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Dear “e-mentor” readers,

I am pleased to share with you the latest collection of papers. The topics covered in this issue are related to trends in education and trends in management. Readers interested in educational trends can explore how the latest technologies are transforming teaching, learning and institutional development. This section contains articles addressing various digital innovation applications, including blockchain and cryptoasset initiatives at Polish higher education institutions, the potential of the Metaverse to enhance educational quality, and the integration of augmented reality in active learning in higher and secondary education. Finally, readers are invited to consider the practical factors that facilitate smart education in the digital age.

The section on management trends covers the impact of digital tools, leadership, and human capital on organisational development. Readers will learn how natural language processing is adopted in HR practice through the lens of the Technology Acceptance Model and how employee commitment and Total Quality Management mediate the relationship between leadership styles and innovation. The section concludes with a conceptual overview of integrating human capital management with ambidextrous business process management.

I hope you will enjoy exploring this issue. At the same time, I would like to cordially invite you to contribute to “e-mentor”. Following the successful completion of the project financed by the Polish Ministry of Science and Higher Education (RCN/SP/0361/2021/1) in October 2024, we are expanding our collaboration with various organisers of academic events in order to internationalise the journal. You can find out more about the conferences in the ‘We recommend’ section.

Furthermore, we have redefined the scope of the journal, focusing on **higher education in management and economics**. Our goal is to make “e-mentor” a journal that serves as a forum for the presentation and discussion of research and ideas related to teaching and learning in management and economics higher education. We aim to provide a platform for the exchange of knowledge and insights on the use of technology in education, including e-learning, forms and methods of education, the verification of learning effects, and the integration of new trends in management and economics into higher education.

“E-mentor” is an open-access journal available free of charge, both online and in printed form. All scientific papers are peer-reviewed and we provide free proofreading of papers accepted for publication. Every article gets an individual DOI registered in Crossref, and the journal is indexed in several global databases, including Web of Science ESCI and EBSCO. There is **no publishing fee for the authors**. Further details are available online at http://www.e-mentor.edu.pl/eng/page/8/Info_for_Authors. Should you have any questions concerning publications in “e-mentor”, please contact the editorial team at redakcja@e-mentor.edu.pl.

Małgorzata Marchewka
Editor

We recommend

ICABM2026 – International Conference on Applied Business and Management, June 25–26, 2026, Porto (Portugal) and online

The 6th edition of the International Conference on Applied Business and Management (ICABM2026) will take place at ISAG – European Business School, in Porto, Portugal, in collaboration with the Research Center in Business Sciences and Tourism (CICET–FCVC). ICABM2026 provides a dynamic forum for researchers, practitioners, and students to share insights, present cutting-edge research, and discuss the latest trends in applied business and management.

More information at: **https://icabm26.isag.pt**

”E-mentor” is one of the Conference supporting journals.

Krzysztof Piech

Blockchain and Cryptoasset Initiatives at Polish Higher Education Institutions: A Structured Inventory and Selected Case Studies

Abstract

This paper documents and analyses the evolution of blockchain- and cryptoasset-related initiatives in Polish higher education institutions (HEIs) over the period 2012–2025. It contributes (i) a structured inventory of sustained, institutionally anchored initiatives (Appendix A) and (ii) harmonised case studies selected using a transparent selection criteria emphasising recurrence, organisational anchoring, stakeholder breadth, and traceability. The scope covers education (degree programmes, postgraduate studies, courses), research groups and projects, recurring academic–industry events, and selected implementation-oriented deployments (notably digital credentials and micro-credentials). Empirically, the Polish trajectory shows an early grassroots wave (2013–2014), a mid-2010s phase of institutionalisation centred on recurring conferences and research groups, and a post-2018 expansion into curricula and implementation-driven initiatives, including micro-credentials supported by distributed ledger technology (DLT). Methodologically, the study combines open-source evidence (official HEI pages, public catalogues, conference materials) with curated documentary archives provided by the author (agendas, archived PDFs, correspondence) when public records are incomplete; vendor-reported information is treated as stakeholder evidence and explicitly flagged. The findings clarify the main channels through which blockchain-related knowledge and practices diffused into Polish academia and identify gaps relevant for research policy and academic–industry collaboration.

Keywords: Blockchain, cryptoassets, higher education, Poland, digital credentials, micro-credentials, industry–academia collaboration, case study

Introduction

Blockchain and cryptoasset-related topics entered higher education through multiple channels: grassroots communities, cryptography and distributed-systems research, dedicated curricula, and implementation-oriented credentialing solutions (digital diplomas, micro-credentials). In Poland, these channels developed in parallel, often at the boundary between academia and industry, yet the record remains fragmented across websites, student-organisation archives, and dispersed documentary traces. This fragmentation matters: higher education is not only a training pipeline for the labour market, but also a key intermediary that translates emerging technologies into standards, institutional practices, and policy-relevant expertise.

This paper documents and analyses the development of blockchain- and cryptoasset-related initiatives at Polish higher education institutions (HEIs) and adjacent HEI-anchored structures. It offers two contributions. First, it compiles a structured, verifiable inventory (Appendix A) of sustained initiatives. Second, it provides a set of harmonised case studies of the most sustained and/or institutionally significant initiatives, including recurring academic–industry conferences, a national postgraduate programme, early Bitcoin seminar series, an international Olympiad in its Polish editions, and selected R&D/implementation-oriented projects.

The study addresses three practical questions: (1) what types of blockchain/crypto initiatives became institutionally anchored in Polish HEIs, (2) when and through which

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waves these initiatives emerged (from early grassroots activity to later curricular and implementation-driven developments), and (3) which mechanisms of academia–industry interaction were most visible in the Polish case. The analysis is intentionally limited to documented evidence: one-off events are excluded unless they formed part of a documented series, and vendor disclosures are treated as stakeholder evidence rather than independent confirmation. The paper is organised as follows: the next section provides a brief international context (with emphasis on credentials and EU reference architectures), and the next ones: explains data and methods, summarises the observed pattern at a high level, presents case studies, and discusses implications and limitations; the Appendix provides the inventory table.

Background and International Context

Prior research discusses blockchain applications in education, including credentialing and credit/record infrastructures, while also highlighting the gap between prototypes and institutionally embedded deployments (Alammary et al., 2019; Turkanović et al., 2018). Early policy-oriented mappings of "blockchain in education" framed the topic primarily through credentialing and administrative use cases (Grech & Camilleri, 2017). Survey-based evidence from Poland discusses micro-credentials as an instrument in academic education and provides contextual signals on adoption and perceived value (Zalewska, 2025).

Internationally, HEIs have engaged with blockchain and related distributed-ledger technologies (DLTs) along three main lines.

First, the most visible and operationally mature strand concerns digital credentialing: issuing and verifying diplomas, certificates, and, increasingly, micro-credentials. The policy rationale is to enable portable, tamper-evident proofs of learning outcomes that can be verified independently, without repeated manual confirmation by the issuing institution. In the European context, micro-credentials have been explicitly framed as an instrument supporting lifelong learning, upskilling, and cross-border recognition, with implementation encouraged through common definitions and quality-related principles (European Commission, 2022). This policy stream aligns naturally with the broader European agenda on verifiable digital credentials and interoperability standards (Jones et al., 2026).

Second, a substantial share of academic activity remains anchored in cryptography and distributed systems research, where blockchain-related questions appear as extensions of long-standing research programmes (e.g., consensus mechanisms, smart-contract security, privacy-preserving protocols). In practice, many "blockchain" research outputs in HEIs emerge from cryptography groups rather than from newly created "blockchain centres", which matters methodologically when mapping initiatives: the same institutional node can generate blockchain-relevant work under broader cryptographic or security umbrellas.

Third, HEI engagement often materialises through recurring academic–industry events (conferences, forums, seminar series), which function both as knowledge-transfer mechanisms and as coordination points between researchers, regulators, and market actors. These events frequently predate formal degree programmes and can act as "institutional catalysts", shaping curricula and partnerships over time.

Within the EU, the European Blockchain Services Infrastructure (EBSI) is relevant as a policy-driven reference architecture for cross-border public services and credential-related use cases. Even when national initiatives do not directly build on EBSI, it provides a shared vocabulary for public-sector credentialing and an interoperability benchmark that influences how HEIs and vendors conceptualise verifiable credentials in education (European Commission, n.d.; Jones et al., 2026). In this paper, the international context is used primarily to motivate the inclusion of credentialing and standards-related implementations in the Polish inventory, rather than to provide a comparative evaluation of outcomes across countries.

Data and Methodology

Initiatives were identified and validated using four evidence streams: (a) official HEI websites and programme pages (including course catalogues where available), (b) conference websites and archived agendas/programmes, (c) public communications of student organisations and university-affiliated lists, and (d) archived documentary materials held by the author (PDFs, emails, agendas, and internal reports) used only where public traces were incomplete.

The inventory is intentionally conservative. Items are included only if they show institutional anchoring (e.g., a university unit, programme, formally affiliated organisation, or documented deployment) and traceability (a public record and/or auditable documentary evidence). One-off events (single lectures, isolated debates) are excluded unless they are part of a documented series with durable outputs.

For the recurring conference series, the evidence base relies on archived agendas, announcements and concept notes from the Digital Money Forum / Digital Money and Crypto/Blockchain Forum / Digital Money and Blockchain Forum series, which have not been published.

Evidence is coded as public record and/or archived documentation; items without a verifiable trace are not included. Approximate dates are explicitly flagged in the narrative rather than presented as exact.

Vendor-provided information (e.g., credentialing platforms) is treated as stakeholder evidence rather than independent confirmation. Such claims are included only when (i) at least partial institutional corroboration exists, or (ii) they are explicitly labelled as vendor-reported and discussed under stated limitations (e.g., disclosure constraints, missing implementation dates). Case studies are selected using a set of criteria emphasising (i) longevity/recurrence, (ii) institutional anchoring, (iii) multi-stakeholder involvement, and (iv) documentary traceability.

In addition, the study uses a limited body of primary qualitative evidence in the form of semi-structured expert interviews. Two interviews were selected ex ante due to their direct relevance to higher-education initiatives analysed in the paper and their strong institutional anchoring. Interview-derived statements are used strictly as corroboration and are triangulated; the study does not claim representativeness.

Two limitations follow from this design: (1) the mapping undercounts initiatives that leave weak public traces, and (2) the evidence base is heterogeneous. The source-register approach mitigates this by making traceability explicit, but it does not eliminate omissions due to documentation gaps.

Results Overview

As explained in the next section, the inventory is conservative and includes only initiatives with institutional anchoring and an auditable trace; therefore, temporal claims are interpreted cautiously and are corroborated in the case-study narratives where documentary evidence is strongest.

The inventory suggests a qualitative, multi-wave trajectory. First, an early grassroots and seminar phase (2013–2014) established visible interfaces between academia and emerging crypto communities. Second, the mid-2010s show consolidation around recurring conferences and research-group activity. Third, after 2018 the landscape expands toward structured education (notably postgraduate and degree-level programmes) and implementation-driven initiatives, including DLT-supported credentialing and micro-credentials. While Appendix A enables a timeline-style reading, date granularity varies across items; accordingly, the discussion prioritises traceability over completeness.

Case Studies

Case studies are reported using a harmonised template covering: (a) origin and timeline; (b) organisational anchoring; (c) scope and outputs; (d) stakeholders and partnerships; (e) evidence base; (f) assessment (what was novel; what scaled; what did not).

Case: Early Bitcoin Seminars at the Warsaw School of Economics (SGH), 2013–2014

Early Bitcoin seminars hosted at the Warsaw School of Economics (SGH) in 2013–2014 are included as a case because they constitute one of the earliest repeatable, university-anchored formats through which cryptoasset-related knowledge was mobilised in Poland. Unlike isolated guest lectures, the SGH initiative is treated here as a traceable seminar sequence that combined academic framing with practitioner and policy-facing discussion at a moment when institutional adoption and regulatory narratives were still nascent.

The case is anchored in three elements: (i) a large open seminar held at SGH on 18 December 2013, and (ii) subsequent follow-up seminars in spring 2014 responding to major credibility and security shocks in the global Bitcoin ecosystem, and (iii) documented involvement of student and academic organisers that connected SGH with adjacent academic networks.

Analytically, the SGH seminars represent an early diffusion mechanism that is different from later, more formalised pathways (postgraduate programmes, credential infrastructures). The seminars operationalised three functions that are relevant for mapping higher-education initiatives:

1. Knowledge mobilisation before institutionalisation: public-facing academic debate created early legitimacy for the topic within a university setting and provided a meeting point for emerging expert communities.
2. Boundary-spanning coordination: the format linked academic discussion with practitioner experience and policy-relevant questions, lowering coordination costs for subsequent educational and professional initiatives.
3. A seedbed for later educational pipelines: seminar-based formats plausibly contributed to the later emergence of structured courses and postgraduate programmes by creating a stable nucleus of organisers, speakers, and repeat participants.

Where the documentary record permits, this case should be treated as the early "grassroots-to-academic-interface" wave in the broader trajectory reconstructed in the next section.

Evidence for the SGH seminar sequence relies on publicly accessible archival traces (e.g., event pages and recordings) and on supplementary documentary materials held in the author's archive where public records are incomplete. A publicly retrievable example is the recorded SGH seminar material published by the SGH-affiliated channel (Bitcoin Club SGH, 2014). The limitations are non-trivial: counts of participants, full programmes, and organiser lists are not consistently preserved in public university repositories, and some claims (including specific inter-university cooperation roles) may require reliance on archived materials and correspondence. Accordingly, this case is used to confirm event occurrence, timing, and institutional anchoring, while avoiding over-precise claims about impact or adoption outcomes.

Digital Money & Blockchain Forum

Digital Money & Blockchain Forum (2014–2026) (DM&BF) represents a rare, long-running and institutionally anchored academic–industry forum focused on blockchain- and cryptoasset-related issues in Poland. Unlike many short-lived events, DM&BF constitutes a recurring coordination mechanism linking higher education, industry practitioners, regulators, and policy-oriented experts over more than a decade.

This longevity and continuity make it analytically suitable for tracing how blockchain-related discourse and expertise diffused into the Polish higher education ecosystem.

The series originated in the mid-2010s under the broader "digital money" framing and gradually evolved into a forum explicitly centred on blockchain and cryptoassets. Over time, DM&BF maintained a stable organisational core while adapting its thematic scope to successive stages of technological and regulatory development. Archival agendas and concept notes confirm continuity of the series across multiple editions from 2014 onwards, with hosting and organisational roles consistently linked to academic institutions and their expert networks.

Across its editions, DM&BF reflects three analytically distinct phases:

1. An exploratory phase focused on defining digital money and early cryptocurrencies, situated at the boundary between academic inquiry and emerging market practice.
2. An expansion phase in which blockchain became a central organising concept, accompanied by growing attention to enterprise use cases, governance, and institutional applications.
3. A maturity phase characterised by regulatory, compliance, and implementation-oriented discussions, including EU-level frameworks, market infrastructure, and operational constraints.

This evolution mirrors broader patterns observed in Polish higher education: early engagement through debate and expertise-building, followed by gradual institutionalisation and closer interaction with regulatory and professional contexts.

For the purposes of this study, DM&BF is not treated as evidence of direct technological adoption within universities, but as an interface institution. It served as a recurring platform for agenda-setting, knowledge exchange, and network formation, reducing coordination costs between academia and non-academic stakeholders. Such hybrid venues appear to have played a demonstrated role in shaping subsequent educational programmes, research agendas, and expert communities.

At the same time, the case has clear limitations. Conference agendas and announcements document thematic continuity and declared objectives but do not allow for systematic assessment of outcomes, such as curriculum change or technology transfer. Accordingly, DM&BF is used here as evidence of sustained institutional attention and coordination, not as a proxy for implementation success.

International Blockchain Olympiad (Poland)

The International Blockchain Olympiad (IBCOL, n.d.) constituted an early, structured mechanism for translating student-led blockchain interest into formalised project-based learning and early research socialisation in Poland. The 2020 Polish edition (IBCOL Poland, n.d.). was coordinated by student organisations affiliated with SGH Warsaw School of Economics, most notably the SGH Blockchain Society, then chaired by Krzysztof Bochenek, under the academic supervision of Dr Wojciech Kurowski. The national coordination process combined open student recruitment, structured whitepaper templates, expert-based project evaluation, and formal academic patronage, including the honorary patronage of the Rector of SGH. The author contributed to the organisational framework, outreach, and institutional liaison, including support for academic patronage and industry sponsorship, while the core operational role remained with SGH-based student and academic actors. This configuration illustrates how student-centred competitive formats functioned as an effective bridge between informal learning communities and formal academic validation, reinforcing educational spillovers later observed in structured blockchain curricula and research initiatives (Bitcoin Club SGH, 2014; Piech, 2026a; 2026b).

