. Analysis of organizational documentation suggests three predominant patterns of implementation across different institutional categories.

Reports from multilateral institutions indicate systematic approaches to addressing SDG 4 (Quality Education) through multiple entry points. A good example comes from UNESCO and UNICEF documentation, which suggests particular attention to crisis response and educational access, as evidenced in programs supporting Syrian refugees and children affected by Russia's invasion of Ukraine. These initiatives appear to create linkages between SDG 4 and other goals, particularly SDG 5 (Gender Equality) and SDG 16 (Peace and Justice), as documented in digital skills training programs for rural women and girls (Ossiannilsson 2023).

Documentation from bilateral and regional partnerships suggests a focus on infrastructure-related SDG targets. For instance, JICA's reported work in Vietnam indicates attention to SDG 9.c (ICT Access) alongside educational targets, while the PALOP initiative documentation shows attempts to combine SDG 1.4 (Basic Services) with SDG 4.6 (Literacy and Numeracy) through radio-based education programs (López 2022). These cases suggest efforts to address technological infrastructure as a foundation for educational access.

Available data from contractors and foundations indicates attention to specific SDG target combinations. For instance, documentation from Chemonics International reports connecting SDG 4.3 (Higher Education Access) with SDG 9.c (ICT Infrastructure) through internet provision that maintained education for 13,000 Liberian students during COVID-19 (Wang and Huang 2021). Similarly, materials from the Gates Foundation and Emerson Collective suggest research focused on connecting SDG 4.4 (Employment Skills) with SDG 10.2 (Social Inclusion) through various educational technology initiatives (Kioupi and Voulvoulis 2019).

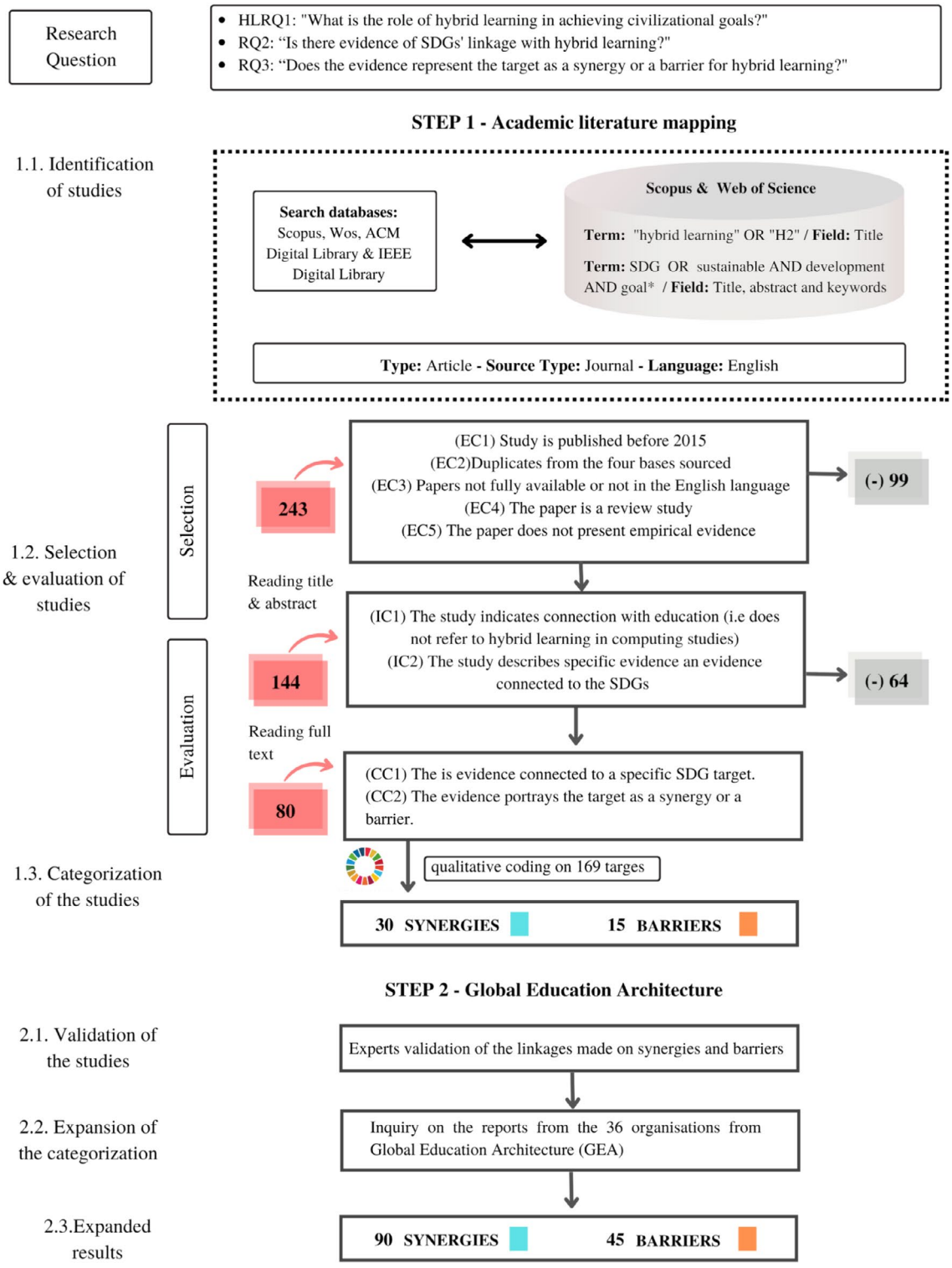

FIGURE 1 | PRISMA flow: Stages of evidence collection, screening, and analysis process.

3.2 | SDGs Mapping

Our analysis of academic sources and international development organization documentation suggests connections between HL and the SDGs framework (Figure 2). The findings indicate 90 potential synergies and 45 barriers across the 169 SDG targets (United Nations 2024). Figure 3 presents these relationships through two circular visualizations, separating synergies and barriers across societal, economic, and environmental dimensions.

