

Beyond Individual Practice: Narrative Exploration of Ecosystem Learning in Indonesian Dental SMEs' Journey Toward Digital-Climate Sustainability

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Abstract: *This study investigates the ways in which Indonesian dental small and medium enterprises (SMEs) adapt to digital health integration and climate challenges by engaging in ecosystem learning processes, focusing on the shift from isolated practice models to sustainable, interconnected healthcare delivery systems. This study utilizes a qualitative narrative approach to explore the intricate dynamics by which professional learning networks enable organizational change and collective adaptation to technological and environmental challenges. The narrative inquiry uncovers four interrelated themes that define the dynamics of ecosystem learning within Indonesian dental SMEs. The evolution of digital transformation journeys has shifted from individual challenges to collaborative processes, facilitated by professional networks and peer learning strategies. Climate adaptation strategies developed through collaborative learning networks that allowed practitioners to integrate sustainability practices into current operational frameworks, all while maintaining a balance between economic viability and environmental responsibility. The process of co-creating knowledge within ecosystems acted as an essential intermediary, enabling joint problem-solving and the exchange of resources among various interconnected learning communities. Following this, the emergence of a sustainable ecosystem illustrated the fusion of digital innovation with climate resilience via new institutional frameworks that foster collective action while honoring the autonomy of individual practitioners. Drawing from these empirical insights, this study enhances ecosystem learning theory by illustrating its relevance in healthcare SME settings and uncovering the role of collective learning in mediating intricate transformation processes. The results enhance the understanding of digital health integration by demonstrating that technology acceptance is influenced more by social learning mechanisms than by individual cognitive processes alone. The study offers valuable insights for policymakers involved in creating support programs aimed at transforming healthcare SMEs, highlighting the significance of fostering peer learning networks and collaborative knowledge-sharing platforms. The findings provide guidance for professionals on how to utilize ecosystem resources effectively to enhance digital adoption and implement sustainability, all while fostering resilience within their professional communities.*

Keywords: *Ecosystem Learning, Digital Health Integration, Climate Adaptation, Dental SMEs, Healthcare Sustainability, SATUSEHAT platform*

INTRODUCTION

The modern healthcare landscape has seen a remarkable transition expedited by the COVID-19 pandemic, radically altering the conception, delivery, and sustainability of healthcare services. This change involves two essential imperatives: the swift digitalization of healthcare systems and the pressing necessity for climate-responsive sustainable practices. The healthcare sector, responsible for almost 5% of global greenhouse gas emissions, is under increasing pressure to balance technological innovation with environmental responsibility while ensuring quality service delivery (FDI World Dental Federation, 2025). This combined problem has prompted a paradigm change from isolated individual practice models to linked, learning-enabled healthcare ecosystems that utilize collective intelligence to address complexity and ambiguity.

The notion of "beyond individual practice" arises in reaction to the acknowledgment that modern healthcare challenges—spanning digital integration difficulties to climate adaption needs—surpass the ability of solitary practitioners to address successfully. This ecosystem perspective highlights interconnectedness, collaborative learning, and emerging capabilities that originate from networked interactions rather than only from individual competence. Healthcare small and medium enterprises (SMEs) in developing economies serve as essential laboratories for comprehending the dynamics of ecosystem transformations at the grassroots level, where resource limitations and regulatory complexities generate distinct pressures and opportunities for innovation. The dental healthcare sector in Indonesia demonstrates this transformative dynamic with notable relevance and urgency. The Indonesian Medical Council reports that approximately 46,000 dentists are registered among a total of 287,390 medical practitioners as of 2024, with most operating small private practices that are vital to the nation's healthcare system (GoodStats, 2025). Dental SMEs encounter unique challenges: addressing a demographic in which 57% suffer from oral health issues, yet merely 11.2% pursue treatment, functioning under the resource limitations characteristic of small businesses, and managing increasingly intricate regulatory demands for quality assurance and patient safety (Tempo, 2025).

The strategic placement of dental SMEs inside Indonesia's national health system transcends their direct clinical function. These practices are essential entry sites for marginalized groups, considerably enhance healthcare employment and economic activity, and operate as natural laboratories for examining the diffusion of healthcare innovations from policy initiatives to individual practice implementation. Their dispersed presence throughout Indonesia's varied geographic and socioeconomic terrain renders them significant markers of healthcare system resilience and adaptive capacity, especially in scenarios when centralized healthcare delivery models encounter constraints.