DoxyChain: Micro-Credentials and HEI Deployments

DoxyChain (Warsaw, Poland) provides a DLT-based infrastructure for issuing and verifying digital credentials, with micro-credentials as the dominant use case in higher education. The case is included because micro-credentials have become an EU-level policy priority and are directly linked to institutional trust infrastructures (verification, auditability, portability), making them analytically distinct from teaching- and event-centred initiatives mapped elsewhere in this study (European Commission, 2022).

The evidentiary base is deliberately conservative and distinguishes between (i) institution-confirmed public materials and (ii) stakeholder (vendor) disclosures. The vendor provided an authorised list of higher-education partners that consented to public naming, while noting that the overall partner list is incomplete due to confidentiality constraints. According to this disclosure, the publicly nameable HEI deployments include: Jagiellonian University, Kozminski University, Warsaw University of Life Sciences, Poznan University of Technology (including the EUNICE European University consortium), Medical University of Lodz, Medical University of Lublin, Koszalin University of Technology, and the University of Gdańsk (M. Stopierzyński, personal communication, January 13, 2026).

The description is based on publicly available case materials provided by the vendor and treated as stakeholder evidence (DoxyChain, n.d.), complemented by an independent press account of the company's scaling and positioning in the micro-credential segment (MyCompanyPolska, 2025).

For a subset of the disclosed list, the existence of micro-credential initiatives can be corroborated through independently citable institutional webpages and/or publicly shareable materials describing micro-credentials and their verification workflow (e.g., Medical University of Lodz, n.d.). In addition, DoxyChain maintains publicly accessible case descriptions and blog materials that can be cited as stakeholder evidence, but these materials are treated as non-independent and are used only within explicitly stated limits (DoxyChain, n.d.).

In the stakeholder analysis, DLT is presented not as an optional add-on but as a core component of the trust model: issued credentials are anchored in an immutable register enabling third-party verification. Because the vendor did not provide pilot/production dates and because independent auditing of "active status" is not available for all named institutions, the case is used here to demonstrate an HEI-facing implementation pathway (credential verification infrastructure), not to quantify diffusion or to construct a precise implementation timeline (DoxyChain, n.d.; M. Stopierzyński, January 13, 2026, personal communication).

Three constraints are material: (i) the disclosed HEI list is incomplete by design (NDA-bound), (ii) implementation dating is missing, preventing robust temporal placement across institutions, and (iii) vendor materials may be selectively curated; therefore, institution-confirmed public pages are prioritised where available, and all non-corroborated elements are explicitly treated as stakeholder evidence rather than independent confirmation (DoxyChain, n.d.).

SGH Postgraduate Blockchain Programme and the Publication Pipeline (Helion)

The postgraduate blockchain programme at the Warsaw School of Economics (SGH), currently offered under the official title "Studia Podyplomowe Blockchain: Biznes, Prawo, Technologia" ["Postgraduate Studies in Blockchain: Business, Law, Technology"], is included as a case because it represents a fully institutionalised educational pathway linking recurring postgraduate teaching with structured knowledge production. The programme is listed as a blended-format postgraduate course delivered by SGH, with academic leadership attributed to Dr Grzegorz Sobiecki (SGH, n.d. b).

The programme has been delivered in annual cohorts for several years. While earlier editions had operated under different titles, it is treated here as a single institutional trajectory anchored in SGH governance and regular delivery (Piech, 2026a; SGH, n.d. b).

In a published interview, Sobiecki reports that SGH currently delivers three distinct elective courses related to the field (digital money/cryptoassets; blockchain; cryptoasset regulation) and that the postgraduate blockchain programme has been delivered for approximately seven years. These statements are used as corroborative qualitative evidence and are triangulated with institutional listings where available (Piech, 2026a).

A distinctive feature of this case is its linkage to a large, multi-author publication project: the *Kompendium Blockchain* [*Blockchain Compendium*] book series published by Helion. According to the editor's statement and publicly available information, the first volume of the series has been published as the first part of a planned trilogy, with a substantial number of contributors drawn from among alumni of the SGH postgraduate programme, alongside contributors affiliated with other institutions, including Lazarski University (Piech, 2026a; Piech et al., 2025). This configuration illustrates a knowledge-production pipeline in which postgraduate education feeds directly into collective expert publications, reinforcing network effects beyond the host university.

For the purposes of this study, the SGH postgraduate programme exemplifies an institutionalisation channel in which early, seminar-based engagement evolves into a durable educational format, and subsequently into collaborative publishing activity. This mechanism differs both from vendor-mediated infrastructure deployment and from grant-funded applied R&D, highlighting the role of higher education institutions as long-term coordinators of expert communities rather than mere training providers.

The available evidence supports claims about programme continuity, leadership, and its linkage to collective publication, but does not permit quantitative evaluation of learning outcomes or career effects among graduates. Accordingly, the case is used to document institutional continuity and network formation, not to assess educational effectiveness.

iVoting: An R&D Consortium Model Linking Business and Academia

The iVoting project is included as a case because it represents a distinct institutional pathway for blockchain-related capability-building in Polish higher education: a publicly funded R&D consortium in which academic partners contribute specialised knowledge within an industry-led implementation effort. In the mapping logic of this paper, the project is coded not as "education" or "conference activity" but as an implementation-oriented research and development initiative that generated auditable artefacts (project documentation and published outputs) and engaged university-affiliated researchers in an applied setting (Gawlas & Piech, 2025; Smart Cables, 2020–2021).

Institutionally, the consortium is reported to have combined an industry lead (Smart Cables) with academic participation, including researchers affiliated with the Czestochowa University of Technology and contributors associated with Polish Academy of Sciences (PAN), alongside the author's involvement from Lazarski University. The analytical relevance lies in the governance structure typical for public R&D programmes: defined roles, reporting obligations, and deliverables that are, at least in principle, verifiable ex post through programme documentation rather than relying on promotional narratives (Smart Cables, 2020–2021).

From the perspective of higher-education initiatives, iVoting illustrates how blockchain-related competence may be institutionalised via grant-funded applied work that couples academic expertise with procurement- and deployment-oriented constraints. This mechanism differs from seminar-based diffusion and from credential infrastructures supplied by vendors: it creates a bounded, audited environment for experimentation but also introduces dependency on programme rules, procurement feasibility, and the durability of post-grant maintenance. Therefore, the case is used to evidence a research–implementation channel, not to claim broad educational diffusion or national adoption of the underlying voting solution (Gawlas & Piech, 2025; Smart Cables, 2020–2021).

The publicly available record is typically stronger on consortium composition and declared objectives than on comparative performance evaluation. Accordingly, claims about effectiveness should be limited to what can be supported by grant reporting and published outputs; any additional details based on the author's direct involvement should be explicitly labelled as such and separated from independently verifiable sources (Gawlas & Piech, 2025; Smart Cables, 2020–2021).

Discussion

The findings indicate that blockchain-related engagement of Polish higher education institutions has followed a selective and path-dependent trajectory rather than a uniform diffusion pattern. Three channels dominate: (i) institutionally anchored education formats (postgraduate studies and recurring courses), (ii) hybrid academic–industry coordination venues, and (iii) narrowly scoped implementation projects, most visibly in digital credentials and micro-credentials.

Interview-based corroboration strengthens several documentary observations. First, the SGH case confirms that blockchain-related teaching in Poland predates formal regulatory and policy frameworks and evolved incrementally through elective courses before crystallising into a dedicated postgraduate programme. Second, the coupling between postgraduate education and multi-author publications (the *Compendium Blockchain* series) illustrates a knowledge-production mechanism in which higher education functions not only as a training provider but also as a coordination hub for expert communities.

At the same time, the evidence highlights clear constraints. Implementation-oriented initiatives remain rare and vendor-mediated, with limited publicly accessible documentation. This restricts the ability to assess scalability, user adoption, and long-term institutional impact. The dominance of recurring events and education-oriented formats suggests that Polish HEIs have prioritised capability-building and agenda-setting over large-scale operational deployment.

Methodologically, the study confirms a trade-off between coverage and verifiability. By focusing on sustained, institutionally anchored initiatives with auditable traces, the inventory underrepresents short-lived or weakly documented activities. However, this conservative approach improves reproducibility and reduces the risk of overstating diffusion.

The regulatory environment for higher education in Poland does not currently impose specific barriers to blockchain-based educational initiatives, including micro-credentials or digital certification systems. Universities retain substantial autonomy in designing continuing education programmes, postgraduate studies, and pilot implementations of digital credentials. At the same time, quality assurance mechanisms are primarily anchored in institutional accreditation and programme approval procedures rather than in technology-specific regulations. Consequently, blockchain-related initiatives in higher education have emerged mainly through bottom-up experimentation within existing academic structures rather than through dedicated national policy frameworks. This institutional flexibility partly explains the diversity of initiatives documented in this study.

While Polish higher-education institutions enjoy substantial autonomy in launching new educational formats, including postgraduate programmes and pilot digital credential systems, the broader diffusion of blockchain-based academic credentials remains limited by the absence of a coordinated national policy initiative. In recent years, public declarations regarding the introduction of digital diplomas have appeared in the policy discourse, yet they have not translated into a systematic nationwide implementation framework. As a result, most initiatives documented in this study emerged through bottom-up experimentation led by individual universities, research groups, or industry partnerships rather than through central policy programmes. This institutional configuration slows the large-scale adoption of DLT in higher education. At the same time, innovation theory shows that the university-driven innovation can function as an early experimentation layer for technologies that may later diffuse into wider public-sector applications.

Future research should therefore move beyond descriptive mapping towards structured comparative analysis, combining archival reconstruction with targeted interviews at the level of university management and administrative units responsible for digital credentials and curricula design. Such work would allow for systematic assessment of adoption barriers, organisational incentives, and the long-term role of blockchain-based infrastructures in higher education.

Conclusions

This article provides a verifiable mapping of sustained blockchain-related initiatives in Polish higher education. The evidence indicates a shift from early community-driven and seminar-style activity toward recurring hybrid venues and implementation-oriented institutional projects—especially in digital credentials and professional education. The resulting landscape is narrower than the full universe of "blockchain mentions" in academia, but it is more robust: each included initiative has a durable organisational form and an auditable public trace.

The key recommendation is both methodological and managerial: initiatives that matter for institutional learning and national capability are those that recur, formalise responsibility, and publish stable artefacts (agendas, syllabi, repositories, university communications). Strengthening Poland's position in this domain is therefore less about adding more one-off events and more about consolidating durable programmes, interoperable credential infrastructures, and academic–industry channels that generate publicly verifiable outputs.

Funding and Competing Interests

The author declares no external funding specifically allocated to this study. The author has participated in selected initiatives discussed in the paper (e.g., as an organiser, moderator, or academic contributor), and this is explicitly acknowledged where relevant. Information obtained from solution providers is limited to items authorised for public disclosure and is treated as stakeholder evidence, triangulated with independent institutional sources where available.

The appendix is available in the online version of the journal.

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The Metaverse as a Catalyst for Quality Education – Implications and Agenda

Abstract

The emergence of the Metaverse, a virtual reality space that enables users to interact and collaborate, offers a remarkable opportunity to revolutionise higher education. Aligned with the Sustainable Development Goals (SDGs), particularly SDG four of Quality Education, the Metaverse offers a new frontier for Higher Education Institutions (HEIs) to deliver inclusive, accessible, and personalised learning experiences. The purpose of the research at hand was to present the higher education landscape, quality education and implications for the Indian HEIs, highlighting challenges and the required course of action related to employing the Metaverse. This research utilised online databases, online search engines, and search terms including Sustainable Development Goals, NEP 2020, Quality Education, HEIs, Technology, and Metaverse to select relevant websites and scholarly published articles. Further, the results were filtered to the period from 2020 to 2024, and publications related to the Indian context were selected to limit the focus of the research at hand.

All the selected studies highlighted the need for quality education in the context of higher educational institute management towards attaining SDG 4. Different perspectives of various stakeholders, including governance, institutional, communities, educators and learners, concerns were addressed, and the requirements involved included recognising the importance of awareness creation to implementation. This further necessitates monitoring, evaluating, and keeping track of the progress and challenges related to educational reforms. This descriptive research highlights effective ways towards higher education and related challenges. Further use of technology, specifically the Metaverse, to support the edtech sector. This suggestion can be utilised by policymakers and HEIs. In line with related studies on higher education, this study is an incremental step towards understanding the current emphasis on Quality Education and a suggested course for integrating technology.

Keywords: Sustainable Development Goals (SDG), Quality Education, Higher Education Institutions (HEIs), Metaverse, Technology

Introduction

The rapid development of Artificial Intelligence (AI) and Information and Communication Technology (ICT) has radically transformed the way knowledge is imparted (Arsénio et al., 2014). Traditionally, education primarily relied on in-person, one-way communication from educators to students. However, the contemporary educational environment has shifted to a more dynamic, interactive, and technology-driven approach, with students and educators actively engaged in virtual spaces. Adel (2024) asserts that the world is now witnessing the integration of advanced technologies such as Artificial Intelligence (AI), Virtual Assistants (Sharma & Singh, 2021), augmented reality (AR), virtual reality (VR), and the internet of things (IoT) in various sectors, with education being one of the most promising areas for innovation.

Brennan and Schafer (2010) examined the evolving role of technology in education, emphasising how the proliferation of social media, interactive platforms, and online learning tools has embedded technology into everyday life. Building on this perspective, Maree (2017) investigated the intensity of social media use and its implications for learning, highlighting the growing virtualisation of communication and educational processes. Although such technologies have been progressively incorporated into educational practices, the emergence of the Metaverse, a multi-dimensional virtual

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environment that enables real-time interaction, collaboration, and learning, offers an unprecedented potential to transform the teaching and learning process (Ball, 2022).

However, it is important to note that the Metaverse ecosystem is not limited to these large, centralised corporate platforms. A rapidly growing segment comprises decentralised Metaverse environments built on blockchain technology and Web 3.0 principles, including Spatial.io, Decentraland, Victoria VR and Somnium Space (Solea & Prezioso, 2022). These platforms employ non-fungible tokens (NFTs), DAOs and token-based governance models that fundamentally alter ownership and incentive structures in the digital space (Esposito et al., 2025). For education, this distinction is essential; decentralised platforms can enable community-governed virtual campuses and incentivise participation that is structurally inaccessible within centralised corporate Metaverse frameworks.

Overview of the Metaverse and Its Potential in Education

The Metaverse is an immersive virtual reality environment where users can interact with each other and the world around them in ways that extend beyond the physical limitations of the real world (Mystakidis, 2022; Nevelsteen, 2018). The Metaverse is not a single, unified platform but a network of interconnected virtual environments enabled by technologies such as virtual reality (VR), augmented reality (AR), and artificial intelligence (AI). It facilitates real-time interaction and collaboration within simulated spaces, allowing users to engage in experiences that may be impractical or impossible in the physical world. Once regarded as a concept rooted in science fiction, the Metaverse is increasingly becoming a tangible reality, as major technology companies – including Meta (formerly Facebook), Microsoft, and Google – make substantial investments in its development (Atrakchi-Israel & Nahmias, 2023).

In the higher educational context, the Metaverse holds significant potential to deliver immersive, engaging, and personalised learning experiences. It enables learners to explore historical settings by virtually navigating environments such as a Roman marketplace, conduct experiments within fully equipped virtual laboratories, or participate in interactive global discussions on contemporary issues; all without physical constraints. By emphasising experiential learning rather than one-way, passive reading or listening without participation, the Metaverse can enhance student engagement and improve learning effectiveness. Additionally, it supports collaborative learning by enabling students from diverse geographic locations to work together in real time, exchange ideas, and collectively solve problems in shared virtual spaces.

Connection to SDG 4: Quality Education

The transformative potential of the Metaverse in education closely aligns with Sustainable Development Goal (SDG) 4, which aims to ensure inclusive, equitable, and high-quality education while promoting lifelong learning opportunities for all. SDG 4 underscores the importance of expanding access to quality education, particularly in contexts where conventional educational infrastructure is limited or inaccessible. By transcending physical and geographical constraints, the Metaverse offers significant opportunities to advance this objective, enabling broader access to immersive, high-quality educational experiences for learners in remote or underserved regions (Elfert, 2019; Hanemann, 2019; Webb et al., 2017). Goal number 4 is having one of the primary objectives – 'to ensure that all learners acquire the knowledge and skills needed to promote sustainable development.' Al-Emran (2023) asserts that the Metaverse can help achieve this objective by providing learners with opportunities to engage in sustainability-focused simulations and experiential scenarios. For instance, students may participate in virtual field trips to examine the impacts of climate change, engage in role-playing activities to analyse the social consequences of poverty, or explore alternative and renewable energy solutions within controlled virtual environments. Such immersive learning experiences facilitate deeper cognitive and affective engagement, enabling learners to develop a more comprehensive understanding of complex global challenges and to foster competencies that support meaningful contributions to sustainable development.