The data reveal distinct patterns of interaction across three key dimensions of sustainable development. In the societal dimension, documentation indicates the strongest concentration of effects, accounting for 73% of identified synergies and 32% of

FIGURE 2 | Sustainable development goals (SDGs): United Nations 2030 Agenda framework overview and 17 core goals.

reported barriers. This dimension shows complete synergy with SDG 4 (Education) and demonstrates substantial positive connections to SDG 5 (Gender Equality) and SDG 3 (Health). The economic dimension presents moderate interaction levels, with 38% of identified synergies and 27% of reported barriers, particularly notable in its effects on SDG 8 (Decent Work and Economic Growth), though the digital divide emerges as a primary barrier (Malik and Gupta 2022). The environmental dimension shows more limited direct interaction, primarily manifesting through selective synergies with SDG 13 (Climate Action) and restricted connections to SDG 15 (Life on Land). This distribution of effects suggests that HL's impact is most pronounced in social development areas, with decreasing but still significant influence in economic domains, and more targeted effects in environmental contexts.

The analysis reveals varying impacts across educational levels. Academic literature seems to focus on higher education (target 4.3), while organizational reports emphasize primary education (targets 4.1, 4.2) and youth employment (targets 4.4, 8.6). Environmental connections primarily emerge through Education for Sustainable Development (target 4.7) initiatives (Hesen, Wals, and Tauritz 2022), such as the Carbon-Footprint educational tool (Priyadarshini et al. 2021). Documentation suggests particular effectiveness in refugee education contexts (target 10.7), as reported by Al-Husban and Shorman (2020) and Dridi et al. (2020). These diverse applications indicate potential for HL across multiple development domains, while also suggesting the need for context-specific implementation strategies that consider both opportunities and barriers, such as the digital divide noted by Malik and Gupta (2022).

4 | Discussion

The following discussion examines our findings through three interconnected themes that emerged from our analysis: challenges and opportunities in equity promotion, crisis mitigation applications and capacity building potential. We begin with an overview of HL applications, followed by detailed analysis of each theme supported by evidence from both academic literature and organizational documentation.

4.1 | Overview

Our findings indicate HL interfacing across various educational stages and contexts, with underlying connections with the SDGs framework. The studies reviewed indicates successful application in primary (Lintunen, Mutta, and Pelttari 2017), secondary (Lazarinis et al. 2019), tertiary (Chaeruman, Wibawa, and Syahrial 2020; Fernández Oliveras, Rodríguez Ponce, and Fernández-Oliveras 2020), and preschool education (Kocour 2019). Beyond formal education, HL has also been implemented in transversal areas like language teaching (Tobing and Pranowo 2020; Garcia-Ponce and Mora-Pablo 2020; Al-Qatawneh, Eltahir, and Alsalhi 2020) and extra-curricular activities such as mentoring (Weber-Main et al. 2019), tutoring (Gunawan, Suranti, and Fathoroni 2020), and peer support (Bertman et al. 2019). These applications align with several SDG targets linked, for instance, with education, equality, and socioeconomic development (e.g., 4.1, 4.2, 4.3, 4.6, 8.4, and 8.6), showing the complex and interconnected potential of HL in meeting diverse educational needs.

Among the major themes, studies indicate that HL models can support collaborative and inclusive approaches to education. For instance, Kiviniemi et al. (2021) examined the benefits of a digitally supported peer-group model, while Lazarinis et al. (2019) described a university outreach program supporting secondary school teachers. Other developments include approaches in augmented reality applications (Pujiastuti and Haryadi 2020), MOOCs for learner autonomy (Mabuan and Ebron 2018), and AI-powered tutoring systems (Gunawan, Suranti, and Fathoroni 2020). However, research suggests that technology integration effectiveness depends not just on frequency of use but on its ability to facilitate active, interactive, and interdisciplinary learning experiences (Sailer, Schultz-Pernice, and Fischer 2021; Plank and Niemann 2020), indicating the relevance of factors

TABLE 2 | SDG links in hybrid learning projects by international organizations: examples of initiatives and outcomes.

Organization type	Organization name	Project/initiative	SDG connection (with targets)	Hybrid learning aspect	Key findings/Outcomes
Multilateral institution	UNESCO	Blended Approach to Teacher Training (BATT)	SDG 4.c (increase supply of qualified teachers)	Technology for soft skills training	Addressed psychosocial needs of Syrian refugee students
Multilateral institution	UNESCO and German Ministry of Economic Cooperation (BMZ)	Cracking the Code: Empowering rural women and girls through digital skills	SDG 5.b (enhance the use of enabling technology to promote empowerment of women), SDG 4.5 (eliminate gender disparities in education)	Digital skills development	Empowered rural women and girls through digital skills
Multilateral institution	UNICEF	Closing the Digital Divide for Good	SDG 4.1 (ensure quality primary and secondary education for all), SDG 10 (Reduced Inequality), SDG 9.c (Access to ICT)	Digital infrastructure development	Addressed the digital divide in education
Multilateral institution	UNICEF	Ready to Come Back: A Teacher Preparedness Training Package	SDG 4.c (increase supply of qualified teachers), SDG 4.a (build and upgrade education facilities)	Teacher preparedness for postpandemic education	Provided guidance and resources for teachers in the Middle East and North Africa
Multilateral institution	UNICEF	Children in Ukraine need an end to this war—their futures hang in the balance	SDG 16 (promote peaceful and inclusive societies), SDG 4.1 (ensure quality education for all)	Education in crisis management	Addressed the educational needs of children affected by the war in Ukraine
Bilateral development assistance	JICA	Infrastructure Improvement in Vietnam	SDG 4.3 (equal access to technical/vocational education) SDG 9.c (increase access to ICT) SDG 4.7 (sustainable development education)	Combination of on-campus and online learning	Improved learning experience and management systems in Vietnam
Contractor	Chemonics International (with USAID)	Liberia Research and Education Network (LRREN)	SDG 4.3 (access to tertiary education) SDG 9.c (ICT infrastructure for education)	Affordable internet coverage enabling e-learning	13,000 students maintained enrollment during COVID-19
Regional cooperation agency	Association for the Development of Education in Africa	PALOP (Portuguese-speaking African Countries)	SDG 1.4 (access to basic services) SDG 4.6 (improve literacy and numeracy)	Radio broadcasts for education	Higher scores in language and mathematics among students who accessed broadcasts
Foundation	Bill and Melinda Gates Foundation	Research Grants	SDG 4.b (higher education scholarships for developing countries)	Various hybrid learning research projects	At least 41 grants fostering hybrid learning research
Foundation	Emerson Collective	XQ Tool	SDG 4.4 (skills for employment) SDG 10.2 (Social, economic, and political inclusion)	Remote and hybrid learning tool	Developed solutions for student engagement and resource efficiency