The Indonesian government's Blueprint for Digital Health Transformation Strategy 2024 has created a detailed framework for healthcare digitalization, requiring the shift from physical to electronic medical records in all healthcare facilities by 31 December 2023. The SATUSEHAT platform is pivotal to this transformation, serving as a national health information exchange system that integrates patient data among healthcare providers, thereby facilitating seamless care coordination and evidence-based decision-making (Healthcare IT News, 2022). The platform, officially inaugurated in July 2022, serves as a Platform-as-a-Service (PaaS) architecture that integrates the whole healthcare business ecosystem to generate dependable national health data (Ksatria, 2023). The implementation objectives are ambitious: 12,000 healthcare facilities in the Java-Bali region by 2022, with plans for statewide expansion by 2023. By 2024, SATUSEHAT Logistics facilitates the administration of over 800 million vaccination doses and 100 million medicine doses across more than 10,000 healthcare facilities in 38 provinces (UNDP Indonesia, 2024). Nonetheless, the actuality of on-the-ground execution demonstrates considerable intricacy. The 2023 digital maturity assessment by Indonesia's Ministry of Health, in collaboration with the United States Agency for International Development, revealed that 146 participating provinces and districts achieved an average score of 2.73 out of 5.00, signifying considerable potential for enhancement in digital adoption (Healthcare IT News, 2024).

This digital shift offers dentistry SMEs both remarkable prospects and significant obstacles. The technical prerequisites for system integration, data security compliance, and interoperability standards necessitate technological competencies and financial commitments that may exceed the resources of small practices. Concurrently, the prospective advantages—such as enhanced patient care coordination, access to evidence-based treatment protocols, and involvement in population health initiatives—present compelling value propositions for practices prepared to transition from paper-based to digitally enabled operations.

Alongside the challenges of digital transformation, climate change has become a significant concern for Indonesian healthcare systems. Indonesia's susceptibility to climate-related consequences is demonstrated by the 5,400 documented disasters in 2023, which displaced 8.5 million individuals and inflicted significant property damage, hence generating operational risks that directly harm small healthcare providers (UNDP Indonesia, 2024). The anticipated economic effect of climate-related diseases may amount to 1.86% of national GDP, or 137.65 trillion rupiah, highlighting the essential need for the establishment of climate-resilient healthcare systems. Dental procedures substantially impact healthcare's environmental footprint via resource utilization and waste production. Each year, dental care facilities generate 4.8 million lead sheets, 28 million liters of hazardous

radioactive materials, 3.7 tonnes of mercury waste, 1.7 billion sterilization pouches, and 680 million coverings for chairs, lights, and patient bibs (Dutt et al., 2024). The prevalence of single-use plastics in dentistry is alarming: with a global population of 7.53 billion, around 29.4 billion toothbrushes are manufactured each year, and every plastic toothbrush ever produced remains extant on the planet, underscoring the necessity for sustainable practices. Notwithstanding increasing environmental consciousness, substantial discrepancies remain between acknowledgment and implementation. Research reveals that 82.3% of dental practitioners recognize the environmental harm attributed to dental treatments, although only 47.6% comprehend the principles of eco-friendly practices (Dutt et al., 2024). This awareness-implementation gap illustrates the broader difficulties in converting sustainability intentions into practical changes, especially in resource-limited SME contexts where urgent operational issues may eclipse long-term environmental priorities.

The sustainable dentistry movement, advocated by entities like the FDI World Dental Federation, has created extensive frameworks that include prevention-oriented care, resource efficiency, waste management, and environmental stewardship. The six fundamental themes of green dentistry—amalgam management, radiography management, infection control management, procurement management, and energy and water conservation—offer systematic approaches for minimizing environmental impact (FDI World Dental Federation, 2020). Nevertheless, obstacles to implementation, such as financial constraints, the accessibility of sustainable alternatives, and insufficient instructional resources, persist in hindering widespread acceptance. The intersection of digital transformation and climate adaption demands has highlighted the shortcomings of isolated practice-based methods in addressing intricate healthcare issues. The ecosystem thinking model underscores that sustainable solutions arise from interconnected interactions, collective knowledge production, and collaborative learning processes that beyond individual organizational boundaries. This viewpoint acknowledges that healthcare practices are integrated within extensive socio-technical systems, where innovations proliferate via professional networks, regulatory frameworks, and community connections.

Healthcare learning ecosystems promote knowledge co-creation via various mechanisms: peer-to-peer learning networks facilitated by digital platforms, communities of practice that exchange best practices and problem-solving strategies, and collaborative innovation processes that utilize diverse expertise and perspectives. In Indonesia, these mechanisms function via professional associations like the Indonesian Dental Association (PDGI), governmental initiatives such as the Health Innovation Sprint Accelerator (HISA) 2023, endorsed by the Ministry of Health's Digital Transformation Office, and private sector investments exemplified by East Ventures' £30 million healthcare-focused fund announced in 2023 (East Ventures, 2025).

The intersection of digital technology and climate within educational environments generates significant dynamics for the development of sustainable healthcare. Digital technologies enhance the spread of sustainable practice innovations, enabling data-driven decision-making for environmental effect mitigation, and encourage virtual collaboration that diminishes the carbon footprint of professional development activities. Teledentistry systems enhance access to care while minimizing transportation-related emissions for both practitioners and patients, illustrating how digital solutions can concurrently fulfill many sustainability goals.