The Metaverse further advances SDG 4's emphasis on inclusivity by enhancing educational accessibility for individuals with disabilities (Bekaroo, 2024). Virtual learning environments can be designed and customised to accommodate diverse physical, auditory, and visual needs, thereby enabling learners with disabilities to participate more fully and equitably in educational activities. Furthermore, the Metaverse provides a platform for personalised learning, where educational content can be tailored to each student's unique needs and learning styles, ensuring that all learners can achieve their full potential.

SDG targets 4.1, 4.3 and 4.5 specifically address the elimination of educational disparities based on geography, gender and socioeconomic status. Decentralised Metaverse platforms will reduce dependencies on expensive proprietary hardware and may offer more accessible pathways to achieve these targets by lowering the barrier of entry through open-source protocols and community-funded infrastructure. A Web3-based educational environment can serve populations that remain excluded from the centralised Metaverse ecosystem due to costly connectivity constraints (Mystakidis, 2022).

India's aspiration is to become a developed nation – Viksit Bharat – by 2047 (innovateindia.mygov.in 2024). Achieving this target will involve sustained economic growth of around 9 per cent per annum for the next 23 years. This will imply growth on all fronts and will require significant managerial capacity. There is, therefore, likely to be a continuing demand for good managers for at least the next two decades.

Management education trends in India cannot mirror those of the developed world, specifically Cyberthreat Protection.

Research Aim and Objectives

The primary aim of this research is to explore the potential of the Metaverse as a catalyst for quality education, particularly for higher education institutions (HEIs) in India. By examining the current educational landscape and the emerging role of technology in education, this research seeks to identify how the Metaverse can be harnessed to enhance the quality of education in alignment with the goals of SDG 4. This study investigates the implications of integrating the Metaverse into the Indian higher education system, highlighting the challenges, opportunities, and required actions for successful implementation. This study aims to examine the higher education landscape, with a focus on quality education and the implications of guidelines, drawing on instances from Indian Higher Education Institutions (HEIs) in the context of Metaverse adoption. It evaluates prevailing challenges and outlines the necessary strategic actions for effective implementation. Specifically, the study seeks to:

- Assess the status of higher education, with particular attention to educational quality, accessibility, inclusivity, and the impact of specific policy reforms such as the National Education Policy (NEP) 2020 applicable in the case of a developing country like India.
- Examine the potential of the Metaverse to enhance teaching and learning practices in HEIs through immersive, collaborative, and personalised educational experiences, while addressing resource and infrastructure limitations.
- Identify key challenges to Metaverse adoption, including technological readiness, digital literacy, financial constraints, and regulatory and ethical concerns.
- Compiling literature to propose strategies and best practices for successful integration of the Metaverse, emphasising infrastructure development, faculty training, and supportive policy frameworks.
- Highlighting the critical role of each of the key stakeholders, e.g. educators, students, policymakers, and technology, in collaboratively advancing inclusive, accessible, and high-quality higher education aligned with SDG 4.

This study adopts a descriptive research design to examine the implications of integrating the Metaverse into higher education institutions. It synthesises evidence from previously published and relevant scholarly literature to present a coherent analysis of the subject. A qualitative research approach is employed to develop an in-depth understanding of the Metaverse's applications in educational practices and its potential to enhance learning outcomes. This methodological approach enables an exploratory examination of emerging educational technologies, with particular emphasis on their benefits, challenges, and practical issues.

This study draws on a systematic review of the literature, policy documents, and case studies to develop a comprehensive understanding of the Metaverse's role in education. Secondary data were collected from peer-reviewed journals, online academic databases, official reports, and white papers published between 2020 and 2024, ensuring relevance to recent technological and educational developments, particularly within the Indian context. Additionally, the study incorporates perspectives from key educational stakeholders, including educators, students, and policymakers, to provide a holistic assessment of the opportunities and challenges associated with Metaverse adoption. This integrative approach strengthens the practical relevance of the findings and offers actionable insights for policymakers and institutional decision-makers.

WEB 3.0 Research Model and Hypothesis

The conceptual framework of this study is grounded in the premise that the Metaverse, as an emerging educational technology, has the potential to enhance the quality of education by fostering greater learner engagement, improving accessibility, and enabling personalised learning experiences. Accordingly, the research model establishes a relationship between the independent variable – the integration of the Metaverse within higher education institutions (HEIs) – and the dependent variable, namely the quality of education.

- The integration of the Metaverse into higher education will lead to more immersive and engaging learning experiences.
- The use of the Metaverse in HEIs will improve access to quality education for students in remote or underserved areas.
- Personalised learning experiences provided by the Metaverse will lead to improved educational outcomes for students with diverse learning needs.
- The successful implementation of the Metaverse will require overcoming technological, financial, and infrastructural challenges within the Indian education system.

The proposed research model also incorporates moderating variables, including technological infrastructure, digital literacy, and institutional readiness, that may influence the relationship between Metaverse integration and educational quality. Examining these moderating factors enables the study to identify the conditions necessary for the effective and sustainable implementation of the Metaverse in higher education institutions. Data collection for this study is primarily based on the analysis of secondary sources, including peer-reviewed journals and academic publications focusing on emerging technologies in education, particularly immersive learning environments such as the Metaverse. In addition, official policy documents and reports related to the

National Education Policy (NEP) 2020 and Sustainable Development Goal (SDG) 4 were reviewed to contextualise educational quality and reform efforts in India. Case examples of institutions that have successfully implemented Metaverse-based learning solutions, both nationally and internationally, were also examined to identify best practices. To complement the secondary data, expert interviews with educators, technologists, and policymakers were conducted to obtain firsthand insights into the opportunities and challenges associated with Metaverse adoption in higher education. This mixed-source approach strengthens the relevance of the findings by grounding them in both empirical evidence and practical perspectives.

A qualitative content analysis was conducted to identify key themes and patterns in the data, focusing on the benefits, implementation challenges, and best practices for the successful adoption of the Metaverse in higher education institutions (HEIs). The analysis categorised findings into key areas, including accessibility, learner engagement, personalisation, and technological infrastructure. Ethical considerations were carefully addressed in this study. As the research primarily relied on secondary data, concerns related to privacy and confidentiality were minimal. For expert interviews, confidentiality was strictly maintained throughout the research process.

Literature Review

The integration of technology in education has gained increasing attention over the past two decades. The emergence of the Metaverse introduces a novel dimension to this discussion. Scholars such as Flagler (2011) emphasise the need for educational practices to evolve through the adoption of digital platforms to enhance student engagement. Similarly, Mangold and Faulds (2009) highlight the growing importance of digital technologies not only as instructional tools but also as mechanisms for developing essential technological literacy among learners. Theoretical frameworks that examine the role of technology in education are crucial for evaluating the educational potential of the Metaverse, as they provide insights into its impact on learning, collaboration, and student engagement. Accordingly, the following sections present key findings on Metaverse integration in education and discuss relevant theoretical perspectives, with specific reference to higher education institutions (HEIs) and Sustainable Development Goal (SDG) 4, which emphasises inclusive and quality education.

Metaverse in Education: An Emerging Paradigm

The Metaverse, defined as an immersive virtual environment that enables real-time interaction and collaboration, has emerged as a promising frontier in educational technology. Its transformative potential lies in its ability to transcend the limitations of traditional physical classrooms by offering expanded, experiential learning opportunities. Within Metaverse-based environments, learners can engage with virtual reconstructions of historical events, conduct sophisticated experiments in simulated laboratories, and collaborate with peers across geographical boundaries. Such immersive settings promote more engaging and personalised learning experiences.

An expanding body of research indicates that the Metaverse can enhance educational outcomes by fostering active learning, collaboration, and critical thinking. Orosz et al. (2015) argue that immersive virtual environments facilitate hands-on learning experiences, thereby improving comprehension and retention of complex concepts. Additionally, the Metaverse supports personalised learning by allowing students to progress at their own pace and focus on areas requiring further development. This adaptability is particularly significant in higher education, where learners exhibit diverse academic backgrounds, learning styles, and competencies.

Orosz et al. (2015) further highlight that virtual environments enable access to customised content, thereby strengthening learner autonomy and engagement. These findings align with Maree (2017), who contends that technology – particularly digital and social platforms – can democratise education by ensuring equitable participation for students from varied backgrounds and locations. However, both studies emphasise the need for thoughtful and strategic integration of digital technologies to mitigate potential challenges, including diminished face-to-face interaction, cognitive overload, and the risk of misinformation.

Despite the growing literature on Metaverse-based education, most scholarly studies confined their analysis to centralised meta platforms, principally those developed and owned by large technology corporations, such as Meta, Microsoft and Roblox. This framing is increasingly recognised as incomplete. Decentralised Metaverse platforms such as Spatial.io, Decentraland, Victoria VR, and Somnium Space operate on fundamentally, different economic and governance model; Spatial.io, for instance enables the creation of free virtual spaces accessible via standard web browsers without requiring high-end, VR hardware, making it particularly relevant for educational institutions in resource constraint environment Victoria VR has developed virtual reality experiences accessible at lower hardware thresholds than many centralised alternatives.

For education, these structural differences carry significant implications. Web3-based education environments can enable learner-owned credentials, community-governed curriculum and a token-based incentive system that rewards participation and achievement. These features address specific SDG4 targets related to equitable access and lifelong learning in ways that proprietary platforms structurally cannot, as their governance and monetisation models prioritise corporate revenue generation over inclusivity.

Another key finding is the potential of the Metaverse to enhance student collaboration (Chen & Huang, 2024; Singh et al., 2024). Traditional classrooms often limit interaction within the confines of a physical space, but the Metaverse allows students to work together in virtual teams, regardless of geographic location. This is particularly relevant in a globalised world where cross-cultural collaboration and communication are essential skills. Orosz et al. (2015) highlight that collaborative learning within virtual environments facilitates the development of essential skills, as learners are required to engage with diverse cultural perspectives and navigate varying social norms while working toward common objectives.

NEP 2020 and Quality Education

The National Education Policy (NEP) 2020, introduced by the Government of India, underscores the need for comprehensive reform in the education sector to make it more inclusive, equitable, and responsive to the demands of the 21st century. A central objective of NEP 2020 is to enhance the quality of education by leveraging technology to improve accessibility, effectiveness, and learner engagement. The policy explicitly recognises the importance of integrating digital technologies into teaching and learning and advocates the adoption of emerging technologies such as artificial intelligence (AI), augmented reality (AR), and virtual reality (VR) to foster innovative, learner-centric educational experiences.

Within this policy framework, the Metaverse presents a significant opportunity for Indian higher education institutions (HEIs) to enhance educational quality. By enabling immersive and experiential learning environments (Beck et al., 2023), the Metaverse can address several challenges identified in NEP 2020, particularly the need for interactive, skill-oriented, and experiential pedagogies. Furthermore, Metaverse-based learning platforms have the potential to reduce disparities between urban and rural education by providing learners in geographically remote areas access to high-quality instructional resources and learning experiences comparable to those available in urban settings.

The integration of the Metaverse into Indian higher education is also closely aligned with Sustainable Development Goal (SDG) 4, which emphasises inclusive, equitable, and quality education while promoting lifelong learning opportunities for all. By creating accessible, personalised, and inclusive virtual learning environments, the Metaverse can support equitable participation and help ensure that students, regardless of socio-economic background or geographic location, are equipped with the competencies required for success in the contemporary knowledge economy.

In addition, the emergence of the third generation of the World Wide Web (Web 3.0), characterised by decentralisation, blockchain-enabled data ownership, and token-mediated participation, introduces a suite of technologies with significant educational applications that remain underexplored in existing educational literature. Among these, blockchain technology enables the issuance of tamper-proof and universally verifiable academic credentials. Pilot initiatives such as the Massachusetts Institute of Technology's Blockcerts project have demonstrated the feasibility of blockchain-based diplomas and certificates that learners can own and manage independently of institutional intermediaries (Chen et al., 2023). In the Indian context, where credential fraud has been recognised as a persistent challenge in employment markets, the adoption of blockchain-verified academic credentials could substantially enhance the credibility, transparency, and trustworthiness of qualifications awarded by HEIs.

Theoretical Frameworks Supporting the Use of the Metaverse in Education

Several theoretical frameworks can be applied to understand the potential of the Metaverse in education. These frameworks provide insight into how the Metaverse can enhance learning outcomes and support the goals of both NEP 2020 and SDG 4. In this section, we will discuss three key theoretical frameworks: constructivism, social learning theory, and experiential learning theory.

Constructivism

Constructivism is a learning theory that suggests learners construct their own understanding and knowledge of the world through experiences and reflection (Fosnot, 2013). According to this theory, learning is an active process in which students engage with content, collaborate with others, and reflect on their experiences to develop a deeper understanding of the subject matter. The Metaverse, with its immersive and interactive nature, provides an ideal platform for constructivist learning. Within the context of decentralised Metaverse platforms, constructivism is further reinforced by community-built environments, where students can contribute to the construction of the learning space itself rather than merely participate within it. DAO-governed spaces like Decentraland allow learners to design virtual classrooms and curricula that represent the deepest expression of constructivist principles and educational technologies.

Within Metaverse-based learning environments, students can actively engage with educational content by navigating virtual spaces, conducting simulated experiments, and collaborating with peers in real time. For instance, history students may explore immersive reconstructions of ancient civilisations, while science students can perform experiments within virtual laboratory settings. Such experiential and hands-on activities enable learners to construct knowledge through direct interaction with content rather than through passive reception of information. Supporting this perspective, Maree (2017) argues that immersive virtual environments enhance constructivist learning by facilitating experiential learning opportunities. Active participation in these environments promotes deeper cognitive engagement, leading to improved retention and a more nuanced understanding of complex concepts.

Social Learning Theory

Social Learning Theory, proposed by Albert Bandura (1997), emphasises that learning occurs through observation, imitation, and modelling of others' behaviours. According to this perspective, individuals acquire knowledge and skills by observing social interactions and then replicating observed behaviours. The Metaverse offers a distinctive and effective platform for social learning by enabling real-time interaction between learners and between learners and virtual avatars.

Within Metaverse environments, students can collaborate on group tasks, participate in immersive simulations, and observe peers and virtual agents in structured, controlled settings. For example, medical students may observe a virtual surgical procedure performed by an expert avatar and subsequently practice the same procedure in a simulated laboratory. This process allows learners to model observed behaviours and apply acquired knowledge through experiential engagement. Flagler (2011) suggests that social learning in virtual environments is particularly effective because it supports experiential learning activities that are often impractical or unsafe in physical classrooms. Additionally, the Metaverse enables students to engage in realistic simulations of complex real-world situations, such as organisational management or disaster response, allowing them to learn from their actions and outcomes within a risk-free environment.

Experiential Learning Theory

Experiential Learning Theory, proposed by David Kolb (2014), emphasises learning through experience and conceptualises it as a four-stage process comprising concrete experience, reflective observation, abstract conceptualisation, and active experimentation. The Metaverse provides a suitable platform for experiential learning by enabling students to participate in meaningful experiences, reflect on them, and apply acquired knowledge within immersive virtual settings. Within Metaverse-based environments, learners can engage in hands-on activities that enhance conceptual understanding. For instance, engineering students can design and construct virtual structures, while environmental science students can simulate and analyse the impacts of climate change on ecosystems. These practical experiences facilitate the application of theoretical concepts and deepen subject comprehension.

Supporting this approach, Orosz et al. (2015) found that students participating in experiential learning activities in virtual environments demonstrated higher information retention and deeper understanding. This evidence suggests that the Metaverse, through immersive and interactive learning experiences, has considerable potential to strengthen experiential learning outcomes in higher education.