(Continues)

TABLE 2 | (Continued)

Organization type	Organization name	Project/initiative	SDG connection (with targets)	Hybrid learning aspect	Key findings/Outcomes
Foundation	Qatar Foundation	Qatar Career Development Center (QCDC) Facilitating Career Development (FCD) Training Program	SDG 8.6 (reduce youth not in employment, education, or training) SDG 4.4 (skills for employment)	Blended learning for career development	Provided career development training with 12 key competencies
International NGO	Enseña at México (Jugamos Juntos)	10-week Family Program	SDG 4.2 (early childhood development) SDG 3.d (capacity for health risk management)	Asynchronous and synchronous learning for families	Enhanced caregiver-child interaction and communication
North–South cooperation	Stefan Steinberger's Project for Refugees	Job Market Integration Program	SDG 8.5 (decent work for all) SDG 4.3 (equal access to vocational education)	Full-time education and training program for refugees	Aimed at integrating refugees into the job market in Vienna

beyond access to technology, such as pedagogical design and context-specific applications.

HL's suitability appears to vary across disciplines. Studies report positive outcomes, for instance, in veterinary education (Kelly, Mihm-Carmichael, and Hammond 2021) but note limitations in arts (Li, Li, and Han 2021), music (Jenkins and Crawford 2016), and theology (Stanislaus 2022). These differences suggest the value of discipline-specific frameworks rather than a universal model, as context-specific factors may influence HL outcomes. Studies discuss the role of cultural and regional contexts in technology adoption (Bond et al. 2020) and suggest that generalizing hybrid models in pursuit of scalability might affect educational quality (Soncin et al. 2022). Additionally, factors such as design considerations, course-specific requirements (Kelly, Mihm-Carmichael, and Hammond 2021), and transitions from traditional to hybrid formats (Mestan 2019) can influence learning outcomes.

Research on student experiences provides additional context. While students appreciate the flexibility and autonomy of HL, some report challenges including motivation issues, feelings of isolation, technical difficulties, and limited collaboration opportunities. In one study, 64.9% of students preferred face-to-face teaching, with 55.4% reporting moderate-to-low satisfaction due to limited interaction with peers and instructors (Kauppi et al. 2020; Lorenzo-Lledó, Lledó, Gilabert-Cerdá, and Lorenzo 2021). These findings suggest that structured interventions, such as orientation sessions, may help balance pedagogical effectiveness and student engagement.

Figure 4 illustrates patterns between HL and SDGs, organizing synergies and barriers into three areas: crisis mitigation, equity promotion, and capacity building. The data show 30 synergies and 15 barriers. In crisis mitigation, evidence suggests connections to SDGs 11 and 13 through responses to extreme events (Manurung et al. 2020) such as pandemics (Bolatov et al. 2021). Equity promotion relates to SDGs 5 and 10 through examples of reduced gender disparities (Yao 2018) and increased social inclusion for adults (Cocquyt et al. 2019). Capacity building shows connections to SDGs 3 and 8 through cases such as public health worker training (Shah et al. 2017) and maritime industry education (Boulougouris et al. 2019). The analysis also identifies barriers including infrastructure limitations (Shah et al. 2017; Hajan and Padagas 2021).

4.2 | Equity Promotion

Recent empirical evidence demonstrates the effectiveness of HL in promoting equity-related SDGs, with evidence from various contexts and populations (Table 3). Studies from this review mainly connect the equity promoting initiatives with SDG 4.5 (equal access to education) and SDG 10.3 (equal opportunities) focusing on leverage HL to address educational inequalities through flexible, asynchronous delivery models (Yao 2018). Successful implementations span multiple contexts, including adult continuing education programs that achieved a 45% reduction in gender and geographic gaps (Yao 2019) and the GIRLS Inspire project, which reached 32,000 women in remote communities. In refugee education contexts aligned with SDG 10.7, 93% of Syrian refugee students reported positive experiences in higher education programs (Al-Husban and Shorman 2020).