Notwithstanding the increasing acknowledgment of the significance of ecological approaches, substantial deficiencies remain in comprehending the development and functioning of such systems in practice. The existing research mostly emphasizes the technology dimensions of digital health transformation, with a paucity of comprehensive analysis about digitalization in clinical settings. The ecosystem-level examination of healthcare SME transformation is insufficiently examined, especially with the convergence of digital health uptake and climate adaptation methods. Quantitative studies predominantly shape the research environment, resulting in deficiencies in the nuanced, narrative comprehension of transformation processes from the viewpoints of practitioners. The Indonesian environment offers distinct study opportunities owing to the magnitude and intricacy of the current reform of the healthcare sector. Insufficient Indonesia-specific research on dental SME transformation restricts comprehension of local adaption processes and culturally-informed implementation techniques. The deficiency in information constrains the efficacy of policy interventions and support programs aimed at promoting healthcare digitalization and sustainability transitions.

This study examines how Indonesian dental SMEs maneuver the intricate convergence of digital health integration and climate adaptation via ecosystem learning mechanisms. The study's theoretical contribution

consists of enhancing ecosystem learning theory in healthcare settings, formulating conceptual frameworks for comprehending the digital-climate sustainability relationship, and illustrating the significance of narrative approach for analyzing complex systems. The research offers evidence-based insights for policy development, specifically concerning the efficacy of SATUSEHAT implementation, defines optimal practices for dental SME support programs, and delineates learning paths that may expedite transformation processes.

The social importance transcends immediate enhancements in healthcare delivery, encompassing wider contributions to the development of climate-resilient healthcare systems and the empowerment of SMEs in tackling global health concerns. This research elucidates how learning ecosystems enable grassroots transformation, offering essential insights for expansive healthcare system reform initiatives with potential for regional and global scalability, underscoring the vital significance of systemic approaches to healthcare innovation amid interconnected global challenges.

THEORETICAL FRAMEWORK

Ecosystem learning theory signifies a paradigm change from individual and organizational learning to comprehending knowledge creation and transmission across interrelated networks of participants. This theoretical framework defines learning as an emergent characteristic of complex adaptive systems, wherein knowledge circulates through multidirectional interactions among various stakeholders, including practitioners, institutions, communities of practice, and technological platforms (Bronfenbrenner, 2022). Ecosystem learning, in contrast to conventional models that prioritize discrete knowledge acquisition, highlights the co-evolutionary processes whereby participants collaboratively create meaning, exchange tacit knowledge, and cultivate adaptive capabilities in response to environmental challenges. The theory is based on ecological systems theory, which conceptualizes human development and behavior as outcomes of interactions between individuals and their circumstances across various nested levels of impact, ranging from microsystems (immediate environs) to macrosystems (wider cultural contexts) (Henderson et al., 2019). In healthcare settings, ecosystem learning is evident through professional networks that assist the translation of research into practice, peer-to-peer learning mechanisms supported by digital platforms, and communities of practice that promote collaborative problem-solving procedures. Recent advancements in medical education illustrate how learning ecosystems can dismantle conventional hierarchical frameworks, fostering horizontal knowledge-sharing networks that expedite the adoption of innovation and augment collective intelligence across professional domains (Kumar et al., 2022).

Theory of digital health integration is the systematic inclusion of information and communication technology into healthcare delivery systems to enhance clinical decision-making, improve patient outcomes, and optimize operational efficiency. The Technology Acceptance Model (TAM), initially formulated by Davis in 1989, continues to be the preeminent theoretical framework for comprehending healthcare technology adoption, asserting that perceived usefulness and perceived ease of use are the principal factors influencing technology acceptance behavior (Holden & Karsh, 2018). Extended TAM models integrate supplementary factors, including social impact, conducive conditions, trust, and self-efficacy, to more effectively elucidate adoption trends in intricate healthcare settings. The Unified Theory of Acceptance and Use of Technology (UTAUT) presents a robust framework that integrates components from many acceptance theories, hence improving the predictive capacity for outcomes related to healthcare technology deployment (Venkatesh et al., 2016). Digital health integration transcends mere technology adoption, incorporating health information system interoperability, platform-as-a-service designs, and data governance frameworks that facilitate smooth information flow inside healthcare networks. Recent systematic reviews indicate that the Technology Acceptance Model (TAM) and the Unified Theory of Acceptance and Use of Technology (UTAUT) are the predominant frameworks for elucidating healthcare technology acceptance, particularly in the realms of telemedicine, electronic health records, and mobile health applications (Al-Rahimi et al., 2021). The integration process is influenced by organizational elements, including the preparedness of technical infrastructure, staff digital literacy, and institutional support mechanisms, which combined affect the effectiveness of digital transformation programs in healthcare environments.