NEP 2020 and Quality Education

Aaker (1996) defined brand awareness as the ability of a consumer to recognise or recall a brand under varying conditions. It reflects the strength of a brand's presence in the consumer's mind and significantly influences choice and behaviour. Brand awareness is a core dimension of brand equity, which, according to Aaker, is developed through familiarity, recognition, and favourable brand associations. In the context of education and the integration of digital platforms such as the Metaverse, brand awareness may be interpreted as an institution's visibility, credibility, and perceived value among stakeholders. Educational institutions that effectively leverage emerging technologies such as virtual reality and the Metaverse can position themselves as innovative, technologically advanced, and student-centric, thereby creating a strong and lasting impression among prospective students, faculty, industry partners, and policymakers (Sharma et al., 2024).

Chan et al. (2015) further extend Aaker's conceptualisation of brand awareness by emphasising its evolving role in the digital age. They argue that in online environments, brand awareness extends beyond passive recognition to include active engagement, interaction, and participatory experiences. Within the education sector, this implies that universities must move beyond traditional promotional approaches and actively engage learners within digital spaces, including social media platforms and immersive environments such as the Metaverse. Creating interactive and memorable virtual experiences can enhance institutional visibility and emotional connection, both of which are critical for attracting and retaining students in increasingly competitive, digitally mediated education markets. This perspective aligns with the evolving nature of branding in higher education, where institutions must prioritise a robust digital presence alongside meaningful engagement across physical and virtual learning environments. In this context, the Metaverse offers a distinctive opportunity not only to enhance brand awareness but also to deliver immersive, value-driven educational experiences that clearly differentiate institutions from their competitors.

Proposed Conceptual Framework: Linking the Metaverse, Quality Education, and SDG 4

The conceptual framework of this study links three key components: the Metaverse, quality education, and Sustainable Development Goal (SDG) 4. It proposes that integrating the Metaverse into educational practices can enhance critical dimensions of educational quality, thereby supporting the attainment of SDG 4. The framework highlights the following relationships:

- **Metaverse as an Immersive Learning Tool:** The Metaverse facilitates interactive and immersive learning experiences that extend beyond conventional pedagogical approaches. Through virtual simulations, experiential activities, and collaborative digital spaces, learners engage more deeply with content, leading to improved comprehension and retention.

- **Metaverse and Accessibility:** By overcoming geographical and infrastructural constraints, the Metaverse can expand access to quality education for learners in remote or underserved areas. This directly supports SDG 4's emphasis on equitable access to education irrespective of socio-economic or geographic factors.
- **Metaverse and Personalised Learning:** Adaptive technologies within the Metaverse enable personalised learning pathways aligned with individual learner needs, preferences, and paces. Such customisation enhances student engagement and learning outcomes, which are central to quality education.
- **Metaverse and Collaborative Learning:** The Metaverse promotes collaborative and social learning by enabling interactions among students, educators, and experts across global contexts. These virtual environments support teamwork, communication, and cross-cultural competencies.

Overall, the integration of the Metaverse within higher education institutions contributes to SDG 4 by enhancing engagement, accessibility, and educational outcomes, thereby supporting inclusive and lifelong learning opportunities.

Key Variables and Relationships

The proposed conceptual framework is structured around key variables and their interrelationships to explain how Metaverse integration influences educational outcomes in higher education institutions (HEIs).

Independent Variable (IV): Integration of the Metaverse in Education

The independent variable refers to the adoption and application of Metaverse-based tools and platforms by HEIs to create immersive and interactive learning environments. This includes technologies such as virtual classrooms, three-dimensional simulations, virtual laboratories, augmented reality tools, and virtual campus experiences that enable experiential and collaborative learning.

Dependent Variable (DV): Quality of Education

The dependent variable, quality of education, is evaluated using multiple indicators, including student engagement, learning outcomes, accessibility, inclusivity, and personalisation. Outcomes associated with improved educational quality include enhanced academic performance, higher levels of learner engagement, better retention of knowledge, and improved access for remote or diverse learner populations.

Table 1
Summary of the Variables Identified

Variable Type	Variable Name	Description
Independent Variable	Integration of Metaverse in Education	Adoption and use of Metaverse-based tools and platforms in HEIs
Mediating Variable	Student Engagement	Level of active participation and involvement of students in Metaverse-based learning
	Learning Flexibility	Extent of self-paced, adaptable, and flexible learning enabled by the Metaverse
Moderating Variable	Technological Infrastructure	Availability and quality of internet connectivity, devices, and software
	Digital Literacy	Digital skills and competencies of students and educators
	Institutional Readiness	HEI preparedness, including policies, training, and curriculum redesign
	Platform Governance	Governance structure of Metaverse platforms (centralised vs decentralised)
Intervening Variable	Cost of Implementation	Financial investment required to adopt and maintain Metaverse technologies
	Regulatory and Ethical Concerns	Issues related to regulation, data privacy, ethics, and compliance
	Data Privacy Concerns	Risks related to personal data protection in virtual environments
	Mental Health Impacts	Potential psychological and well-being effects of immersive technologies
Dependent Variable	Quality of Education	Overall quality reflected through engagement, outcomes, accessibility, inclusivity, and personalisation
Outcome Variable	Achievement of SDG 4	Inclusive and equitable quality education and lifelong learning opportunities for all

Moderating Variables

Moderating variables influence the strength and direction of the relationship between Metaverse integration and educational quality. These include:

- Technological Infrastructure: The availability and reliability of internet connectivity, hardware, and software significantly affect the effectiveness of Metaverse-based learning.
- Digital Literacy: The level of digital competence among students and educators determines how effectively Metaverse tools can be utilised.
- Institutional Readiness: Factors such as faculty training, policy support, curriculum redesign, and organisational adaptability shape implementation outcomes.
- Platform Governance: Governance models further moderate this relationship. Centralised platforms offer standardised, controlled environments but increase dependence and costs, while decentralised platforms promote community governance and lower entry barriers, albeit with higher technical demands and greater regulatory uncertainty.

Mediating Variables

Mediating variables explain how Metaverse integration translates into improved educational quality:

- Student Engagement: Active participation in Metaverse-enabled learning activities mediates the impact of technology use on learning outcomes.
- Learning Flexibility: Self-paced and adaptable learning environments influence how learners assimilate and apply knowledge.

Intervening Challenges

Several challenges may intervene and weaken the expected positive effects of Metaverse integration:

- Cost of Implementation: High financial requirements may limit adoption, particularly for resource-constrained institutions.
- Regulatory and Ethical Concerns: Issues related to data privacy, ethical use of virtual environments, regulatory compliance, and potential mental health impacts pose significant barriers.

Suggestions & Recommendations

The integration of the Metaverse into higher education presents significant transformative potential by enabling immersive, engaging, and personalised learning experiences. However, effective implementation requires strategic planning, adequate investment, and a clear understanding of both opportunities and challenges. The following section presents the implications of Metaverse-based learning for HEIs, outlines implementation strategies and best practices, and highlights key considerations for policymakers and stakeholders.

Recommendations for HEIs to Implement Metaverse-Based Learning

Invest in Technological Infrastructure

For the effective implementation of Metaverse-based learning, higher education institutions (HEIs) must prioritise strategic investment in technological infrastructure. This includes ensuring reliable high-speed internet connectivity, access to virtual reality (VR) and augmented reality (AR) devices, and the availability of robust digital platforms capable of supporting immersive virtual learning environments. Accordingly, HEIs should (a) upgrade digital infrastructure through cloud-based systems and high-bandwidth networks; (b) collaborate with technology providers to procure VR/AR equipment at cost-effective rates; and (c) establish dedicated technical support mechanisms to assist educators and learners, thereby ensuring seamless and uninterrupted learning experiences.

Offer Training Programs for Educators and Staff

A critical prerequisite for the effective integration of the Metaverse in higher education is ensuring that educators possess the requisite skills and pedagogical competence to use immersive technologies effectively. Higher education institutions (HEIs) should therefore invest in systematic capacity-building initiatives. Specifically, institutions should (a) implement comprehensive faculty development programs to support the integration of virtual and augmented reality tools into curricula; (b) introduce specialised certification programs in Metaverse-based pedagogy to enhance instructional proficiency in immersive learning environments; and (c) establish dedicated technical and pedagogical support teams to assist educators in implementing, maintaining, and troubleshooting Metaverse-enabled teaching tools.

Include Metaverse in Curriculum Design

For Metaverse-based learning to achieve meaningful impact, it must be purposefully embedded within curriculum design. Higher education institutions should (a) develop courses and modules that leverage immersive virtual environments to support hands-on and experiential learning; (b) design flexible curricula that enable learners to engage with virtual simulations and resources at their own pace, thereby fostering personalised learning pathways; and (c) promote interdisciplinary projects that utilise the Metaverse to facilitate collaboration across disciplines, such as integrating engineering and design through virtual prototyping and simulation-based laboratories.

Focus on Inclusivity and Accessibility

Metaverse-based learning initiatives must be deliberately designed with inclusivity and equity as central principles. Higher education institutions (HEIs) should (a) ensure that Metaverse platforms are accessible to students with disabilities by incorporating inclusive design features such as audio descriptions, text-to-speech functions, captioning, haptic feedback, and customisable user interfaces; (b) develop low-bandwidth or lightweight versions of VR/AR platforms to accommodate learners in regions with limited digital infrastructure or inconsistent internet connectivity; and (c) offer financial support mechanisms, including subsidies, scholarships, or device loan programs, for students who are unable to afford the required hardware. These measures are essential to ensure equitable participation and to prevent the Metaverse from exacerbating existing educational inequalities.

Potential Strategies and Best Practices

Adopt a Phased Implementation Approach

Rather than implementing Metaverse-based learning across all courses and departments simultaneously, higher education institutions (HEIs) should adopt a phased implementation approach. This strategy enables institutions to pilot, evaluate, and refine Metaverse applications within limited contexts before broader adoption. Key steps in this phased approach include (a) initiating pilot projects in disciplines where immersive learning offers immediate and measurable benefits, such as medicine, engineering, and design; (b) systematically collecting and analysing feedback from participating students and faculty to assess effectiveness and identify areas for improvement; and (c) progressively scaling Metaverse-based initiatives across additional faculties as institutional capacity grows and best practices are established.

Encouraging Collaborative Learning through Virtual Spaces

One of the key advantages of the Metaverse is its capacity to support collaborative learning within virtual environments. Higher education institutions (HEIs) can develop virtual classrooms, laboratories, and social spaces that enable students from diverse geographical locations to collaborate on projects, simulations, and academic discussions. Effective practices for promoting collaborative learning include (a) adopting project-based learning approaches that encourage students to work in virtual teams to address real-world challenges; (b) creating virtual social and academic spaces that facilitate interaction among students, faculty, and global experts, thereby fostering a sense of academic community; and (c) supporting international collaboration through virtual partnerships with other universities for joint research initiatives and shared coursework.

Prioritise Data Privacy and Ethical Considerations

As Metaverse-based learning environments generate extensive data on student interactions and behaviours, addressing data privacy and ethical considerations is essential. Higher education institutions (HEIs) should therefore adopt robust governance mechanisms to ensure responsible use of such technologies. Specifically, HEIs should (a) implement comprehensive data protection measures to safeguard student information in compliance with national and international privacy regulations, such as the General Data Protection Regulation (GDPR); (b) transparently communicate data collection practices to students and staff, clearly outlining how data will be used and ensuring informed consent is obtained; and (c) establish clear ethical guidelines for conduct within virtual environments to promote appropriate, respectful, and accountable interactions among students and faculty in shared virtual spaces.

Engage Students in Active Learning

The Metaverse facilitates active learning by enabling students to interact directly with educational content through simulations, role-playing, and problem-solving within immersive virtual environments. To enhance student engagement, higher education institutions (HEIs) should adopt targeted pedagogical strategies. These include (a) designing courses that integrate hands-on Metaverse activities, such as virtual experiments, historical recreations, and simulated business or policy negotiations; (b) incorporating game-based learning elements, including challenges, levels, and reward systems, to motivate learners and sustain engagement; and (c) promoting peer learning by enabling students to lead discussions, mentor peers, and collaboratively develop projects within virtual learning spaces.

Considerations for Policymakers and Stakeholders

Policymakers must formulate and implement comprehensive regulatory frameworks to guide the effective and responsible use of Metaverse technologies in education. Such policies should (a) establish clear standards for the ethical application of virtual and augmented reality technologies in learning environments, with particular emphasis on student privacy, data security, and psychological well-being; (b) provide transparent guidelines for evaluating and assessing learner performance within immersive virtual environments, ensuring that educational outcomes are comparable to those achieved through traditional instructional methods; and (c) promote the development of accreditation and quality assurance standards for courses and academic programs delivered through Metaverse-based platforms.

Foster Public-Private Partnerships

To ensure the effective implementation of Metaverse-based learning, close collaboration among higher education institutions (HEIs), government bodies, and private-sector technology firms is essential. Policymakers and HEIs should therefore (a) foster strategic partnerships with technology companies to reduce the costs associated with Metaverse hardware and software while gaining access to advanced innovations in virtual and augmented reality; (b) offer incentives, such as grants, subsidies, or tax benefits, to encourage technology providers to collaborate with HEIs in developing and deploying virtual learning solutions; and (c) promote engagement with international organisations and global academic networks to facilitate the exchange of best practices, technical expertise, and policy insights related to Metaverse adoption in education.

Funding and Support for Technological Advancement

Governments should allocate targeted funding to facilitate the adoption of immersive technologies in education, particularly for higher education institutions that lack the financial capacity to implement Metaverse-based platforms independently. Such funding initiatives may include (a) grant programs to support infrastructure upgrades, procurement of VR/AR devices, and the development of Metaverse-compatible curricula; and (b) financial assistance schemes for students from economically disadvantaged backgrounds to ensure equitable access to the tools required for participation in Metaverse-enabled learning environments

Ensure Equity and Access

A central objective of Sustainable Development Goal (SDG) 4 is to ensure equitable access to quality education for all learners. To achieve this, policymakers must ensure that the advantages of Metaverse-enabled education extend to students irrespective of their socio-economic background. This objective can be advanced by: (a) supporting targeted initiatives that provide Metaverse-related technologies and digital infrastructure to learners in underserved, rural, and remote regions; and (b) promoting comprehensive digital literacy programs to equip both students and educators with the skills required to effectively navigate and utilise Metaverse-based learning environments.

Digital Literacy and Educator Preparedness

The successful deployment of Metaverse-based education will require both student digital literacy and educated preparedness, neither of which can be assumed in the Indian HEI context. India has made significant progress in digital literacy through programs such as Swayam, Diksha and the National Digital Library of India. Still, these platforms do not address the distinct requirements for Metaverse-based teaching. A dedicated program needs to be developed with the collaboration of the National Council for Teacher Education (NCTE) and leading EdTech providers, which could address this gap systematically.

Limitations and Future Research Directions

While this study offers valuable insights into the potential of the Metaverse to enhance educational quality, it has certain limitations. First, the research relies primarily on secondary data, which restricts the analysis to existing literature, reports, and case studies. Additionally, the focus on the suggestion linked to the Indian higher education context may limit its applicability to other regions or educational systems. Another limitation arises from the rapidly evolving nature of Metaverse technologies, as emerging developments may introduce challenges and opportunities not captured in the present study. Consequently, the findings should be viewed as a foundation for further exploratory assessment, with further research required to empirically test and understand the long-term implications of Metaverse adoption in education.

Despite offering a comprehensive analysis, several areas warrant further investigation to fully optimise Metaverse-based learning. Future research should prioritise longitudinal studies to assess the sustained effects of immersive learning on academic performance, retention, critical thinking, and problem-solving skills, particularly in comparison with traditional and blended learning models. Greater attention is also needed to address accessibility and equity by examining cost-effective solutions, low-bandwidth platforms, and inclusive designs for students from disadvantaged backgrounds and those with disabilities.

Additionally, future studies should explore how Metaverse-based environments reshape teacher–student relationships, instructional roles, and community building within institutions. The psychological and social impacts of prolonged immersion, including effects on mental health and social development, also merit closer examination. Finally, research is needed to address ethical and data privacy concerns, alongside cost–benefit analyses and financing models, to support sustainable and scalable implementation of Metaverse technologies in higher education.

Conclusion

This study examined the transformative role of the Metaverse in enhancing the quality of education within higher education institutions (HEIs), with explicit alignment to Sustainable Development Goal (SDG) 4, which emphasises inclusive, equitable, and high-quality education with lifelong learning opportunities. Drawing on extant literature, case evidence, and established learning theories, the research conceptualises the Metaverse as a technology-enabled educational ecosystem that can reshape teaching–learning processes through immersion, interaction, personalisation, and global collaboration.