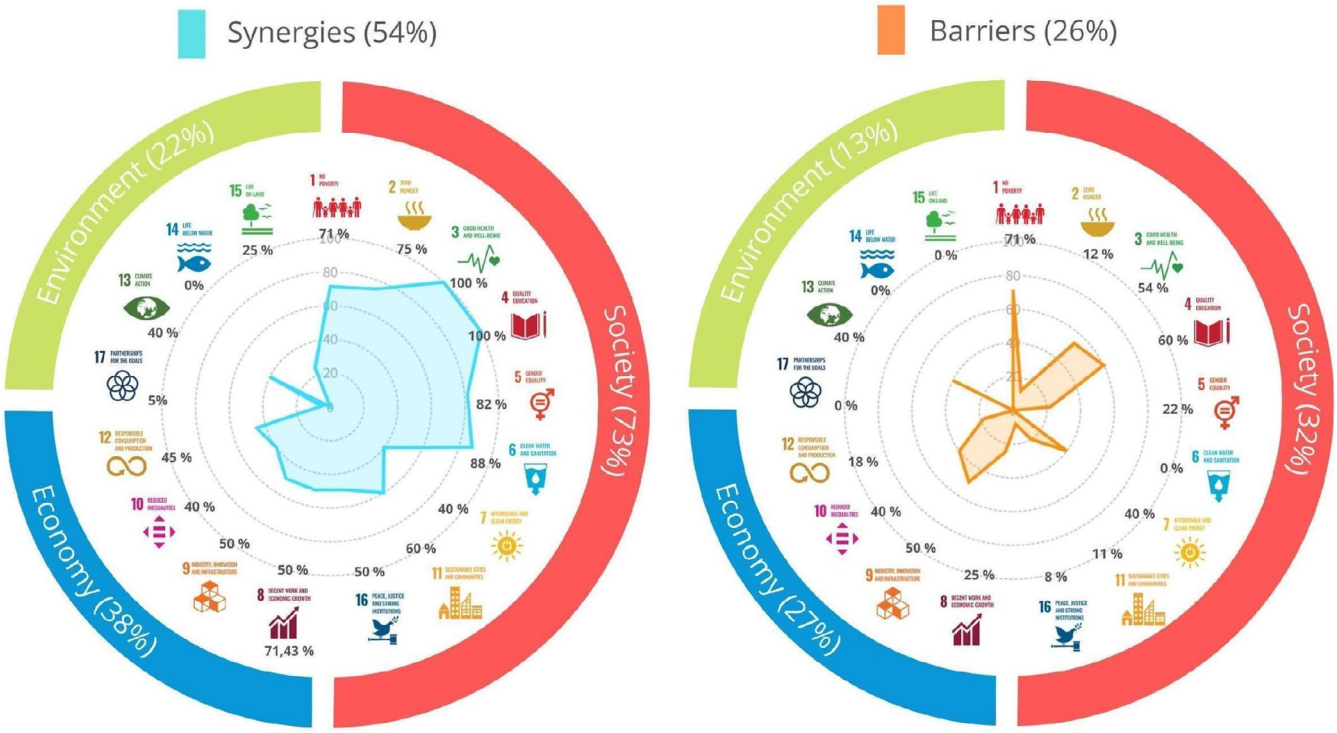

FIGURE 3 | Mapping of hybrid learning impacts: Synergies and barriers across SDGs, visualization adapted from Vinuesa et al. (2020).

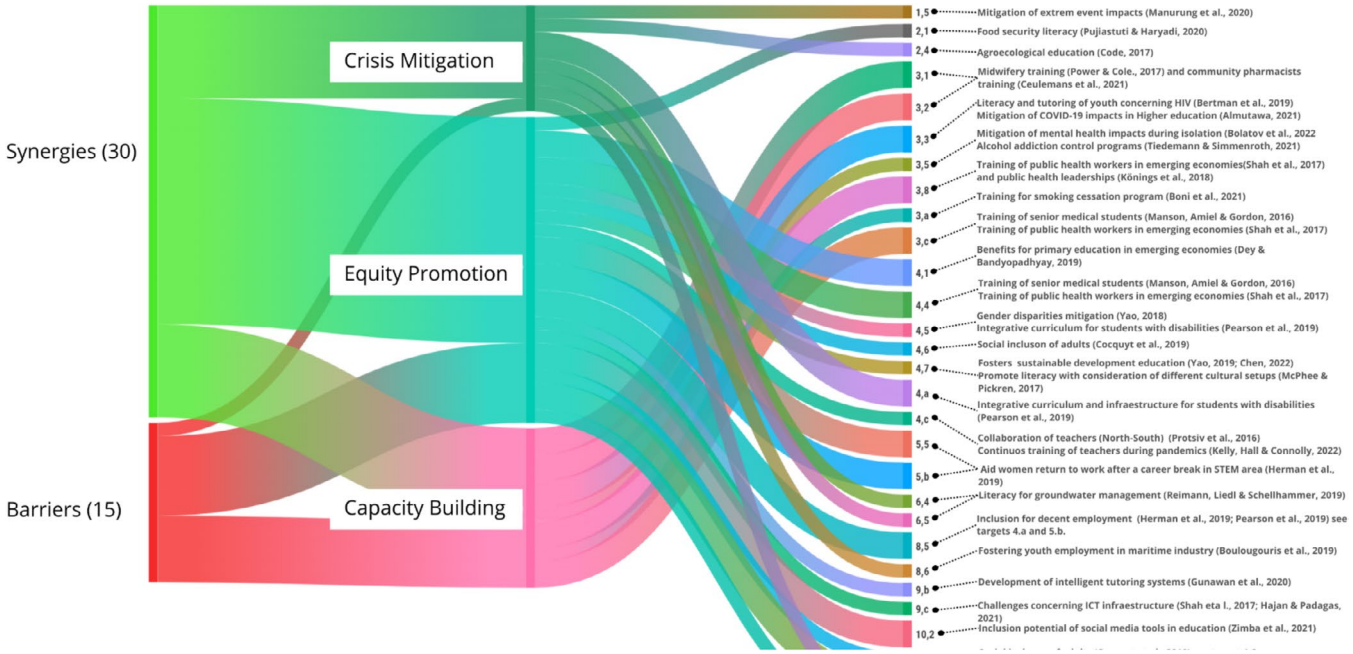

FIGURE 4 | Research evidence landscape: systematic mapping of hybrid learning contributions to SDGs including synergies, barriers, and implementation pathways.

Furthermore, in low-resource settings, HL approaches demonstrated measurable impact, as evidenced by an ICT literacy course achieving 85% completion rates among community healthcare workers in Malawi (Mastellos et al. 2018).

Drawing from these cases, three key factors emerge as critical for HL's equity promotion potential. First, asynchronous online and offline discussions enable broader participation, fostering collaborative knowledge development through peer interactions (Islam, Sarker, and Islam 2022). Second, active-learning methodologies facilitate critical thinking through interactive online activities (Ustun and Tracey 2021). Third, student-centered approaches incorporating creative tasks strengthen community building and personal exploration (Hesen, Wals, and Tauritz 2022).

However, implementing HL for educational equity faces substantial barriers, particularly in developing regions. The digital divide remains significant in a world context where, in 2020, internet

TABLE 3 | Examples from equity promotion in hybrid learning projects: Interventions and SDG connections.

Study/author	Hybrid learning aspect	Key findings/outcomes	SDG connection (with targets)
Yao (2018)	Blended learning environment	Promoted adult education development, reduced inequality between genders and geographical areas	SDG 4.5 (equal access to education) SDG 10.3 (ensure equal opportunities and reduce inequalities)
Herman et al. (2019)	Blended learning approach	Aided women returning to work after career breaks in STEM areas	SDG 5.5 (women's participation and equal opportunities) SDG 4.4 (increase skills for employment)
Zhang et al. (2020)	Blended learning environments	Improved educational outcomes for students with limited resources in China and Russia	SDG 10.2 (social, economic, and political inclusion) SDG 4.1 (ensure quality education for all) SDG 4.3 (equal access to tertiary education)
Al-Husban and Shorman (2020)	Blended learning for refugees	Positive experiences for 93 Syrian refugee students in higher education	SDG 4.3 (equal access to higher education) SDG 10.7 (facilitate orderly, safe, and responsible migration)
Yao (2018)	Blended learning environment	Reduced development inequality between genders	SDG 5.b (use of technology for women's empowerment) SDG 9.c (increase access to information and communications technology)

access covers only 60% of the population (Nakayama et al. 2023), and 16% of students from low-income families lack basic resources for online education access (Gu 2021). These challenges appear particularly significant in middle- and low-income countries, where existing educational inequalities may limit technological integration benefits (Billon, Crespo, and Lera-Lopez 2018). The disparities are exemplified in national cases, such as in one analysis of the Brazilian context that suggests digital learning opportunities tend to cluster in households with higher material and educational resources (Brito et al. 2016). Theoretical frameworks also indicate that effective technology integration likely requires not only infrastructure but also contextual elements including teacher knowledge, skills, attitudes, student preparedness, and institutional support (Sailer, Schultz-Pernice, and Fischer 2021).