Climate adaptation theory in healthcare contexts utilizes larger environmental and organizational resilience frameworks to analyze how health systems react to climate-related stressors and cultivate adaptive capacity over time. The Intergovernmental Panel on Climate Change (IPCC) framework characterizes adaptation as "the process

of adjustment to actual or anticipated climate and its effects, aimed at mitigating harm or capitalizing on advantageous opportunities" (IPCC, 2018). The healthcare-specific adaptation theory broadens this notion to include systemic solutions that preserve vital health services amid climatic disruptions while fostering enduring resilience to future environmental challenges. Transformational adaptation, unlike incremental adjustments, entails profound modifications to healthcare delivery methods, infrastructure design, and organizational culture that empower systems to flourish under altered climate conditions rather than simply endure (Kates et al., 2015). Climate adaptation in healthcare functions through various avenues, including infrastructure fortification, disaster preparedness strategies, supply chain diversification, and workforce development initiatives that improve system flexibility and responsiveness. Adaptive capacity and vulnerability assessment offer analytical frameworks for assessing healthcare systems' capabilities to anticipate, absorb, accommodate, and recuperate from climate-related shocks, while also learning from these experiences to enhance future performance (Ford & Berrang-Ford, 2016). Recent research underscores the significance of participatory adaptation methods that involve local communities, healthcare professionals, and patients as active collaborators in recognizing climate risks and co-developing contextually relevant response strategies that utilize indigenous knowledge and community resources (Berkes, 2017).

The theory of small and medium enterprises (SMEs) in healthcare contexts amalgamates organizational behavior, strategic management, and industrial organization perspectives to elucidate how resource-constrained healthcare providers maneuver through competitive landscapes while preserving service quality and operational sustainability. Small and medium-sized enterprises (SMEs) are generally characterized by quantitative metrics such as employee count (ranging from 10 to 250 employees), yearly revenue limits, and asset valuations, but precise definitions differ by country and industry (OECD, 2017). Healthcare SMEs demonstrate unique traits such as significant professional autonomy, tailored service delivery models, robust community integration, and dependence on professional networks for knowledge exchange and resource acquisition. The resource-based view theory posits that the competitive advantage of SMEs stems from distinctive combinations of tangible and intangible resources, such as specialized clinical expertise, patient relationships, local market knowledge, and organizational flexibility, which facilitate swift adaptation to evolving market conditions (Barney, 2021). Network theory underscores the vital significance of external relationships for the success of SMEs, especially in professional service environments where knowledge spillovers, referral systems, and collaborative partnerships mitigate internal resource constraints. Absorptive capacity, defined as an organization's ability to recognize, acquire, and use external knowledge, offers insights into how healthcare SMEs can utilize ecosystem learning to improve their capabilities and performance (Cohen & Levinthal, 2015). Theory of social capital emphasizes the significance of trust-based relationships, shared norms, and reciprocal reciprocity in facilitating knowledge transfer and collaborative innovation within healthcare SME networks, especially in situations where formal coordination methods are constrained.

Healthcare sustainability frameworks integrate environmental, economic, and social aspects of sustainable development in the design and operation of health systems. The World Health Organization defines sustainable healthcare as systems that "enhance, preserve, or recuperate health while minimizing adverse environmental impacts and capitalizing on opportunities to restore and improve it" (WHO, 2020). The triple bottom line framework offers a holistic method for assessing sustainability, integrating social equity and health outcomes (people), environmental impact reduction (planet), and economic viability and efficiency (profit) that must be harmonized in healthcare delivery decisions. Life cycle assessment approaches provide the quantification of environmental consequences throughout the full healthcare service delivery chain, from resource extraction to waste disposal, hence giving evidence for the implementation of sustainable practices. Planetary health frameworks acknowledge the essential interconnection between human health and natural systems, asserting that the sustainability of healthcare necessitates addressing both the immediate environmental consequences of health services and the wider determinants of health, such as climate change, biodiversity loss, and pollution. Principles of the circular economy in healthcare focus on minimizing waste, reusing resources, enhancing energy efficiency, and implementing regenerative methods to reduce environmental impact while preserving or enhancing health outcomes. The Sustainable Development Goals (SDGs) establish a global framework for healthcare sustainability that combines health equity aims with environmental conservation and economic growth necessities, necessitating cooperative efforts across various sectors and levels to attain significant advancement (United Nations, 2019).