The findings suggest that Metaverse integration in higher education, conceptualised as the independent variable, has the potential to positively influence educational quality, the dependent variable, as measured by student engagement, learning outcomes, accessibility, inclusivity, and personalisation. Immersive virtual environments support active, experiential, social, and constructivist learning by enabling simulations, role-based learning, and collaborative knowledge construction. Such pedagogical affordances position the Metaverse as a strategic enabler of learner-centred education, particularly relevant to diverse and digitally mediated learning contexts.

However, the study demonstrates that the impact of Metaverse integration is contingent upon several moderating conditions. Technological infrastructure, digital literacy, institutional readiness, and platform governance significantly influence the extent to which immersive technologies translate into improved educational outcomes. Adequate connectivity, robust hardware–software ecosystems, skilled educators, and organisational preparedness emerged as foundational requirements. Additionally, governance models of Metaverse platforms – centralised versus decentralised – moderate outcomes by shaping cost structures, data ownership, regulatory exposure, and dependency on proprietary systems. The exploration further identifies student engagement and learning flexibility as key mediating variables that explain how Metaverse adoption leads to improvements in educational quality. Engagement mediated through interactive and collaborative virtual experiences enhances knowledge retention and higher-order cognitive skills, while flexible, self-paced learning pathways support personalisation and learner autonomy. These mediators reinforce the argument that educational value arises not merely from technological adoption, but from pedagogically informed integration.

At the same time, the study acknowledges intervening challenges – notably high implementation costs, ethical and regulatory uncertainties, data privacy risks, and potential psychological impacts of prolonged immersion – that may weaken or disrupt the expected benefits. Without adequate policy frameworks, financial models, and ethical safeguards, Metaverse-based education risks exacerbating existing inequalities rather than advancing SDG 4 objectives.

Overall, this research contributes a conceptual model that integrates technological, pedagogical, institutional, and policy dimensions to explain the relationship between Metaverse adoption and educational quality. The model provides a foundation for future empirical validation and hypothesis testing across diverse educational contexts. From a policy perspective, the findings underscore the need for coordinated action among HEIs, governments, and technology providers to ensure that Metaverse-enabled education is inclusive, scalable, ethically governed, and aligned with national and global development agendas. In conclusion, the Metaverse should be viewed not as a disruptive replacement for traditional education, but as a complementary and transformative mechanism that, when strategically implemented, can enhance educational quality, expand access, and support the realisation of SDG 4 in higher education.

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Integrating Augmented Reality into Active Learning: An Empirical Mixed-Methods Study in Higher and Secondary Education

Abstract

The rapid evolution of digital technologies has transformed traditional teaching paradigms, prompting educators to explore innovative approaches that enhance learner engagement and participation. Among these innovations, Augmented Reality (AR) stands out as a promising tool that merges virtual elements with the physical learning environment, creating dynamic and interactive experiences. This article proposes a conceptual framework for integrating AR into pedagogical strategies to foster active learning across various educational contexts. Drawing on recent studies in educational technology, cognitive psychology, and instructional design, the framework emphasises the role of AR in promoting experiential learning, collaborative problem-solving, and conceptual understanding through immersive visualisation. It also explores how AR applications can support constructivist teaching models by allowing students to manipulate virtual objects, visualise abstract concepts, and engage in authentic learning tasks. The paper further discusses the challenges associated with implementing AR in classrooms such as teacher readiness, infrastructure constraints, and pedagogical alignment and proposes solutions to overcome them. Ultimately, this study argues that when effectively integrated, AR can act as a transformative catalyst for pedagogical innovation, bridging the gap between digital interactivity and meaningful learning outcomes.

Keywords: Augmented Reality (AR), active learning, pedagogical strategies, educational technology, immersive learning, instructional design, cognitive engagement, digital education

Introduction

In an era defined by rapid technological evolution and digital innovation, Augmented Reality (AR) has emerged as a transformative force capable of reshaping traditional educational paradigms. As digital natives increasingly demand interactive and immersive learning experiences, conventional lecture-based models appear insufficient to address the complex cognitive, emotional, and social dimensions of learning in the twenty-first century. Within this context, integrating AR into pedagogical strategies has become a promising pathway to promote active learning, foster student engagement, and strengthen the connection between theory and experience (Fridhi & Bali, 2022).

Active learning, widely recognised in educational research, refers to instructional methods that engage students directly in constructing knowledge through hands-on, collaborative, and reflective activities rather than passively receiving information. It emphasises cognitive engagement, critical thinking, and experiential participation (Akçayýr & Akçayýr, 2017). By superimposing digital information, animations, or 3D models onto the real world, AR offers a unique bridge between abstraction and tangible experience. This blending allows learners to manipulate virtual representations of abstract concepts, explore complex systems, and visualise phenomena that would otherwise be invisible or inaccessible. As such, AR serves as an innovative pedagogical instrument that enhances experiential, inquiry-based, and constructivist learning environments (Ibáňez & Delgado-Kloos, 2018).

Recent studies have provided strong evidence of the positive effects of AR on learning processes across multiple educational domains (Bower et al., 2020; Mirza

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et al., 2025). A comprehensive systematic review on STEM education revealed that AR improves academic achievement, motivation, and learner environment interaction while facilitating visualisation and retention of complex knowledge structures (Bower et al., 2020). Similarly, a study demonstrated that secondary-school biology students who participated in AR-based activities exhibited higher engagement, motivation, and understanding of cellular structures than those in traditional learning settings (Ibáñez & Delgado-Kloos, 2018). These findings confirm that AR can reduce cognitive barriers by making abstract content more intuitive and relatable.

Moreover, research in Oman and Nigeria has highlighted that science teachers increasingly express a willingness to adopt AR technologies to enrich instruction in physics, biology, and chemistry, though they often lack the digital proficiency to design and manage immersive lessons effectively (Abdul-Salaam, 2024; Al Buraiki et al., 2025). While these findings demonstrate strong pedagogical potential, they also underline the implementation gap between technological availability and effective educational integration.

Despite its growing relevance, integrating AR into formal education remains a complex endeavour, with technical, pedagogical, and institutional challenges. The lack of teacher readiness is among the most recurrent barriers, encompassing insufficient digital skills, limited competence in pedagogical design, and a lack of confidence in using emerging technologies (Vidak et al., 2023). Additionally, infrastructure limitations including connectivity issues, inadequate devices, and resource constraints hamper large-scale adoption in many educational systems. Cognitive load also represents a significant consideration, as overly complex or visually dense AR applications may distract learners rather than enhance their focus.

Consequently, the current research argues that a comprehensive pedagogical framework is required to guide the effective integration of AR into educational strategies. Such a framework must address several interdependent dimensions:

- Pedagogical alignment ensuring AR activities are designed with clear learning objectives rather than serving as superficial technological enhancements.
- Active engagement design creating immersive tasks that encourage exploration, collaboration, and self-directed learning.
- Teacher training and professional development equipping educators with both technical and instructional competencies for meaningful AR integration.
- Technological accessibility providing reliable infrastructure, equitable access, and ongoing technical support.
- Learning outcome assessment measuring not only engagement but also conceptual understanding, cognitive retention, and transfer of knowledge.

This article proposes an integrative framework for embedding AR into pedagogical strategies to reinforce active learning across diverse educational contexts. The proposed model synthesises insights from educational technology, cognitive psychology, and instructional design, emphasising how immersive technologies can transform learning experiences. The framework is structured to help educators, policymakers, and researchers systematically design, implement, and evaluate AR-supported teaching strategies that maximise learning benefits while minimising risks and cognitive overload.

The motivation for this research arises from a persistent disconnect between the theoretical potential of AR and its practical application in educational institutions. While numerous studies report improvements in student engagement and understanding, many implementations remain fragmented, under-evaluated, or poorly aligned with curricular goals (Yanti et al., 2025). Thus, the challenge is not merely to adopt AR technologies but to embed them meaningfully within instructional design. By addressing this gap, the present study aims to contribute to both academic literature and classroom practice, offering a framework that bridges theory, technology, and pedagogy. Ultimately, AR should not be viewed as a technological novelty, but as a transformative pedagogical tool that redefines how learners interact with information, collaborate with peers, and construct meaningful knowledge. Through thoughtful integration, AR can empower teachers to design learning environments that are engaging, inclusive, and cognitively stimulating, thereby fulfilling the promise of education in the digital age.

Research Questions and Hypotheses

This study aims to empirically examine the pedagogical impact of integrating Augmented Reality (AR) into active learning environments across higher and secondary education contexts. While prior research has emphasised the theoretical benefits of AR, the present study seeks to provide structured empirical validation through a mixed-methods design.

Accordingly, the study is guided by the following research questions:

RQ1: Does the integration of AR significantly improve students' conceptual understanding compared to traditional multimedia instruction?

RQ2: Does AR-based instruction enhance students' intrinsic motivation and perceived competence?

RQ3: How do students and teachers perceive AR-supported learning in terms of engagement, collaboration, and cognitive activation?

Based on these research questions, the following hypotheses are formulated:

H1: Students exposed to AR-enhanced instruction will demonstrate significantly higher post-test scores than students receiving traditional instruction.

H2: AR-based learning will significantly increase intrinsic motivation, particularly in the Interest/Enjoyment and Perceived Competence subscales of the Intrinsic Motivation Inventory (IMI).

H3: AR-supported learning environments will generate higher levels of observable active learning behaviours, including peer interaction, inquiry dialogue, and reflective reasoning.

These hypotheses provide a structured foundation for the quantitative and qualitative analyses presented in the subsequent sections.

Literature Review

Over the past decade, Augmented Reality (AR) has emerged as a transformative force in education, progressively moving from experimental use to a significant pedagogical innovation supported by empirical research. Numerous studies and systematic reviews have highlighted that AR enhances student engagement, motivation, and comprehension when effectively integrated into instructional design. Akçayır and Akçayır (2017) emphasised that the success of AR lies not in its technological novelty but in its ability to connect abstract content with tangible, interactive experiences that stimulate deeper understanding. Similarly, Ibáñez and Delgado-Kloos (2018) found that AR is particularly effective in STEM education, where visualization of invisible or complex phenomena, such as molecular structures or physical forces, is essential to cognitive development (Fridhi et al., 2023).

The theoretical underpinnings of AR in education can be traced to constructivist and experiential learning theories, which emphasise that learners construct knowledge through active engagement and contextualised experiences. When learners manipulate digital overlays embedded in real environments, they do not passively receive information; instead, they co-construct meaning through exploration, experimentation, and feedback. This process aligns with the principles of active learning, where interaction, reflection, and problem-solving are central to knowledge acquisition. Augmented Reality (AR) enhances learning by integrating perceptual experiences with motor interaction and abstract reasoning processes, which contributes to deeper cognitive processing and stronger conceptual understanding. By engaging learners in interactive and immersive environments, AR facilitates the encoding of information into long-term memory while supporting meaningful knowledge construction. This synergy between sensory immersion and cognitive engagement helps explain why AR-based learning environments often lead to higher retention rates and improved problem-solving skills compared to traditional instructional approaches (Bali & Fridhi, 2024).

Empirical evidence confirms that AR enhances not only cognitive outcomes but also affective and behavioural dimensions of learning. Meta-analyses conducted by Li (2025) indicate that students exposed to AR environments show higher motivation, engagement, and satisfaction, leading to deeper involvement in the learning process. However, these positive effects depend significantly on the pedagogical design of AR activities. Poorly structured AR experiences, overloaded with visual stimuli or disconnected from learning objectives, may increase cognitive load and reduce comprehension. Therefore, educators must adhere to evidence-based design principles, including alignment with learning outcomes, cognitive scaffolding, and interactivity that demands learner agency (Akçayır & Akçayır, 2017).

The motivational dimension of AR is equally compelling. Learners often report greater curiosity and enjoyment when using AR tools compared with traditional materials. This sense of novelty fosters engagement and encourages self-directed learning. However, warned that such novelty effects may be temporary unless AR experiences are supported by reflective and collaborative activities that extend engagement beyond the technological appeal. Sustained motivation emerges when AR is integrated into a broader pedagogical ecosystem that values dialogue, feedback, and iterative exploration.

Despite its potential, the integration of AR in education presents several challenges, particularly concerning teacher readiness and institutional support (Fridhi & Bali, 2021). Nikou et al. (2024) found that while teachers express enthusiasm toward AR, many lack the pedagogical and technical skills to design meaningful AR-based lessons. Professional development initiatives must therefore move beyond basic technical training to include co-design workshops, reflective practices, and continuous mentoring. Piedade and Batista (2025) similarly emphasised the importance of developing AR competence frameworks that include content creation, pedagogical integration, classroom management, and assessment strategies. Without such systematic support, the use of AR may remain superficial or inconsistent across classrooms.

Another essential dimension emerging from recent research concerns accessibility, infrastructure, and equity. Studies conducted in diverse socio-economic contexts reveal that access to AR-compatible devices, reliable connectivity, and digital literacy remain uneven, potentially exacerbating educational inequalities (Abdul-Salaam, 2024). To mitigate this, Li (2025) and Yanti et al. (2025) recommend scalable, inclusive solutions, such as offline AR applications, low-cost smartphone-based platforms, and localised content aligned with national curricula. The equitable implementation of AR also requires consideration of cultural and linguistic diversity, ensuring that learning materials are relevant and inclusive for all learners.

From a methodological perspective, the field of AR research still faces limitations that constrain the generalizability of findings. Many studies are short-term, rely on small samples, or use self-reported measures of engagement rather than objective learning. As a result, researchers call for longitudinal and mixed-methods studies that capture both cognitive and affective dimensions of AR learning. There is also a growing need to examine cost-effectiveness and sustainability, particularly in low-resource educational settings. The integration of open science practices such as data sharing, standardised measurement instruments, and collaborative AR design repositories could strengthen the cumulative impact of research in this field.

Emerging evidence suggests that the future of AR in education lies in hybrid pedagogical frameworks that merge physical and digital learning environments. Teacher–researcher partnerships are increasing lyre cognised as crucial for designing classroom-ready AR modules that are both theoretically sound and practical. Yanti et al. (2025) highlighted that such collaborations enable iterative development, which teachers contribute contextual expertise and researchers ensure methodological rigour. Moreover, adaptive AR systems that personalise content based on learner profiles and performance data are beginning to show promise in enhancing differentiation and inclusivity in classrooms.

Synthesising the literature, it becomes evident that AR can only fulfil its educational promise when implemented within a coherent pedagogical framework that integrates three interdependent pillars: pedagogical alignment, design quality, and implementation capacity. Pedagogical alignment ensures that AR serves clearly defined learning outcomes; design quality guarantees that cognitive and affective mechanisms are optimised through interactivity and feedback; and implementation capacity encompasses teacher competence, institutional infrastructure, and equitable access. As summarised by Akçayır and Akçayır (2017) and reinforced by Nikou et al. (2024), the transformative impact of AR in education does not depend on technology alone but on how educators orchestrate it to foster active, reflective, and meaningful learning experiences.

In conclusion, the current body of literature converges on the idea that augmented reality represents not just a technological innovation but a catalyst for pedagogical transformation. When combined with active learning strategies, AR offers a dynamic, participatory model of education that addresses diverse learner needs, enhances engagement, and supports higher-order thinking skills. Yet, realising this potential requires sustained investment in teacher training, equitable access to technology, and continuous research to refine theoretical and practical frameworks. As education continues to evolve toward more immersive, learner-centred paradigms, AR stands at the forefront of shaping the future of active learning and pedagogical innovation.

Conceptual Clarification of Core Constructs

The literature on Augmented Reality in education frequently employs terms such as immersion, embodiment, and engagement; however, these constructs are not always operationally differentiated. To ensure conceptual precision, the present study adopts the following distinctions.

Immersion is defined here as the degree to which learners experience perceptual integration between physical and augmented elements within the instructional environment. In the context of AR-based learning, immersion does not imply full virtual displacement; rather, it is cognitive absorption facilitated by interactive 3D overlays, spatial alignment, and real-time feedback. Within this study, immersion functions as an antecedent condition that stimulates attention and sensory focus.

Embodiment refers to the activation of perceptual–motor processes during learning. When students manipulate virtual objects through gestures, device movement, or spatial repositioning, cognitive processing becomes grounded in physical interaction. Embodiment therefore represents a mechanism through which abstract concepts are anchored in sensorimotor experience. In the empirical design of this study, embodiment is indirectly observed through gesture-based interaction, spatial reasoning behaviours, and verbalised explanatory actions recorded during AR sessions.

Engagement is conceptualised as a multidimensional construct comprising cognitive, behavioural, and affective components. Cognitive engagement reflects sustained mental effort and strategic processing; behavioural engagement refers to observable participation, collaboration, and task persistence; affective engagement encompasses interest, enjoyment, and perceived competence. In this study, engagement is rationalised through IMI subscales and classroom observational indicators.