To bridge these gaps, HL must align with SDG targets 4.5 and 10.3 through locally adapted strategies. Research by Dash et al. (2022) demonstrates that user engagement varies significantly based on local context and individual needs. This suggests a three-tiered approach: (1) infrastructure development aligned with SDG 9.c, (2) capacity building supporting SDG 4.4, and (3) community-specific adaptation addressing SDG 10.2. Success metrics should include both quantitative measures of access and qualitative assessments of user satisfaction and learning outcomes. These findings suggest the need for structured approaches to digital infrastructure development, pointing toward standardized frameworks for measuring and ensuring equitable access—an overlooked question in the current SDG targets.

4.3 | Crisis Mitigation

Educational institutions have increasingly adopted HL as a crisis response mechanism (Reimers 2022), demonstrating connections with multiple SDGs. This adaptation aligns particularly with SDG 11 (Sustainable Cities and Communities) and SDG 13 (Climate Action) through enhanced disaster resilience capabilities (Abu Talib, Bettayeb, and Omer 2021). The reviewed studies shows that implementations range from gradual community-based initiatives to rapid institutional transitions (Dash et al. 2022). In refugee contexts in Uganda, for instance, successful programs have developed comprehensive "thick" models that integrate psychosocial support and contextual learning designs (Nanyunja et al. 2021). The implementation of such models, as some examples shown in Table 4, has been significantly facilitated by strategic infrastructure development.

Early technology infrastructure investments, aligned with SDG 9.c (Access to Information and Communications Technology), have facilitated this transition. Evidence from Liberia shows how affordable internet access enabled 13,000 students to maintain educational continuity during COVID-19 (Chemonics 2021), while in Indonesia, hybrid approaches proved effective during natural disasters (Manurung et al. 2020). However, these technological advances, while promising, have also revealed significant implementation challenges across different contexts.

The rapid adoption of HL during crises highlights significant challenges connected to SDG 4.5 (equal access to education), particularly in resource-limited communities (Barrot, Llenares, and Del Rosario 2021; Khan et al. 2024). In refugee education contexts, Dridi et al. (2020) found that persistent connectivity issues severely impacted learning experiences, though human connections through face-to-face interactions and onsite facilitators proved crucial in bridging technological gaps. Similar findings from Nanyunja et al. (2021) demonstrated that successful blended learning in refugee settings requires substantial

TABLE 4 | Examples of crisis mitigation in hybrid learning projects: implementations and outcomes.

Study/author	Hybrid learning aspect	Key findings/outcomes	SDG connection (with targets)
Manurung et al. (2020)	Blended learning implementation	Helped educational institutions cope with problems caused by earthquake/tsunami in Indonesia	SDG 1.5 (resilience to climate-related events and disasters) SDG 13.1 (strengthen resilience to climate-related hazards and natural disasters)
Almutawa (2021)	Hybrid learning	Mitigated the impact of pandemics in higher education at a Kuwait university	SDG 3.3 (end epidemics and combat diseases), SDG 3.d (strengthen capacity for early warning, risk reduction, and health risks)
Manurung et al. (2020)	Blended learning implementation	Assisted educational institutions in coping with natural disasters	SDG 11.5 (reduce impact of disasters) SDG 13.1 (resilience to climate-related disasters)
Bolatov et al. (2021)	Blended learning	Mitigated mental health impacts on medical students	SDG 3.4 (promote mental health and well-being), SDG 4.7 (promote education for sustainable development and well-being)
Tiedemann and Simmenroth (2021)	Blended learning approach	Trained health workers for counseling in alcohol/smoking abuse	SDG 3.5 (prevention of substance abuse) SDG 3.c (health workforce development and retention)

psychosocial support and physical learning centers, while Alkhatib and Jaradat (2021) emphasized how technological innovations alone cannot improve learning outcomes without addressing underlying social barriers. The varied institutional responses highlight the absence of standardized crisis readiness metrics in educational systems, suggesting the need for dedicated digital resilience targets within the SDG framework.

Emergency responses to crises often result in hastily implemented HL solutions that, without proper planning and support, can perpetuate or worsen existing educational inequalities. This is evident in various contexts, from war-affected regions where institutions must rapidly transform their entire educational delivery (Lugovyi et al. 2023) to everyday classroom settings where teachers face increased technological demands alongside their regular responsibilities (Batac, Baquiran, and Agaton 2021), while students from less privileged backgrounds encounter significant adaptation difficulties (Hajan and Padagas 2021). Such systemic issues affect progress toward SDG 10.2 (Social, Economic and Political Inclusion), especially when institutions lack adequate support systems for HL implementation. These challenges put in evidence the role of institutional capacity in sustaining effective crisis response.

The development of effective crisis response through HL depends heavily on institutional learning and adaptation capabilities, supporting SDG 16.6 (Effective, Accountable Institutions) (Franken et al. 2021). While crisis-driven adoption has shown potential for educational resilience, evidence from refugee education settings reveals that success requires sustained investment in both digital and physical infrastructure, alongside systematic approaches to building technological confidence and addressing psychosocial barriers (Alkhatib and Jaradat 2021). This is further supported by findings from Uganda's refugee education program, which demonstrates the effectiveness of comprehensive support systems that combine technological and human-centered approaches (Nanyunja et al. 2021). Studies indicate that institutions often struggle to sustain the initial momentum of emergency responses, particularly regarding ongoing technological maintenance, professional development, and adaptation to evolving educational needs (Barasa, Mbau, and Gilson 2018). Rather than rapid transformation, successful crisis response through HL requires sustained institutional capability development that considers local contexts, aiming to create sustainable models effective in both emergency and postemergency situations.