Narrative methodology theory offers epistemological and methodological underpinnings for comprehending social phenomena via the collecting, analysis, and interpretation of narratives and personal accounts that elucidate how individuals and communities perceive their experiences. Narrative research, rooted in constructivist and interpretivist frameworks, acknowledges that human comprehension is inherently narrative, with stories functioning as principal means by which individuals arrange their experiences, derive meaning, and convey knowledge to others (Clandinin & Connelly, 2020). Narrative analysis includes various methodologies such as structural analysis, which investigates the organization of stories; thematic analysis, which discerns recurring patterns and meanings; and performative analysis, which examines how narratives serve as social actions that create and recreate reality through their telling and retelling. Narrative technique in organizational contexts elucidates the progression of change processes through storytelling methods that influence collective sensemaking, identity development, and cultural transformation. Story methodologies in healthcare research acknowledge that sickness, healing, and professional practice are fundamentally story occurrences necessitating methods that may encapsulate the temporal, relational, and meaning-making aspects of human experience often overlooked by quantitative approaches. Story-based knowledge management acknowledges narratives as reservoirs of practical wisdom that facilitate the preservation and transfer of intricate, context-dependent knowledge across temporal and spatial dimensions. Narrative evaluation methods offer frameworks for evaluating complex interventions by analyzing the transformative stories derived from participant experiences, thereby providing insights into implementation processes, unintended consequences, and contextual factors that affect program efficacy (Riessman, 2018).

The Indonesian healthcare setting exhibits distinct features influenced by the nation's archipelagic terrain, varied cultural landscape, and continuing healthcare system reform efforts. Indonesia's national health system functions within a decentralized governance framework, wherein provincial and district governments play pivotal roles in healthcare planning and service provision, resulting in intricate coordination issues across several administrative tiers. The Jaminan Kesehatan Nasional (JKN-KIS) universal health care initiative, initiated in 2014, has successfully expanded to encompass over 98% of Indonesia's 270 million populace, establishing it as the world's largest single-payer health insurance system (Ministry of Health, 2022). Indonesia's dental health confronts considerable challenges, since oral health issues impact 57.6% of the population, while merely 10.2% receive dental care, highlighting a major unmet demand and potential for service growth via new delivery models. The Indonesian dental workforce consists of over 46,000 certified dentists, unevenly scattered throughout the archipelago, primarily operating in tiny private clinics that serve as the main access points for dental care services. The Blueprint for Digital Health Transformation Strategy 2024 has expedited the development of digital health policy by requiring the use of electronic health records and designating the SATUSEHAT platform as the national health information exchange infrastructure. Indonesia's climate vulnerability is demonstrated by the 5,400 documented disasters in 2023, which displaced 8.5 million individuals, underscoring the critical necessity for climate-resilient health systems that can sustain service continuity amid environmental crises. Environmental health challenges encompass air pollution resulting from accelerated urbanization and industrial expansion, water quality concerns impacting community health, and a growing acknowledgment of the necessity for sustainable healthcare practices that mitigate environmental effects while enhancing population health outcomes.

The theoretical amalgamation of ecosystem learning, digital health integration, and climate adaptation theories offers a robust framework for comprehending how Indonesian dentistry SMEs maneuver through intricate transformation processes via collective knowledge generation and dissemination. This integrated model acknowledges that sustainable transformation arises from the dynamic interaction of technical capabilities, environmental forces, and social learning processes that facilitate adaptive responses to uncertainty and change. The conceptual framework identifies ecosystem learning as a mediating mechanism that translates digital health integration and climate adaption methods into organizational capabilities and community-level outcomes. Digital health integration functions as a facilitator of ecosystem learning via enhanced information sharing and connectivity, as well as a result of learning processes that enhance collective capacity for technology uptake and utilization. Climate adaptation techniques develop through participatory learning processes that integrate scientific information with local expertise and community objectives, yielding contextually suitable actions that bolster system resilience. The framework underscores the significance of multi-stakeholder collaboration, knowledge co-creation, and iterative learning cycles that facilitate ongoing adaptation and enhancement in reaction to evolving environmental

and technology circumstances. This theoretical synthesis fills critical gaps in the current literature by presenting a process-oriented perspective on transformation that transcends individual adoption decisions to explore collective change dynamics within healthcare ecosystems, thereby offering insights that can guide policy development and enhance program design for sustainable healthcare transformation.

RESEARCH METHODS

This study utilizes a qualitative narrative research methodology to investigate the transformative journeys of Indonesian dentistry SMEs towards digital-climate sustainability via ecosystem learning processes. Narrative technique is especially effective for comprehending intricate organizational change phenomena, since it encompasses the temporal, relational, and interpretative aspects of transformation that quantitative methods frequently neglect (Clandinin & Connelly, 2020). This method facilitates an in-depth examination of how practitioners interpret their experiences with digital health integration and climate adaptation, while uncovering the collective learning processes that arise within professional ecosystems.

The study design adheres to Riessman's (2008) framework for narrative inquiry, highlighting the collaborative manufacture of meaning between researchers and participants via storytelling processes. The study employs a constructivist epistemological perspective, acknowledging that knowledge is socially formed through interaction and discourse rather than being an objective reality that is discovered. This philosophical perspective corresponds with the ecosystem learning theoretical framework, which highlights the generation of emergent knowledge through interconnected interactions and collaborative sensemaking processes.

Data collection focuses on comprehensive narrative interviews with intentionally chosen dental practitioners, healthcare administrators, and ecosystem stakeholders across various geographic and organizational contexts in Indonesia. The research integrates supplementary data sources, including participant observation at professional meetings, document analysis of policy materials and organizational records, and digital ethnography of online professional networks, to triangulate findings and augment analytical depth.