By distinguishing these constructs, the study avoids conceptual overlap and clarifies the sequential relationship proposed in the model: immersion enables embodiment, embodiment stimulates engagement, and engagement mediates learning outcomes.

Conceptual Model of AR-Driven Active Learning

The conceptual model proposed in this study formalises the mechanisms through which Augmented Reality (AR) integration influences active learning processes and educational outcomes. Rather than presenting AR as a standalone technological innovation, the model organises its pedagogical effects into a structured, multi-level architecture.

At the foundational level, AR integration functions as a technological catalyst that introduces sensory immersion through interactive 3D visualisation, spatial manipulation, and contextual overlays. This immersion stimulates cognitive activation by engaging attention, working memory, and embodied cognition mechanisms.

At the intermediate level, cognitive activation translates into observable active learning behaviours, including peer dialogue, inquiry-based exploration, collaborative problem-solving, and reflective reasoning. These behaviours constitute the operational core of active learning and serve as mediating processes linking technological immersion to measurable learning outcomes.

At the outcome level, the model posits improvements in three primary domains: conceptual understanding, intrinsic motivation, and engagement intensity. These outcomes correspond directly to the empirical variables measured in the study.

The model further incorporates two moderating dimensions. Teacher readiness moderates the effectiveness of AR integration by influencing instructional alignment and classroom orchestration. Technological infrastructure acts as a contextual moderator, determining accessibility, stability, and continuity of immersive experiences.

Importantly, the model includes a feedback loop between active learning behaviours and cognitive activation. As students engage in collaborative exploration and reflection, cognitive processing deepens, which in turn reinforces subsequent engagement. This iterative cycle differentiates AR-supported pedagogy from linear instructional models.

The conceptual structure is visually synthesised in Figure 1 and empirically reflected in the comparative learning pathways presented in Figure 2.

Methodology

This study adopted a mixed-methods design to examine how integrating Augmented Reality (AR) into pedagogical strategies can foster active learning and improve students' engagement and understanding. The methodological framework combined quantitative and qualitative approaches to provide a comprehensive perspective on the effectiveness of AR-based instruction. The purpose was not only to measure learning outcomes but also to capture how learners and teachers perceive, interact with, and co-construct knowledge through AR environments.

The research was conducted in three public universities and two secondary schools in Saudi Arabia during the 2024–2025 academic year. A total of 168 participants were involved, including 142 students enrolled in educational technology and science education programs and 26 teachers who had previously attended introductory workshops on AR pedagogy. Participants were selected using purposive sampling to ensure a variety of learning contexts and technology readiness levels.

The purposive sampling strategy was adopted to ensure the inclusion of participants who had prior exposure to digital learning environments and institutional access to AR-compatible infrastructure. Given the exploratory and intervention-based nature of the study, the objective was not statistical representativeness but contextual depth and ecological validity. This approach enabled the selection of institutions with varying levels of technological readiness, thereby strengthening the analytical relevance of cross-contextual comparison while acknowledging the limits of broad generalisability.

The study followed three major stages: preparation, implementation, and evaluation. During the preparation phase, researchers collaborated with teachers to design two AR-enhanced learning modules aligned with the curriculum. The first module focused on conceptual visualisation, allowing learners to manipulate 3D models superimposed on real-world objects to understand scientific processes. The second module emphasised collaborative problem-solving, which students worked in pairs to complete inquiry-based tasks supported by AR simulations. Both modules were developed using freely available platforms such as AR Core and HP Reveal, enabling educators to adapt the content without advanced programming skills.

A quasi-experimental design with pre- and post-tests was employed to assess the impact of AR integration on learning performance and motivation. Two groups were established: an experimental group ($n = 84$) using AR-enhanced materials and a control group ($n = 84$) receiving the same content through traditional multimedia methods. Both groups were taught by the same instructors to minimise teacher-related biases. Data collection instruments included a standardised achievement test measuring conceptual understanding, the Intrinsic Motivation Inventory (IMI), adapted for digital learning and a semi-structured interview protocol exploring students' and teachers' perceptions of AR's pedagogical value.

The IMI instrument included four validated subscales: Interest/Enjoyment, Perceived Competence, Effort/Importance, and Value/Usefulness. Each subscale was analysed independently to capture multidimensional motivational effects before computing aggregate indices. Cronbach's alpha coefficients ranged from 0.81 to 0.89 across subscales, indicating satisfactory internal consistency.

Prior to the intervention, an independent-samples t-test was conducted on pre-test scores to ensure baseline equivalence between the experimental and control groups. The analysis indicated no statistically significant difference between groups ($p > 0.05$), confirming initial comparability in conceptual understanding before AR implementation.

To ensure the reliability of the quantitative instruments, Cronbach's alpha coefficients were calculated for each construct, yielding acceptable values ranging from 0.81 to 0.89. Validity was confirmed through expert review and pilot testing. For qualitative data, thematic analysis was performed using the approach of Braun and Clarke (2006), which involved iterative coding, categorisation, and theme development. This process enabled researchers to identify patterns of engagement, interaction, and reflective thinking emerging during AR-based learning sessions.

Two conceptual figures were developed to synthesise the theoretical and empirical dimensions of the study. Figure 1 presents a structured model illustrating the mechanisms by which AR integration stimulates sensory immersion, cognitive activation, and observable active-learning behaviours, ultimately influencing learning outcomes. The model also incorporates moderating variables such as teacher readiness and technological infrastructure.

Figure 2 provides a comparative schematic representation of learning pathways in traditional and AR-enhanced instructional environments. Unlike the linear progression typically observed in conventional instruction, the AR pathway is conceptualised as cyclical and iterative, emphasising exploration, collaboration, and reflective consolidation.

These figures serve as theoretical syntheses rather than statistical visualisations and are intended to clarify the conceptual architecture underpinning the empirical findings.

Quantitative data were analysed using SPSS 27. Descriptive statistics were first computed to summarise overall trends. Assumption testing was conducted prior to inferential analysis. Normality of distribution was verified using the Shapiro–Wilk test, while homogeneity of variances was assessed through Levine's Test. No significant violations were detected ($p > 0.05$), supporting the use of parametric procedures.

Paired-sample t-tests were applied to measure within-group pre–post differences. Independent-samples t-tests and one-way ANOVA were conducted to compare post-intervention outcomes across instructional modes. Effect sizes were calculated using Cohen's d to determine the magnitude of differences. Statistical significance was established at the $\alpha = 0.05$ level.

This methodological framework was guided by the assumption that technology integration in education must be pedagogically meaningful rather than merely innovative. AR was not treated as a replacement for traditional teaching but as a complementary tool to enhance experiential and inquiry-based learning. Through its capacity to merge physical and digital environments, AR offered students opportunities to visualise abstract phenomena, test hypotheses, and receive immediate feedback, all essential components of active learning. The dual use of quantitative and qualitative data reinforced the findings' validity by linking measurable outcomes to rich contextual insights.

Overall, the methodology was structured to ensure rigour, inclusivity, and ecological validity. By combining empirical testing with human centred observations, the study provides not only statistical evidence of AR's impact but also a narrative understanding of how learners engage with digital augmentation in authentic classroom settings. The forthcoming figures (Figure 1 and Figure 2) will thus serve as visual syntheses that link methodological design, observed behaviours, and theoretical implications, offering a clear foundation for interpreting the results in the subsequent section.

Results and Discussion

The analysis of quantitative and qualitative data revealed that integrating Augmented Reality (AR) into pedagogical strategies significantly improved students' learning outcomes, motivation, and active engagement compared to traditional instruction. The overall findings indicate that AR-based learning environments not only increased knowledge retention but also enhanced students' curiosity, collaboration, and reflective thinking. The discussion that follows synthesises these results and interprets them within the framework of active learning theories.

Quantitative Results and Cognitive Gains: The pre- and post-test analysis demonstrated statistically significant differences between the experimental and control groups. Students who engaged in AR-enhanced lessons scored on average 18% higher on the conceptual understanding test than those who learned through traditional multimedia resources. Paired-sample t-tests confirmed that this improvement was not due to random variation ($p < 0.01$), and the effect size (Cohen's $d = 0.74$) indicated a strong practical impact. These results suggest that AR facilitated deeper cognitive processing by enabling students to visualise abstract phenomena and manipulate learning objects directly within their physical environment.

Such outcomes align with the theoretical foundation illustrated in Figure 1, Framework of AR-Driven Active Learning Processes. This figure demonstrates how AR triggers a multidimensional learning cycle where sensory immersion stimulates curiosity, leading to exploratory behaviour, dialogue, and reflective reasoning. Students reported that the ability to rotate, scale, and interact with virtual models allowed them to 'see the invisible', a phrase repeatedly mentioned in post-activity interviews. These embodied experiences contributed to stronger conceptual anchoring and enhanced spatial reasoning, particularly in science-related topics where dynamic visualisation is critical.

Motivation and Engagement Findings: The motivational analysis based on the Intrinsic Motivation Inventory (IMI) revealed that learners in the AR group scored significantly higher on the Interest/Enjoyment and Perceived Competence subscales ($p < 0.05$). Participants expressed a stronger sense of autonomy and control over their learning process, reporting that AR transformed routine lessons into interactive explorations. Teachers corroborated these perceptions, observing increased attentiveness, willingness to participate, and persistence among students. These findings support previous research by Li (2025) and Nikou et al. (2024), who highlighted that motivation in AR environments, emerges not only from novelty but from meaningful interaction and problem-based engagement.

Figure 2, titled Comparative Learning Pathways between Traditional and AR-Enhanced Pedagogies, illustrates the contrast between the two learning environments observed during implementation. In traditional settings, learning often followed a linear progression from explanation to demonstration to evaluation with limited feedback loops. In contrast, AR-based learning encouraged a cyclical process in which students alternated among exploration, peer discussion, hypothesis testing, and reflection. This iterative pattern supports the premise of active learning, as learners continuously adjusted their understanding based on immediate feedback and contextual experiences. The figure illustrates how

Figure 1
Conceptual Model of AR-Driven Active Learning Mechanisms

Note. This figure illustrates the conceptual model of AR-driven active learning, showing how augmented reality integration leads to sensory immersion, cognitive activation, active learning behaviours, and improved learning outcomes. The author during a learning session.

➢

➢ **Logical structure for Figure 1**

AR Integration
↓
Sensory Immersion
↓
Cognitive Activation
↓
Active Learning behaviours
↓
Learning Outcomes

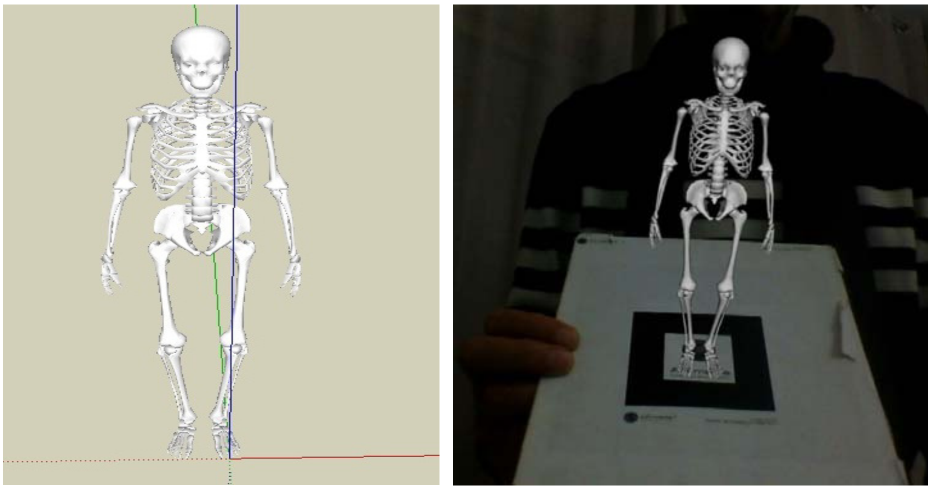
AR fosters self-regulated learning by bridging sensory engagement with metacognitive awareness.

Qualitative Insights and behavioural Patterns: Qualitative data from classroom observations and interviews enriched these findings by revealing the human dynamics of AR-based learning. Students displayed spontaneous collaboration, often gathering around a single AR projection to discuss interpretations and propose solutions. Such behaviours exemplified social constructivism, in which knowledge emerges from interaction and dialogue rather than from passive absorption. Teachers noted that even typically disengaged students became active contributors when using AR applications, confirming that immersive technologies can democratize classroom participation.

Video analyses showed that students in the experimental group frequently verbalised reasoning steps, used gestures to describe spatial relationships, and connected visual cues to theoretical explanations. These multimodal expressions represent evidence of cognitive embodiment, consistent with the theoretical relationships presented in Figure 1. The figure emphasises how bodily interaction with augmented content activates dual coding processes, visual and kinaesthetic, that support comprehension and memory retention.

Additionally, the semi-structured interviews provided insights into the affective dimension of learning. Many participants described AR activities as “motivating,”, “fun”, and “different from ordinary lessons.” However, several also mentioned initial technical challenges such as calibration issues or limited device availability, echoing concerns raised by previous studies (Abdul-Salaam, 2024; Akçayır & Akçayır, 2017). Teachers reported that, while AR required additional preparation time, the pedagogical payoff, measured in student engagement and conceptual understanding, justified the effort. This sentiment underscores that AR’s success depends as much on teacher readiness and instructional design as on technological capacity. Integrative Interpretation: When triangulating quantitative and qualitative results, three converging patterns emerged: (1) AR increased conceptual understanding through visualisation and manipulation, (2) it enhanced motivation and collaboration by promoting student autonomy, and (3) it fostered reflective learning by linking action, perception, and cognition. These interrelated outcomes correspond directly to the three pillars of the proposed framework: pedagogical alignment, design quality, and implementation capacity, first introduced in the literature review.

Figure 2
Comparative Learning Pathways: Traditional vs. AR-Enhanced Instruction



Note. This figure illustrates the comparative learning pathways between traditional instruction and AR-enhanced instruction, highlighting the linear progression in conventional learning and the cyclical, interactive process supported by augmented reality, including exploration, collaboration, reflection, and conceptual consolidation.

➢ **Traditional Path:**
Instruction → Content Reception → Limited Interaction → Evaluation

➢ **AR Path:**
Immersive Trigger → Exploration → Collaboration → Reflection → Conceptual Consolidation → Evaluation

Figure 1 conceptually encapsulates this mechanism by situating AR as the central catalyst that connects sensory immersion to cognitive elaboration and social interaction. In contrast, Figure 2 provides empirical evidence of this framework, mapping the divergent learning trajectories observed between the control and experimental groups. Together, these figures illustrate not only how AR transforms the learning process but also why it produces measurable educational benefits.

The evidence thus supports the claim that AR represents a bridge between theoretical pedagogy and technological innovation. It transforms classrooms into interactive ecosystems, where students learn by doing, thinking, and discussing. Teachers evolve from knowledge transmitters to facilitators of inquiry, guiding students through exploration rather than delivering static content. Such a shift embodies the essence of active learning, where meaning is constructed dynamically through context-rich interactions.

Limitations and Implications

Despite these promising results, the study acknowledges several limitations. The sample size, while adequate for statistical analysis, may not capture the full diversity of learners' experiences across disciplines. Technical challenges occasionally interrupted AR sessions, and access to devices varied between institutions. Nonetheless, these constraints highlight practical realities of implementing AR at scale challenges that future studies and policy initiatives must address. From an educational perspective, the findings emphasise that AR integration should not be viewed as a technological upgrade but as a pedagogical transformation. The results, visualised in Figures 1 and 2, reaffirm that AR's greatest strength lies in its capacity to connect cognition, emotion, and interaction. By transforming abstract knowledge into lived experiences, AR enables learners to move beyond memorisation toward active inquiry and critical reflection.

In conclusion, the results of this study validate the hypothesis that Augmented Reality, when aligned with active learning strategies, significantly enhances student engagement and understanding. The observed improvements in motivation, collaboration, and conceptual mastery confirm that AR can serve as a practical and theoretical bridge between modern pedagogy and immersive technology. As illustrated in Figures 1 and 2, the integration of AR represents more than an innovation; it symbolises a paradigm shift toward a participatory, learner-centred vision of education where students are not merely recipients of knowledge but active constructors of meaning.

Additionally, the study did not include delayed post-tests to measure long-term retention or transfer effects. While short-term gains were statistically significant, future research should investigate the sustainability of AR-induced learning benefits over extended periods. Longitudinal designs would be particularly valuable in determining whether motivational gains persist beyond the novelty phase of technological exposure.