4.4 | Capacity Building

HL supports capacity development through integrated approaches to competency building at individual and organizational levels, combining online and face-to-face instruction in adaptive learning environments (Raes et al. 2020). This approach directly connects to SDG 4.4 (Skills for Employment), with implementations across sectors demonstrating various pathways for supporting multiple SDG targets (Table 5). For example, the "FamMed Essentials" blended learning program for general practitioners in Pakistan demonstrated significant enhancement of clinical competencies through its modular structure and asynchronous-synchronous balance, supporting both SDG 3.c (Health Workforce Development) and SDG 4.4 (Khan et al. 2024). In sustainable development education, Chen's (2022) work shows how hybrid approaches can serve multiple development objectives while building institutional capacity, addressing both SDG 4.7 (Education for Sustainable Development) and SDG 12.8 (Information for Sustainable Lifestyles).

Healthcare education exemplifies the broad impact of HL applications across different scales, supporting SDG 3.c (Health Workforce

TABLE 5 | Examples from capacity building in hybrid learning projects: programs and SDG alignments.

Study/author	Hybrid learning aspect	Key findings/outcomes	SDG connection (with targets)
Shah et al. (2017)	Distance blended learning	Upgraded district health workers in Nepal and nondoctor anesthesia providers globally	SDG 3.c (health workforce development), SDG 4.4 (skills for employment)
Yao (2018)	Blended learning environment	Promoted adult education development and reduced inequalities	SDG 4.4 (increase skills for employment), SDG 8.5 (full and productive employment for all)
Boulougouris et al. (2019)	Online tools in blended learning	Aided training of professionals in the maritime industry	SDG 8.6 (reduce proportion of youth not in employment or training), SDG 4.3 (equal access to vocational training)
Biancardi et al. (2023)	Sustainable community-based learning in higher education	Development of sustainable communities through integration of education, research and innovation practices	SDG 4.7 (education for sustainable development), SDG 11.3 (participatory planning for sustainable communities), SDG 17.16 (multistakeholder partnerships), SDG 13.3 (improve education on climate change)
Chen (2022)	Blended learning	Fostered development of sustainability-oriented literacy curriculum in higher education	SDG 4.7 (education for sustainable development), SDG 12.8 (ensure people have relevant information for sustainable lifestyles)
Kailin et al. (2021)	Blended learning	Efficient training of pediatricians in echocardiography knowledge	SDG 3.2 (end preventable deaths of newborns and children), SDG 4.1 (ensure quality education for all)
Reimann, Liedl, and Schellhammer (2019)	Blended learning	Effective teaching of groundwater management in engineering classes	SDG 6.4 and 6.5 (water management), SDG 13.3 (improve education and awareness on climate change and water resources)

Development). Examples range from basic healthcare training in resource-limited settings to specialized medical education, as evidenced in programs for district health workers in Nepal (Shah et al. 2017) and pediatric specialists (Kailin et al. 2021). Beyond healthcare, educational institutions have demonstrated diverse applications: higher education institutions leverage hybrid approaches to foster sustainable community development through interdisciplinary collaboration (Biancardi et al. 2023), addressing SDG 17.16 (Multistakeholder Partnerships), while professional education programs in the maritime industry (Boulougouris et al. 2019) and groundwater management (Reimann, Liedl, and Schellhammer 2019) show how HL can enhance both technical skills and sustainability awareness.

The success of these capacity building initiatives hinges on several critical factors. Institutional climate significantly influences teaching effectiveness and research capacity (Chakraborty and Biswas 2020), while infrastructure and access disparities affect implementation outcomes (Adedoyin and Soykan 2023). These implementation patterns reveal the interconnected nature of infrastructure, teaching competencies, and resource access—elements that would benefit from explicit recognition in SDG education targets. Successful implementation requires robust support systems, with educator training playing a central role in effective technology integration (Rapanta et al. 2021). Additionally, while adult education programs have shown promise in reducing inequalities and promoting employment (Yao 2018), their success depends on sustained institutional commitment to professional development and technological infrastructure (Maesaroh and Masyitoh 2022).

5 | Conclusion

This study explored the potential of HL as a tool for advancing SDGs by mapping its relationships with the 169 SDG targets through the 2030 Agenda framework. Our analysis identified 90 enabling synergies compared to 45 barriers, revealing that HL intersects significantly with three critical dimensions of development: crisis mitigation, equity promotion, and capacity building. While this positive balance suggests considerable potential for supporting sustainable development objectives, successful implementation depends heavily on infrastructure that enables effective pedagogical development while balancing cost, quality, and scalability. Although technology's versatility can help overcome some resource constraints through widely available tools like television, radio broadcasts, and social media platforms, HL also reflects broader challenges related to the digital divide, including material restrictions and technological literacy inequality.

5.1 | Practical Implications

The recurring themes of infrastructure standards, teaching competencies, and crisis readiness across all three dimensions suggest the need for a more comprehensive framework for digital-resilient education. The analysis of HL's links with SDGs reveals gaps particularly concerning digital education infrastructure and resilience. Recent studies examining SDG 4 indicators in conflict zones (Sareen and Mandal 2024) and longitudinal evaluations of digital learning models (Nedungadi et al. 2024) further highlight these gaps. While our findings indicate that internet access is still a global challenge, the implications for education extend beyond connectivity—infrastructure accessibility fundamentally shapes both teaching quality and research capacity across regions. The current SDG 4 framework, while comprehensive in educational metrics and with a considerable degree of interconnection with other SDGs (i.e., SDG 5 Gender Equality and SDG 8 Decent work and Economic Growth), it has room for specific targets addressing digital learning infrastructure, system resilience, technological capacity building, and the crucial link between educational technology and equity. These gaps become particularly significant as successful HL implementation requires a careful balance of technological infrastructure and pedagogical approaches, a balance that varies substantially across different regional contexts.

Based on this analysis, we recommend establishing key action priorities aligned with the proposed SDG Target 4.8. As illustrated in Figure 5, our SDG-Hybrid Learning Alignment Framework identifies critical components for implementation. For policymakers, essential actions include:

- Establishing national standards for minimum digital infrastructure requirements in educational institutions, including reliable internet connectivity and basic learning management systems
- Creating frameworks for measuring and supporting institutional crisis preparedness, with clear guidelines for maintaining educational continuity during disruptions
- Developing funding mechanisms to support both initial infrastructure development and ongoing maintenance, particularly in underserved regions

For educational institutions, priority actions should focus on:

- Building teacher capacity through comprehensive professional development programs that combine technical skills with pedagogical approaches
- Creating robust support systems that include both technical infrastructure and human resources for ongoing assistance
- Developing flexible learning frameworks that can adapt to local contexts while maintaining educational quality standards

The effectiveness of these recommendations depends heavily on contextual adaptation and systematic implementation. Local educational authorities should assess their specific needs and constraints before developing detailed implementation plans.