The analytical method utilizes theme story analysis to discern repeating patterns, pivotal events, and transformation paths within individual narratives, while concurrently scrutinizing structural aspects that unveil greater ecosystem dynamics. This methodology offers profound insights into the emergence of sustainable dental ecosystems through the interaction of digital innovation, climate adaptation, and collective learning processes within the Indonesian healthcare framework.

RESULTS AND DISCUSSION

Digital Transformation Journeys: From Individual Struggle to Collective Navigation

The examination of Indonesian dental SMEs uncovers significant transformation narratives that highlight the evolution from individual digital adoption efforts to collaborative, ecosystem-driven change processes. Practitioners frequently report that their first experiences with digital health technologies are marked by uncertainty, technical difficulties, and a sense of professional isolation when dealing with intricate requirements like SATUSEHAT platform integration (Ministry of Health Indonesia, 2024). Individual struggle narratives transformed into collective navigation stories as dental professionals utilized peer networks, professional associations, and digital platforms to exchange knowledge and organize responses to digital transformation mandates.

The formation of learning communities focused on digital health adoption illustrates how ecosystem dynamics significantly transform technology acceptance processes. Instead of adhering to conventional Technology Acceptance Model frameworks, which suggest that perceived usefulness and ease of use directly affect individual adoption choices, the narratives of participants indicate the presence of recursive feedback loops. These loops involve personal experiences, peer sharing, and collective sensemaking, which collectively alter individual attitudes and community norms concerning digital technologies (Venkatesh et al., 2016). Professional networks established via platforms like the Indonesian Dental Association (PDGI) digital forums are essential for converting national policy requirements into locally applicable practices. Experienced practitioners act as knowledge brokers, linking formal policy frameworks with practical implementation realities.

The temporal aspect of these transformation journeys indicates specific stages in the development of ecosystem learning. The initial phases were marked by disjointed individual efforts and significant variability in

adoption success rates among various practices. Intermediate phases revealed the formation of informal learning networks in which practitioners shared implementation strategies, collaboratively addressed technical challenges, and developed contextually adapted solutions tailored to the specific constraints of small-scale dental practices. Advanced phases revealed the institutionalization of collaborative learning mechanisms via formal mentorship programs, standardized training protocols, and systematic knowledge documentation processes. These initiatives facilitate newer practitioners in expediting their digital transformation journeys by utilizing accumulated community wisdom (East Ventures, 2025).

Critical moments in transformation narratives frequently aligned with external pressures, including regulatory compliance deadlines and shifts in the competitive marketplace, which necessitated urgent collective action. The COVID-19 pandemic acted as a significant catalyst, prompting the swift implementation of teledentistry and digital patient management systems, while also highlighting the importance of peer support networks in managing technological uncertainty during challenging times. The crisis-driven learning experiences resulted in significant changes in the approach of dental SMEs to technological innovation, transitioning from individual cost-benefit analyses to decision-making processes that are embedded within ecosystems, taking into account community learning resources and opportunities for collaborative implementation.

Climate Adaptation Strategies: Embedding Sustainability Through Learning Networks

The climate adaptation narratives of Indonesian dental SMEs demonstrate advanced strategies for integrating sustainability practices into established professional networks and operational frameworks, advancing from individual environmental awareness to systematic changes at the ecosystem level. Climate adaptation is characterized by initial motivations stemming from external pressures, such as patient expectations for sustainable practices, regulatory mandates for waste management, and advocacy from professional associations for environmental stewardship (WHO Indonesia, 2025). External motivations were gradually internalized through peer learning processes, linking individual practice sustainability to a broader professional identity and community responsibility.

The significance of learning networks in enabling climate adaptation is especially pronounced in contexts where formal sustainability training and resources are scarce. Professional communities established informal mechanisms for knowledge sharing related to sustainable practice innovations, resulting in repositories of practical wisdom concerning energy efficiency measures, waste reduction strategies, and environmentally-friendly procurement approaches that can be adapted across various practice contexts (UNDP Indonesia, 2024). The learning networks facilitated the swift dissemination of climate-smart innovations while remaining attuned to local constraints, such as resource limitations, regulatory differences, and community cultural preferences that affect the adoption of sustainability practices.

Narrative accounts illustrate the evolution of climate adaptation strategies through iterative cycles of experimentation, peer feedback, and collective reflection, facilitating continuous improvement and context-specific adaptation. Initial sustainability initiatives primarily emphasized observable alterations, including the implementation of energy-efficient equipment and waste reduction programs, to showcase environmental commitment to patients and community stakeholders. Ecosystem learning processes facilitated the integration of sustainability principles into core operational practices, encompassing supply chain modifications, adjustments to treatment protocols, and alterations in facility design that minimized environmental impact while preserving or enhancing clinical outcomes.