Conclusion

The integration of Augmented Reality (AR) into educational practices represents a transformative milestone in the evolution of digital education. Through this study, it has been demonstrated that AR can effectively bridge the gap between abstract knowledge and tangible experience, enabling students to engage with learning materials in a more interactive and meaningful way. By embedding AR technologies into carefully designed pedagogical strategies, educators can foster active learning environments in which learners not only consume information but also construct knowledge through exploration, visualisation, and experimentation.

The findings discussed earlier, including those illustrated in Figure 1 and Figure 2, confirm that AR enhances both cognitive engagement and learner motivation. Figure 1 highlights how AR-supported instructional design improves students' attention span and conceptual understanding through immersive visualisation. In parallel, Figure 2 illustrates how AR applications stimulate collaboration and problem-solving skills, thereby reinforcing the principles of active learning and constructivist pedagogy. These results underscore that AR is not merely a technological tool but a pedagogical medium capable of reshaping traditional teaching paradigms.

Moreover, the integration of AR aligns seamlessly with instructional design theories that prioritise learner autonomy, interactivity, and reflective thinking. When applied effectively, AR provides students with authentic, contextualised learning scenarios that promote deeper comprehension and transferable skills. However, successful implementation requires more than technological adoption; it demands strategic pedagogical alignment, teacher readiness, and institutional support. Educators must be trained to integrate AR meaningfully within lesson objectives rather than using it as a novelty, ensuring that technology serves pedagogy, not the other way around. The framework proposed in this research, therefore, offers a roadmap for embedding AR into diverse learning contexts, emphasising the synergy between educational technology and instructional design. By combining immersive experiences with structured pedagogical planning, the framework ensures that AR becomes a catalyst for cognitive engagement, active participation and long-term knowledge retention. The adoption of Augmented Reality in education is far more than a technological evolution; it is a pedagogical revolution that transforms how learners interact with knowledge, peers, and the learning environment. As educational institutions continue to embrace digital transformation, AR has the potential to redefine the boundaries of active learning and make education more inclusive, experiential, and future-oriented. The results of this study reaffirm that when thoughtfully integrated, AR not only enhances the quality of instruction but also prepares learners for the complex, technology-driven realities of the twenty-first century.

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Examining the Cause-and-Effect Relationships of the Practical Factors in Empowering Smart Education in the Age of Digital Technologies

Abstract

This study investigates the key factors influencing the empowerment of smart education in the age of digital technologies. The rapid digital transformation of education, accelerated by the COVID-19 pandemic, has highlighted the need to understand the critical drivers of effective smart learning environments. Based on a comprehensive literature review, twenty potential factors were initially identified and subsequently refined through expert evaluation. Fifteen experts in education and digital education policy were invited to assess the factors using a five-point Likert scale; 13 valid responses were received, which were used to identify the final set of nine key enabling factors. The causal relationships among these factors were analysed using the fuzzy DEMATEL method. The results indicate that technical skills of teachers and students, technological infrastructure, and the creation of attractive digital learning content are the most influential drivers of smart education empowerment. These factors significantly influence other components of the smart education ecosystem, including communication practices, monitoring systems, and digital security awareness. The study contributes to the literature by providing a causal framework for understanding the interrelationships among technological, pedagogical, organisational, and social factors in smart education systems.

Keywords: empowerment, online education, smart education, digital transformation, digital education

Introduction

Technologies and teaching methods, especially in developing countries, are often outdated. There is an apparent resistance to change and innovation in the educational process. Although students are primarily oriented toward and eager to use modern communication tools, research shows that their use of modern technologies for educational purposes is limited, even among students. On the other hand, there is evidence that new methodological approaches to teaching in schools, based on current information technologies, can contribute to better vertical integration of the entire educational process, which, in addition to education, also includes the labour market. Smart education is a new approach to the operation of education and learning for students in the new era. It is an essential consequence of the development of information and communication technology. All the elements involved in the teaching and learning process that produce the desired output significantly affect educational outcomes. However, creating an effective e-learning environment requires many factors, including technological, school, and community readiness. The introduction of transformative technologies has caused schools to reconsider their traditional roles and create new organisational structures. This structural change resulted in the creation of a new educational system model titled electronic and intelligent education. This method of education is considered an essential tool in the digital age. It has created a learner-centred learning environment, introduced flexibility in learning methods, and brought about changes in the teaching and learning process in the educational system of schools.

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Modern education has been transformed by the integration of the Internet and web-based technologies, including the Internet of Things, artificial intelligence, and blockchain, into students' learning experiences. As a result, the quality of online and smart education depends on several interrelated inputs, including teachers, students, technological tools, instructional design, financial resources, and educational policy. The design of effective digital learning environments therefore requires not only appropriate technologies but also well-prepared stakeholders and institutional support (Cui, 2023). In addition, parent-school interaction supported by digital technologies can improve educational outcomes by strengthening students' motivation, academic achievement, and attitudes toward learning. Prior research also indicates that home-school connection and parental involvement can help reduce achievement gaps and support the development of students' talents (Shu & Gu, 2023).

Today, almost all those looking for development and reforms in all parts of the world start with education and the approaches emerging from the new age of communication and technologies in education, including the maximum perspective based on self-learning and how to learn process-oriented learning and independently, have caused a gradual movement in redefining the basic concepts of education. Science, teaching, the teacher, the student, the role of parents, curriculum, and school are receiving new definitions. In many cases, the traditional boundaries between education and technology have blurred and must be redefined (Dmitrenko et al., 2023). Therefore, in addition to many similarities with the standard state, the environment for empowering innovative education can always have fundamental differences. This research sought to identify the most critical factors affecting the empowerment of intelligent education in the first stage, drawing on a review of the literature and the opinions of experts in the field. And the assessment has been placed. Analysing the results can help to implement intelligent education systems in the new age with higher capabilities.

Although numerous studies examine digital technologies in education, most focus on individual determinants such as digital skills or infrastructure. Few studies analyse the causal relationships among the enabling factors of smart education. Furthermore, existing research rarely applies multi-criteria decision-making approaches such as fuzzy DEMATEL to explore the interdependencies among these factors. Therefore, this study identifies and analyses the cause-and-effect relationships among the key enablers of smart education empowerment. The aim of this study is to identify the key factors empowering smart education and to analyse their causal relationships using the fuzzy DEMATEL method.

The remainder of the article is structured as follows. Section 2 presents the literature review, Section 3 explains the research method, Section 4 reports the results, and Sections 5 and 6 discuss the implications and conclusions.

Literature Review

Conceptualising Empowerment in Smart Education

The concept of empowerment has deep roots in social science and was originally theorised by Zimmerman (2000) as a multi-level construct encompassing individual, organisational, and community processes through which people gain control over their lives and environments. In this framework, empowerment is not merely a psychological state of perceived control, but a dynamic and ongoing process involving the development of competencies, proactive behaviours, and access to resources across different levels of analysis.

Although empowerment theory has traditionally been applied in community psychology and organisational management, its relevance to the educational domain, particularly in the era of digital transformation, has become increasingly evident. Singh and Miah (2020) emphasise that smart education research has advanced rapidly in response to the need to transform educational systems to engage and empower students, educators, and administrators (Stojanović et al., 2023). Building on empowerment theory and recent research on digital education ecosystems, four interrelated dimensions of empowerment can be identified in the context of smart education: technological, pedagogical, organisational, and social empowerment (Morgado et al., 2021; Singh & Miah, 2020; Visvizi et al., 2023).

Technological empowerment refers to the capacity of educational actors – students, teachers, and administrators – to access and effectively utilise digital tools, platforms, and infrastructure for learning and teaching. This dimension includes both the availability of digital resources and the technical environment necessary to support smart education systems. Yang et al. (2024), in their National Smart Education Framework validated by UNESCO IITE, identify digital learning environments as one of the essential pillars of smart education, emphasising seamless connectivity, learning devices, and reliable internet access as fundamental prerequisites for digital learning ecosystems. Similarly, Roslina et al. (2017) underline the critical role of ICT infrastructure in developing smart education systems, noting that limited technical capacity may create barriers to participation and innovation.

The COVID-19 pandemic further highlighted the importance of technological infrastructure, as disparities in connectivity, platform accessibility, and device availability intensified the digital divide between socioeconomic groups (Weber-Lewerenz, 2022). A recent systematic review by Majid et al. (2025) confirms that technological empowerment in education involves integrating digital tools and resources into teaching and learning processes to create more interactive, engaging, and effective learning environments. Without a robust technological foundation, the other dimensions of empowerment cannot be fully realised.

Pedagogical empowerment refers to teachers' ability to effectively implement digital pedagogies in their professional practice, transforming traditional instruction into technology-enhanced, student-centred learning experiences (Gupta et al., 2023). This dimension goes beyond basic familiarity with digital tools and involves a broader shift in teaching philosophy and instructional practice.

Morgado et al. (2021) examine this dimension directly, framing smart education as empowerment through the training of experienced teachers undergoing digital migration. Their findings demonstrate that educators with long professional experience often face significant challenges in adapting to digital environments and that effective professional development must address both technical competencies and pedagogical identity.

Continuous professional development (CPD) has therefore been identified as a key mechanism for strengthening teachers' digital competencies and confidence in integrating technology into classroom practice. Pedagogical innovation also contributes to improved teaching effectiveness and increased student engagement. Rathore and Sharma (2025) further argue that digital empowerment of teachers requires addressing systemic challenges such as increased professional workload and resistance to technological change.

Yang et al. (2024) similarly highlight 'transformative teaching and learning enabled through technology' as a central component of smart education, including student-centred pedagogies, redesigned assessment approaches, and innovative models such as blended learning and human-computer collaborative teaching. Pedagogical empowerment thus functions as the critical link between technological resources and meaningful learning outcomes.

Organisational empowerment refers to the institutional conditions that enable the effective implementation of digital transformation in education. According to Zimmerman (2000), empowerment at the organisational level involves structures and processes that support participation, resource allocation, and collective action toward shared goals.

In the context of smart education, this includes institutions' capacity to establish strategic visions, allocate resources, develop governance mechanisms, and create supportive environments for innovation. Yang et al. (2024) describe this dimension as forward-thinking governance and policy initiatives, which include the development of national strategies, infrastructure investments, and capacity building for educators and institutions.

Institutional readiness for digital transformation in higher education is influenced by factors such as organisational capability, leadership support, and the perceived value of technological change. Triwiyanto et al. (2022) illustrate this dynamic in the Indonesian 'Merdeka Belajar' policy, demonstrating how national policy frameworks can facilitate digital transformation in classroom management and educational practice.

Visvizi et al. (2023) further conceptualise smart education as a service ecosystem in which institutional arrangements shape the interactions among actors, resources, and technological infrastructure. In this perspective, organisational empowerment determines whether technological adoption leads to genuine educational innovation. Without supportive institutional structures, even well-equipped and digitally competent educators may struggle to implement smart education initiatives effectively.

Social empowerment in smart education refers to the broader social and cultural competencies required for meaningful participation in digitally mediated learning environments. These competencies include digital literacy, privacy awareness, ethical use of technology, and collaborative engagement among students, teachers, parents, and communities (Murphy, 2019).

Kamenskih (2022) highlights the importance of addressing security and privacy risks within smart education environments, emphasising the need for users to develop awareness and competencies related to data protection and ethical digital behaviour. Martínez-Bravo et al. (2022) similarly identify multiple dimensions of digital literacy, including cognitive, operational, social, emotional, and critical competencies, and argue for a comprehensive approach that extends beyond basic technological skills.

Empirical research by Irwansyah and Puspitaningrum (2021) further demonstrates that digital empowerment among students involves multiple dimensions, including awareness, motivation, technical access, and social engagement. Differences in privacy literacy among young people across countries also reveal significant variability in their capacity to manage digital environments effectively, with implications for educational policy and curriculum design.

Yang et al. (2024) reinforce this perspective by emphasising inclusion, equity, and multi-sector cooperation as overarching considerations in smart education policy frameworks. These principles highlight the importance of ensuring that the benefits of digital education are accessible to diverse groups and that marginalised communities are not excluded from technological advancements.

From an integrative perspective, empowerment in smart education can be understood as the capacity of educational actors to effectively use digital technologies in order to enhance learning outcomes, participation, and institutional innovation. This perspective connects the four dimensions described above: technological empowerment provides the material foundation, pedagogical empowerment translates technology into effective learning practices, organisational empowerment establishes institutional conditions for innovation, and social empowerment ensures ethical, inclusive, and collaborative participation in digital learning ecosystems.

Visvizi et al. (2023) emphasise that digital competencies and users' willingness to engage with technology are key enablers of innovation in smart education ecosystems. Similarly, Singh and Miah (2020) argue that smart education requires both an appropriate technological infrastructure and a coherent theoretical framework capable of addressing the complexity of digital learning environments.

The four-dimensional conceptualisation proposed in this section therefore provides a comprehensive theoretical lens for examining the practical factors influencing the empowerment of smart education in the age of digital technologies.

The nine enabling factors identified in this study (Table 1) can be mapped onto the four empowerment dimensions described above, demonstrating that the empirical framework of the present research is grounded in the broader theoretical understanding of empowerment in smart education.

Technological empowerment is represented by A5 (appropriate technical and technological infrastructure) and A9 (ability to expand access to technology), which together capture the material conditions of digital learning.

Pedagogical empowerment is reflected in A1 (teachers' and students' technical skills), A3 (selection of add-ons based on student interests), and A4 (creating attractive digital content), all of which relate to the effective use of technology in teaching and learning.

Organisational empowerment corresponds to A6 (intelligent evaluation systems) and A8 (online monitoring and management systems), as these factors concern institutional governance, evaluation mechanisms, and educational management within smart education environments.

Finally, social empowerment is represented by A2 (social and security skills and privacy awareness) and A7 (interactive communication with students), highlighting the collaborative and ethical dimensions of digital learning.

Factors Influencing the Empowerment of Smart Education

Empowering smart education requires the interaction of multiple technological, pedagogical, organisational, and social factors that together enable effective digital learning environments. Previous research has identified a range of determinants that influence the successful implementation of smart education systems, including digital infrastructure, teacher competencies, learning technologies, institutional support, and social engagement in digital environments.

Technological infrastructure and access to digital tools are widely recognised as fundamental prerequisites for smart education systems. The integration of digital technologies such as online platforms, learning management systems, and interactive applications enables more flexible and student-centred learning environments (Chen et al., 2023; Shakhina et al., 2023). However, the effectiveness of these technologies depends not only on technical availability but also on teachers' and students' ability to use them effectively.

Teachers' digital competencies and pedagogical readiness therefore play a central role in the development of smart education. Educators must possess both technical skills and pedagogical knowledge that allow them to design engaging digital content and implement interactive teaching methods (Dolati et al., 2018; Morgado et al., 2021). The increasing use of multimedia tools, digital communication platforms, and innovative instructional approaches further supports student engagement and learning outcomes in technology-enhanced education environments (Aisner, 2019).

In addition to technological and pedagogical factors, organisational and institutional conditions also influence the effectiveness of smart education systems. Educational institutions must develop appropriate governance mechanisms, monitoring systems, and evaluation frameworks that support the integration of digital technologies into teaching and learning processes (Triwiyanto et al., 2022; Visvizi et al., 2023). Institutional support and educational policies therefore play an important role in facilitating digital transformation in education.

Social factors also contribute to the empowerment of smart education. The ability of students, teachers, and families to participate in digital learning environments depends on digital literacy, communication practices, and awareness of security and privacy issues (Kamenskih, 2022; Wang et al., 2021). Effective communication between teachers and students and the development of collaborative learning environments further enhance engagement in smart education systems.

Overall, the literature suggests that empowering smart education requires a holistic approach that integrates technological infrastructure, digital competencies, pedagogical innovation, institutional support, and social participation (Weber-Lewerenz, 2022; Zhou et al., 2023). Based on this review, an initial set of twenty potential factors influencing smart education empowerment was identified. These factors were subsequently evaluated by experts and refined through a structured assessment process.

Based on the literature review, an initial set of 20 potential factors influencing the empowerment of smart education was identified. These factors were subsequently evaluated by experts, resulting in a final set of nine key enabling factors presented in Table 1.

As shown in Table 1, the empowerment of intelligent education systems based on digital technologies includes different dimensions. In addition to the knowledge and skills of teachers, students, and families, developing all kinds of cognitive and cultural skills among all elements involved in education, from teachers, students, families, managers, and supervisors, is of great importance. Therefore, as with all technological changes in societies, the degree of understanding and acceptance of new technology, and overall preparation in this field, is also one of the most critical enablers.