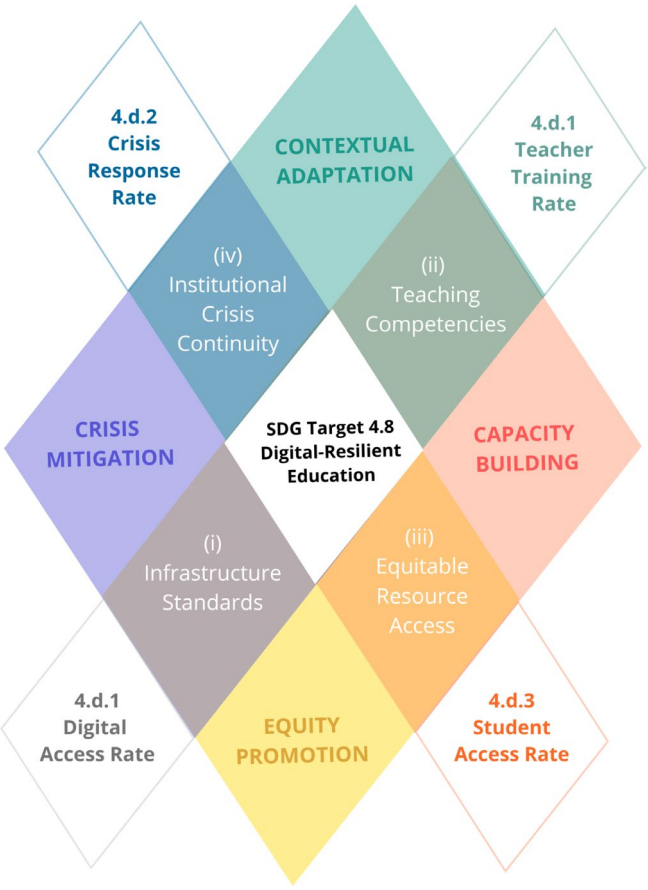

FIGURE 5 | SDG-Hybrid Learning Alignment Framework: infrastructure standards, teaching competencies, resource access, and crisis continuity components.

Regular monitoring and evaluation using the proposed indicators can help track progress and identify areas needing additional support or modification.

Based on this analysis, we propose the SDG Target 4.8 Digital-Resilient Education, which could serve as both an addition to the current framework and a model for future global educational policy frameworks beyond 2030:

4.8 By 2030, ensure universal access to resilient hybrid learning infrastructure and capabilities, with a specific focus on: (i) establishing minimum digital infrastructure standards for educational institutions, (ii) developing hybrid teaching and learning competencies, (iii) ensuring equitable access to digital learning resources, and (iv) building institutional capacity for educational continuity during crises.

The proposed indicators for this target can consider, but not be limited to:

4.d.1: Proportion of educational institutions with access to: (a) reliable internet connectivity, (b) basic digital learning platforms, and (c) hybrid learning support systems.

4.d.2: Proportion of educators trained in hybrid teaching methodologies.

4.d.3: Proportion of students with access to necessary digital learning tools and resources.

4.d.4: Proportion of educational institutions with operational crisis response plans incorporating hybrid learning.

5.2 | Theoretical Contributions

Our study advances understanding of hybrid learning's role in sustainable development by examining three key perspectives. Through SDG mapping, we build on digital inclusion theory (Warschauer 2003; van Deursen and van Dijk 2019) to identify how access barriers, skill gaps, and usage patterns manifest differently across development contexts. This analysis suggests valuable research directions for examining educational technology through sustainable development frameworks.

Second, complex systems perspectives (Jacobson, Levin, and Kapur 2019) offer insights into how hybrid learning outcomes emerge from interactions between infrastructure, institutional capabilities, and societal resources. Our SDG mapping indicates opportunities for future research examining these system interactions across different development contexts, particularly in understanding implementation variance between high- and low-resource environments.

Third, our analysis points to promising research directions in educational resilience. The SDG-Hybrid Learning Alignment Framework provides a starting point for exploring how digital resilience develops within educational systems, though further empirical validation is needed.

Author Contributions

Conceptualization, F.M. and I.I.B.; methodology, F.M. and I.I.B.; validation, L.C., L.L., D.D., I.B., R.P., L.M., and S.I.; formal analysis, F.M. and L.C.; investigation, F.M. and I.I.B.; resources, I.I.B.; data curation, F.M., G.C.C., and A.S.; writing – original draft preparation, F.M.; writing – review and editing, F.M., I.I.B., G.C.C., D.D., and R.P.; visualization, F.M.; supervision, I.I.B.; project administration, F.M.; funding acquisition, I.I.B. All authors have read and agreed to the published version of the manuscript.

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Ethics Statement

This article does not contain any studies with human participants performed by any of the authors. For this reason, no special permissions were required to conduct this study.

Consent

This study assessed data gathered from peer-reviewed scientific journals; therefore, this article does not contain any studies with human participants performed by any of the authors, hence informed consent was not required.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The datasets generated during the current study are available upon request to the corresponding authors.

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Appendix A

- The search strings combine: hybrid learning-related keywords within the TITLE field boolean operator AND
- SDG-related keywords in the field "Article title, abstract and keywords" (for Scopus) and Topic (for Wos)
- Filters for year range 2015–2022, document type: article, language: English

Scopus

Query to be inserted in the "Advanced search" field.