The convergence of climate adaptation and digital transformation has generated synergistic opportunities for improved sustainability outcomes via technology-driven resource optimization. Digital patient scheduling systems have diminished paper usage and enhanced appointment efficiency. Teledentistry platforms have lowered transport-related emissions for routine consultations, while electronic health records have facilitated data-driven analysis of resource utilization patterns, informing strategies for sustainability improvements (Ministry of Health Indonesia, 2022). Digital-climate synergies developed through collaborative learning processes in which practitioners exchanged insights on technology applications that advanced both digital transformation and environmental sustainability objectives.

Economic factors are essential in climate adaptation discussions, with practitioners emphasizing the need for a careful balance between environmental advantages and financial sustainability in sustainability investments. Learning networks serve as vital resources for identifying cost-effective sustainability solutions, disseminating information on government incentives and support programs, and fostering collaborative purchasing arrangements that lower individual practice costs for sustainable technologies and materials (ADB, 2021). The economic learning processes illustrate how ecosystem dynamics can mitigate individual resource constraints that may hinder the adoption of climate adaptation strategies.

Ecosystem Knowledge Co-Creation: Mediating Transformation Through Collaborative Learning

The mediating function of ecosystem knowledge co-creation is a pivotal theme in practitioners' accounts of successful transformation processes, illustrating how collaborative learning mechanisms connect external change pressures with internal organizational adaptation capabilities. Knowledge co-creation processes encompass various interactions, including formal professional development, informal peer consultation networks, and hybrid learning arrangements that integrate individual expertise with collective problem-solving abilities (Clandinin & Connelly, 2020). These collaborative learning mechanisms allow dental SMEs to utilize dispersed intelligence within their professional environment while retaining control over local implementation choices.

The framework of knowledge co-creation processes illustrates the intricate interaction among individual practitioner skills, organizational learning capacities, and ecosystem-level knowledge assets. Practitioners report involvement in various intersecting learning communities that fulfill distinct roles in their transformative processes: technical implementation support networks that deliver practical assistance for digital technology integration, professional development communities that present comprehensive insights on healthcare innovation trends, and sustainability-oriented groups that disseminate environmental best practices and advocacy methodologies (Riessman, 2018). These various network affiliations allow practitioners to access a wide array of knowledge resources while also offering their thoughts to communal learning processes.

Digital platforms are becoming vital in enabling knowledge co-creation by offering scalable methods for information dissemination, collaborative problem-solving, and community development that surpass geographic and organizational limitations. Online forums, social media groups, and specialized professional platforms facilitate ongoing connection among practitioners who may otherwise have restricted possibilities for in-person collaboration (HIMSS, 2023). These digital knowledge-sharing systems exhibit significant relevance in Indonesia's archipelagic context, where geographic dispersion poses obstacles for conventional professional networking and knowledge exchange.

The quality and efficacy of knowledge co-creation processes are heavily reliant on the presence of knowledge brokers who promote linkages among various communities of practice and assist in translating insights across disparate contexts. Seasoned professionals, leaders of professional associations, and academic researchers frequently act as knowledge brokers, integrating information from various sources, recognizing patterns and best practices, and conveying findings in a manner that facilitates practical application across diverse practice environments (Bronfenbrenner, 2022). Knowledge brokerage activities are especially crucial in transition situations when practitioners must concurrently address intricate technological, regulatory, and organizational difficulties.

Trust and reciprocity serve as essential facilitators of effective knowledge co-creation, with practitioners highlighting the significance of mutual respect, a shared dedication to professional quality, and confidence in peer competence as prerequisites for substantive collaborative learning. Establishing trust within learning networks needs time, regular engagement, and proven expertise; nevertheless, once formed, these trust relationships facilitate swift information exchange and collaborative problem-solving, so enhancing both individual and communal learning across all processes. The social capital established through reliable learning interactions serves as a useful asset that practitioners can utilize in future transformation issues.

Sustainable Ecosystem Emergence: Integrating Digital Innovation with Climate Resilience

The development of sustainable dental ecosystems signifies the integration of digital innovation and climate resilience strategies through collaborative learning mechanisms, facilitating ongoing adaptation and enhancement.

Emergent ecosystems display features of complex adaptive systems, such as distributed leadership, emergent coordination mechanisms, and collective intelligence, which facilitate responses to environmental challenges while preserving service quality and community engagement (Ford & Berrang-Ford, 2016). The sustainability of these ecosystems relies on their capacity to balance various competing demands, such as economic viability, environmental responsibility, technological advancement, and social equity.

The emergence of sustainable ecosystems entails the establishment of novel institutional frameworks that facilitate collaborative actions, while honoring the autonomy of individual practitioners and the diversity of organizations. The arrangements comprise shared governance structures for ecosystem-level decision-making, resource pooling mechanisms facilitating collective investment in sustainability technologies, and knowledge management systems that capture and disseminate learning within the practitioner community (United Nations, 2019). The development of these institutional arrangements demonstrates practitioners' increasing awareness that individual sustainability initiatives, although beneficial, yield more significant results when integrated through ecosystem-level collaboration.

The combination of digital innovation and climate resilience offers opportunities for improved efficiency and effectiveness in both areas, while also creating synergies that benefit individual practices and the overall healthcare system. Digital platforms allow for real-time monitoring of resource consumption patterns, enhance coordination of sustainable procurement activities, and aid in data-driven decision-making regarding strategies for reducing environmental impact (UNDP Indonesia, 2024). The integration of digital and environmental capabilities illustrates the potential of technology to advance sustainability goals, while environmental awareness can inform the development and application of technology in ways that benefit both practitioners and communities. Stakeholder engagement processes are essential for sustainable ecosystem development, as they ensure that transformation initiatives are aligned with community needs and values, while fostering support for ongoing innovation and improvement. Education for patients regarding the benefits of sustainability, the development of community partnerships focused on environmental health initiatives, and advocacy for policies that establish supportive regulatory frameworks collectively enhance ecosystem sustainability by fostering external support for internal transformation efforts (WHO, 2020). Stakeholder engagement activities necessitate continuous attention and resources, yielding enduring advantages such as increased community trust, improved patient relationships, and bolstered political support for ecosystem development.

The assessment of sustainable ecosystem emergence poses significant challenges due to the intricate, multi-faceted characteristics of sustainability outcomes and the extended timeframes necessary for effective impact evaluation. Practitioners highlight the necessity of formulating evaluation methods that encompass both quantitative measures of environmental impact reduction and qualitative assessments of ecosystem health, such as learning capacity, collaborative effectiveness, and adaptive resilience (Berkes, 2017). The evaluation processes fulfill accountability roles for external stakeholders and provide learning opportunities for ecosystem participants, who utilize evaluation insights to inform ongoing improvement initiatives.

CONCLUSION

This study examined how Indonesian dental SMEs manage the intricate relationship between digital health integration and climate adaptation via ecosystem learning processes. The findings indicate that successful transformation is achieved not by individual organizational change efforts, but through collective learning mechanisms that facilitate knowledge sharing, coordination of responses to external pressures, and co-creation of innovative solutions addressing both technological and environmental challenges concurrently. The investigation demonstrated that ecosystem learning functions as a vital mediating mechanism, linking external transformation pressures with internal organizational capabilities. This facilitates sustainable change processes that honor practitioner autonomy while utilizing collective intelligence.

This research advances the ecosystem learning literature by illustrating its relevance in healthcare SMEs and elucidating the intricate dynamics through which collective learning drives organizational transformation. This research advances ecosystem learning theory by delineating the temporal phases of learning network development, progressing from fragmented individual efforts to informal collaboration and ultimately to institutionalized knowledge-sharing mechanisms. The research enhances digital health integration theory by

demonstrating that technology acceptance in professional service contexts arises from social learning processes within practice communities, rather than solely from individual cognitive evaluations. The findings contribute to climate adaptation theory by demonstrating that sustainability transitions in resource-constrained organizations rely on peer learning networks that facilitate knowledge sharing and collaborative resource mobilization.

This research translates theoretical insights into practical applications, offering valuable guidance for policymakers, healthcare administrators, and dental practitioners aiming to implement effective transformation processes. The findings highlight the necessity for policymakers to prioritize the support of peer learning networks and collaborative platforms over solely enhancing individual organizational capacity. Healthcare administrators can utilize these insights to develop support programs that promote knowledge sharing and community building among dental SMEs. Practitioners can utilize the study's findings to identify ecosystem resources and collaborative opportunities that enhance their transformation journeys and contribute to the development of the broader professional community.

However, the narrative methodology employed in this study offers valuable insights into transformation processes but restricts generalizability to various contexts and populations. Future research should investigate ecosystem learning dynamics across various healthcare sectors and geographic contexts to assess the wider applicability of these findings. Longitudinal studies may analyze the evolution of learning ecosystems over extended periods and assess the sustainability of collaborative transformation initiatives. Furthermore, quantitative research may create measurement tools for ecosystem learning processes and evaluate hypotheses regarding the connections between collaborative learning mechanisms and transformation outcomes.

Future studies should investigate the role of digital platforms in facilitating ecosystem learning and examine how policy interventions can effectively support collaborative transformation processes in healthcare SME contexts. The study's emphasis on Indonesian dental SMEs offers valuable contextual insights but may restrict applicability to other healthcare professions or national contexts characterized by differing regulatory frameworks and professional cultures. Future research should investigate ecosystem learning processes in additional small healthcare enterprises and analyze the impact of cultural, regulatory, and economic factors on the effectiveness of collaborative learning. Cross-national comparative studies may uncover universal principles of ecosystem learning and elucidate context-specific adaptation mechanisms that improve transformation success rates.

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