(TITLE ("hybrid learning" OR "blended learning" OR "blended-learning" OR "technology-mediated instruction" OR "technology-mediated education" OR "web-enhanced instruction" OR "web-enhanced education" OR "mixed-mode instruction" OR "mixed-mode education") TITLE-ABS-KEY ("SDG 1" OR "vulnerable" OR "poor" OR "poverty" OR "misery" OR "SDG 2" OR "hunger" OR "food security" OR "improved nutrition" OR "sustainable agriculture" OR "bad nutrition" OR "malnutrition" OR "overweight" OR "SDG 3" OR "Healthy life" OR "Healthy lives" OR "well-being" OR "wellbeing" OR "communicable disease" OR "non-communicable disease" OR "SDG 4" OR "inclusive education" OR "equitable education" OR "quality education" OR "promote lifelong learning" OR "SDG 5" OR "gender equality" OR "women empower" OR "girl empower" OR "gender discrimination" OR "gender identity" OR "gender violence" OR "SDG 6" OR "sanitation" OR "water security" OR "clean water" OR "water quality" OR "water resource" OR "human consumption" OR "SDG 7" OR "affordable energy" OR "reliable energy" OR "sustainable energy" OR "modern energy" OR "energy efficiency" OR "sustainable energy" OR "SDG 8" OR "sustained economic growth" OR "inclusive economic growth" OR "sustainable economic growth" OR "decent work" OR "decent jobs" OR "health and safety at work" OR "productivity" OR "SDG 9" OR "resilient infrastructure" OR "inclusive industrialization" OR "sustainable industrialization" OR "foster innovation" OR "innovative" OR "SDG 10" OR "inequality" OR "equality" OR "equity" OR "social inclusion" OR "equal opportunities" OR "SDG 11" OR "inclusive cities" OR "safe cities" OR "resilient cities" OR "sustainable cities" OR "inclusive settlements" OR "safe settlements" OR "resilient settlements" OR "sustainable settlements" OR "sustainable urbanization" OR "SDG 12" OR "sustainable consumption" OR "sustainable production" OR "sustainable supply chain" OR "green supply chain" OR "environmental innovation" OR "SDG 13" OR "climate action" OR "climate crisis" OR "climate change" OR "greenhouse gas" OR "SDG 14" OR "Conservation of the ocean" OR "Conservation of the sea" OR "Conservation of marine resources" OR "Sustainable use of the ocean" OR "Sustainable use of sea" OR "Sustainable use of marine resources" OR "marine pollution" OR "sea water quality" OR "SDG 15" OR "Protect terrestrial ecosystems" OR "restore terrestrial ecosystems" OR "Sustainable use of terrestrial ecosystems" OR "Sustainably manage forests" OR "Combat desertification" OR "Land degradation" OR "Biodiversity loss" OR "biodiversity" OR "ecosystem service*" OR "terrestrial biome" OR "aquatic ecosystem" OR "sustainable use of biodiversity" OR "SDG 16" OR "peaceful societies" OR "inclusive societies" OR "Access to justice" OR "Accountable institutions" OR "Inclusive institutions" OR "access to peace" OR "SDG 17" OR "Global partnerships" OR "International capacity-building" OR "International cooperation" OR "international agreement" OR "international cooperation")) AND (LIMIT-TO (SRCTYPE, "j")) AND (LIMIT-TO (PUBSTAGE, "final")) AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (PUBYEAR, 2022) OR LIMIT-TO (PUBYEAR, 2021) OR LIMIT-TO (PUBYEAR, 2020) OR LIMIT-TO (PUBYEAR, 2019) OR LIMIT-TO (PUBYEAR, 2018) OR LIMIT-TO (PUBYEAR, 2017) OR LIMIT-TO (PUBYEAR, 2016) OR LIMIT-TO (PUBYEAR, 2015)) AND (LIMIT-TO (LANGUAGE, "English"))

Web of Science

Query to be inserted in the "Advanced Search Query Builder" field:

(TS = ("SDG 1" OR "vulnerable" OR "poor" OR "poverty" OR "misery" OR "SDG 2" OR "hunger" OR "food security" OR "improved nutrition" OR "sustainable agriculture" OR "bad nutrition" OR "malnutrition" OR "overweight" OR "SDG 3" OR "Healthy life" OR "Healthy lives" OR "well-being" OR "wellbeing" OR "communicable disease" OR "non-communicable disease" OR "SDG 4" OR "inclusive education" OR "equitable education" OR "quality education" OR "promote lifelong learning" OR "SDG 5" OR "gender equality" OR "women empower" OR "girl empower" OR "gender discrimination" OR "gender identity" OR "gender violence" OR "SDG 6" OR "sanitation" OR "water security" OR "clean water" OR "water quality" OR "water resource" OR "human consumption" OR "SDG 7" OR "affordable energy" OR "reliable energy" OR "sustainable energy" OR "modern energy" OR "energy efficiency" OR "sustainable energy" OR "SDG 8" OR "sustained economic growth" OR "inclusive economic growth" OR "sustainable economic growth" OR "decent work" OR "decent jobs" OR "health and safety at work" OR "productivity" OR "SDG 9" OR "resilient infrastructure" OR "inclusive industrialization" OR "sustainable industrialization" OR "foster innovation" OR "innovative" OR "SDG 10" OR "inequality" OR "equality" OR "equity" OR "social inclusion" OR "equal opportunities" OR "SDG 11" OR "inclusive cities" OR "safe cities" OR "resilient cities" OR "sustainable cities" OR "inclusive settlements" OR "safe settlements" OR "resilient settlements" OR "sustainable settlements" OR "sustainable urbanization" OR "SDG 12" OR "sustainable consumption" OR "sustainable production" OR "sustainable supply chain" OR "green supply chain" OR "environmental innovation" OR "SDG 13" OR "climate action" OR "climate crisis" OR "climate change" OR "greenhouse gas" OR "SDG 14" OR "Conservation of the ocean" OR "Conservation of the sea" OR "Conservation of marine resources" OR "Sustainable use of the ocean" OR "Sustainable use of sea" OR "Sustainable use of marine resources" OR "marine pollution" OR "sea water quality" OR "SDG 15" OR "Protect terrestrial ecosystems" OR "restore terrestrial ecosystems" OR "Sustainable use of terrestrial ecosystems" OR "Sustainably manage forests" OR "Combat desertification" OR "Land degradation" OR "Biodiversity loss" OR "biodiversity" OR "ecosystem service*" OR "terrestrial biome" OR "aquatic ecosystem" OR "sustainable use of biodiversity" OR "SDG 16" OR "peaceful societies" OR "inclusive societies" OR "Access to justice" OR "Accountable institutions" OR "Inclusive institutions" OR "access to peace" OR "SDG 17" OR "Global partnerships" OR "International capacity-building" OR "International cooperation" OR "international agreement" OR "international cooperation")) AND TI = ("hybrid learning" OR "blended learning" OR "blended-learning" OR "technology-mediated instruction" OR "technology-mediated education" OR "web-enhanced instruction" OR "web-enhanced education" OR "mixed-mode instruction" OR "mixed-mode education")