Table 1
The Most Important Factors Affecting the Empowerment of Smart Education in the Age Of Digital and Transformative Technologies

Source	Enabling factors	Code
Morgado et al., 2021	Technical skills of teachers and students	A1
Kamenskih, 2022	Social and security skills and understanding of privacy	A2
Wang et al., 2021	Selection of additional add-ons in online education according to the level of interest among students	A3
Cui, 2023	Creating attractive content using the facilities and capabilities of the digital space, such as the use of multimedia	A4
Roslina et al., 2017	Appropriate technical and technological infrastructure	A5
Kadam, 2023	The existence of intelligent evaluation systems considering individual characteristics	A6
Shakhina et al., 2023	Interactive, continuous, and integrated communication with students	A7
Wang et al., 2021	Online and intelligent monitoring and management systems	A8
Wang et al., 2021	Ability to expand access to technology	A9

Research Method

This study aims to analyse the causal relationships among the key factors influencing the empowerment of smart education in the age of digital technologies. The research procedure consisted of two main stages. First, potential factors affecting the empowerment of smart education were identified through a comprehensive literature review. Based on this review, an initial list of twenty factors was developed. These factors were then evaluated by a panel of experts specialising in education and digital education policy. Using a five-point Likert scale, experts assessed the relevance and importance of each factor. Based on the level of consensus among the experts, the list was refined and reduced to nine key enabling factors, which are presented in Table 1.

In the second stage, the relationships among these factors were analysed using the fuzzy DEMATEL method. Multi-criteria decision-making (MCDM) methods are widely used to analyse complex decision problems involving multiple interrelated criteria. Among these methods, the DEMATEL (Decision-Making Trial and Evaluation Laboratory) technique is particularly suitable for identifying cause-and-effect relationships among factors within complex systems.

The DEMATEL method allows researchers to construct a structural model that visualises the interdependencies among factors and distinguishes between influencing (cause) factors and influenced (effect) factors. Compared with other MCDM techniques such as AHP or ANP, DEMATEL is especially useful for exploring the causal structure of relationships among variables rather than merely prioritising them.

However, many real-world decision problems involve uncertainty and ambiguity in expert judgements. To address this limitation, fuzzy set theory, introduced by Zadeh (1965), can be integrated with the DEMATEL method. The fuzzy DEMATEL approach enables linguistic evaluations provided by experts to be converted into fuzzy numbers, thereby providing a more realistic representation of uncertain human judgements.

Therefore, the fuzzy DEMATEL method was applied in this study to analyse the causal relationships among the nine factors influencing the empowerment of smart education. In order to collect expert evaluations, linguistic variables were used to represent different levels of influence among factors. These linguistic variables were subsequently transformed into triangular fuzzy numbers. The linguistic scale used in the study is presented in Table 2.

Table 2
Linguistic Fuzzy Scale for DEMATEL's Method

Linguistic variable	Triangular fuzzy scale
Very low	(0, 0, 0.25)
Low	(0, 0.25, 0.5)
Medium	(0.25, 0.5, 0.75)
High	(0.5, 0.75, 1)
Very high	(0.75, 1, 1)

Note. Linguistic assessments provided by experts are converted into triangular fuzzy numbers using this scale.

Many models have been proposed for performing fuzzy DEMATEL calculations, and fuzzification methods have strongly influenced the widely used model. The implementation algorithm of fuzzy DEMATEL is as follows:

Step 1: Calculate the Direct Relationship Matrix

After collecting the opinions of the experts, the fuzzy natural correlation matrix $\tilde{X}$ is formed. The simple fuzzy average method is used to aggregate experts' opinions. If there are n experts and each direct fuzzy matrix object is given with the symbol $\widetilde{X_{ij}}$, then it is calculated as follows:

$$\tilde{X}_{ij} = \left(\frac{\sum l_{ij}}{n}, \frac{\sum m_{ij}}{n}, \frac{\sum u_{ij}}{n} \right) \quad (1)$$

Step 2: Normalise the Direct Correlation Matrix

To normalise T, the value of $\sum u_{ij}$ must be calculated in each row. By dividing the $\tilde{X}$ matrix by the maximum values, the values of the fuzzy normal matrix are obtained:

$$k = \max\left(\sum_{j=1}^{n} u_{ij}\right) \qquad \tilde{N} = \frac{1}{k}\tilde{X} \quad (2)$$

Step 3: Calculate the Complete Relationship Matrix

The relationship $N \times (I - N)^{-1}$ is used to calculate the complete correlation matrix. In the fuzzy method, the standard fuzzy matrix is divided into three definite matrices:

$$N_l = \begin{bmatrix} 0 & l_{12} & \dots & l_{1n} \\ l_{21} & 0 & \dots & l_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ l_{2n} & l_{n2} & \dots & 0 \end{bmatrix}$$

$$N_u = \begin{bmatrix} 0 & u_{12} & \dots & u_{1n} \\ u_{21} & 0 & \dots & u_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ u_{2n} & u_{n2} & \dots & 0 \end{bmatrix} \quad (3)$$

$$N_m = \begin{bmatrix} 0 & m_{12} & \dots & m_{1n} \\ m_{21} & 0 & \dots & m_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ m_{2n} & m_{n2} & \dots & 0 \end{bmatrix}$$

Then the same $I_{n\times n}$ matrix is formed, and the following operations are performed:

$$T_l = N_l \times (I - N_l)^{-1},\ T_u = N_u \times (I - N_u)^{-1},\ T_m = N_m \times (I - N_m)^{-1} \quad (4)$$

$$\tilde{t}_{ij} = \left(t_{ij}^{\ l}, t_{ij}^{\ m}, t_{ij}^{\ u}\right) \quad (5)$$

We define r and c as two n×1 matrices that show the sum of rows and columns of the complete relationship matrix.

$$r = [r_i]_{n\times1} = \left(\sum_{j=1}^{n} t_{ij}\right)_{n\times1} \quad (6)$$

$$c = [c_j]'_{1\times n} = \left(\sum_{i=1}^{n} t_{ij}\right)_{1\times n} \quad (7)$$

In which r_i is equal to the sum of the i^{th} row of the total relation matrix T. Therefore, r_i shows the effect of the sum of factor i on other factors. This effect includes direct and indirect effects. c_j is equal to the sum of j columns of the total relationship matrix T. Therefore, c_j Represents the overall effect that factor j received from other factors. This effect includes direct and indirect effects. Therefore, when j=i, then $(r_i + c_i)$ is equal to the total effect applied and received by factor i. In other words, $(r_i + c_i)$ shows the importance of factor i in the system. Also, $(r_i - c_i)$ represents the net effect that factor i exerts on the whole system. When $(r_i - c_i)$ is a positive value, it means that factor i is an influencing factor in the whole system, and when $((r_i - c_i))$ is a negative value, which means that factor i is an influential factor in the system.

Step 4: Determining the Threshold Value and Relational Map

In many studies, to show the structural relationship between factors while keeping the system's complexity manageable, it is necessary to set a threshold value of p to display only insignificant effects in T. Only the products in the T matrix that are greater than the threshold value should be selected and displayed in the causal relationship map diagram. In this step, we obtain the sums of the rows (D) and the columns (R) of the complete communication matrix. And then, we calculate the value of $D + R$ and $D - R$. In this phase, diffusing product relationships are used to defuzzify the values.

Research Findings

In this research, the factors affecting smart education in the age of digital technologies have been evaluated. For this purpose, in the first stage, as presented in Table 1, the most critical factors were identified through a literature review and refined through experts' opinions. Also, this research used the fuzzy DEMATEL method to assess the effects of factors on one another. For this purpose, fuzzy questionnaires were sent to fifteen experts for detailed analysis. These experts were selected from among active experts in education, policy-making, and monitoring of smart education. Experts have strong records in the field of study and were selected based on researcher availability. The experts were asked to express their views on the extent of the internal effects of these practical factors based on linguistic variables. Thirteen of these questionnaires were completed and received. Therefore, the final fuzzy DEMATEL analysis was conducted on 13 valid expert responses. A fuzzy direct relationship matrix was formed for the factors affecting the empowerment of intelligent education, as presented in Table 3. In addition, Table 4 shows the general fuzzy relationship matrix.

The sums of the rows and columns of the total relation matrix were calculated to construct the causal map of the factors influencing smart education. These values are called R-effective vectors and D-effective vectors. In the DEMATEL analysis, D represents the

Table 3
Fuzzy Direct Relati onship Matrix Between Factors Affecting the Empowerment of Smart Education

A1				A2			…			A8			A9		
A1	0	0	0				…	…	…	0.85	0.77	0.25	0.84	0.56	0.21
A2	0.85	0.75	0.45	0	0	0	…	…	…	0.92	0.81	0.24	0.82	0.75	0.34
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
A8	0.95	0.77	0.35	0.84	0.66	0.22	…	…	…	0	0	0	0.88	0.65	0.21
A9	0.91	0.81	0.27	0.89	0.74	0.35	…	…	…	0.84	0.66	0.22	0	0	0

Note. Each cell represents the aggregated fuzzy evaluation of the direct influence of one factor on another, derived from experts' linguistic assessments and converted into triangular fuzzy numbers.

Table 4
The Matrix Of the Entire Fuzzy Relationship Between the Factors Affecting the Empowerment of Smart Education

	A1			A2			…			A8			A9		
A1	0.22	0.11	0.04				…	…	…	0.19	0.11	0.05	0.11	0.10	0.04
A2	0.11	0.10	0.05	0.21	0.10	0.07	…	…	…	0.17	0.10	0.05	0.27	0.11	0.01
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
A8	0.22	0.12	0.04	0.22	0.11	0.02	…	…	…	0.14	0.10	0.05	0.16	0.10	0.02
A9	0.22	0.08	0.04	0.21	0.09	0.06	…	…	…	0.15	0.10	0.05	0.14	0.10	0.04

Note. The matrix presents the total (direct and indirect) fuzzy influence of each factor on all other factors, as derived from the fuzzy DEMATEL procedure. The values combine experts' linguistic assessments, converted into triangular fuzzy numbers, and capture both primary (direct) impacts and secondary (indirect) propagation effects within the system.

sum of the effects exerted by a factor on other factors, while R represents the sum of the effects received from other factors. The values of $(D + R)$ indicate the overall importance of each factor in the system, while $(D \quad R)$ identifies whether a factor belongs to the cause group (positive values) or the effect group (negative values). The results are shown in Table 5.

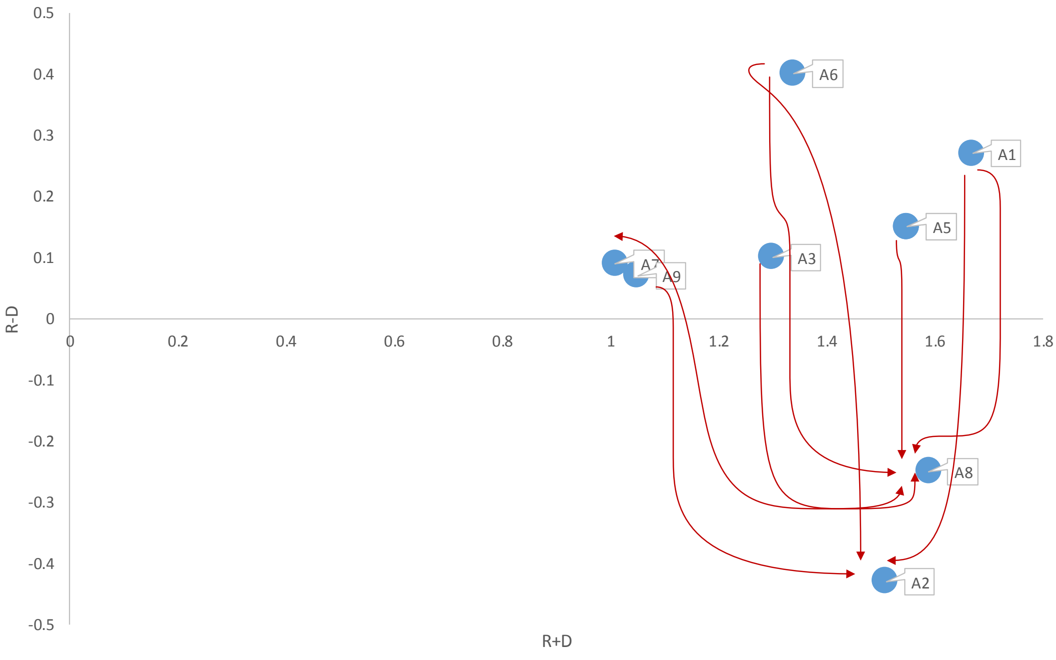
The results show that teachers' and students' technical skills, technological infrastructure, and the production of attractive content are among the most influential factors in empowering smart education in the digital age. These factors also affect increasing social skills and attention to privacy. Therefore, these things should always be considered for developing

Table 5
The Results of Calculating the Internal Effects of Factors Affecting the Empowerment of Smart Education

Code	Effective factor	*D*	*R*	*D + R*	*D – R*
A1	Technical skills of teachers and students	0.97	0.7	1.67	0.27
A2	Social and security skills and understanding of privacy	0.54	0.97	1.51	–0.43
A3	Selection of additional add-ons in online education according to the level of interest among students	0.7	0.6	1.3	0.1
A4	Creating attractive content using the facilities and capabilities of the digital space, such as the use of multimedia	0.85	0.7	1.55	0.15
A5	Appropriate technical and technological infrastructure	0.85	0.7	1.55	0.15
A6	The existence of intelligent evaluation systems considering individual characteristics	0.87	0.47	1.34	0.4
A7	Interactive, continuous, and integrated communication with students	0.55	0.46	1.01	0.09
A8	Online and intelligent monitoring and management systems	0.67	0.92	1.59	–0.25
A9	Ability to expand access to technology	0.56	0.49	1.05	0.07

Note. D represents the sum of the effects exerted by each factor on the others, *R* represents the sum of the effects received from other factors, *D + R* indicates the overall importance of a factor in the system, and *D – R* distinguishes cause (positive) and effect (negative) factors.

Figure 1
Causal Map of the Key Factors Influencing Smart Education in the Age of Digital Technologies



Note. Technical skills of teachers and students; A2 – Social and security skills and understanding of privacy; A3 – Selection of additional add-ons in online education according to the level of interest among students; A4 – Creating attractive digital content using the facilities and capabilities of the digital space (e.g., multimedia); A5 – Appropriate technical and technological infrastructure; A6 – Existence of intelligent evaluation systems considering individual characteristics; A7 – Interactive, continuous, and integrated communication with students; A8 – Online and intelligent monitoring and management systems; A9 – Ability to expand access to technology.

and implementing smart education. The effect and effectiveness of the factors obtained in this research are shown in Figure 1.

Discussion and Implications

The results of the fuzzy DEMATEL analysis reveal several important insights into the structure of relationships among the factors influencing the empowerment of smart education. The analysis not only identifies the most important factors but also distinguishes between those that act as causal drivers and those that function primarily as resulting factors within the system.

The findings indicate that the technical skills of teachers and students (A1) are among the most influential factors in the system. With the highest value of ($D + R$), this factor demonstrates the strongest overall interaction with other variables. This result confirms previous studies emphasising the critical role of digital competencies in the effective implementation of smart education environments (Morgado et al., 2021; Shakhina et al., 2023). Teachers and students who possess strong digital skills are better able to utilise digital tools, participate in online learning environments, and adapt to technological innovations in education.

Another significant factor identified in the analysis is appropriate technical and technological infrastructure (A5). The results show that infrastructure plays a central role in enabling other elements of smart education. Without reliable internet connectivity, digital platforms, and technological support systems, implementing innovative learning methods becomes difficult. This finding is consistent with earlier research highlighting infrastructure as a foundational condition for digital transformation in education (Roslina et al., 2017; Zhou et al., 2023).

The creation of attractive digital learning content (A4) also emerged as an important driver within the system. Engaging multimedia materials and interactive learning environments can significantly increase students' motivation and participation in digital learning systems. This supports previous studies suggesting that the effectiveness of technology-enhanced education depends not only on access to technology but also on the quality and design of digital learning materials (Cui, 2023).

In contrast, several factors were identified primarily as effect factors, meaning that they are influenced by other variables in the system. For example, social and security skills and understanding of privacy (A2) and online monitoring and management systems (A8) show negative values in the ($D – R$) indicator, indicating that they are mainly affected by other enabling suggests that impro factors rather than acting as primary drivers. This vements in infrastructure, digital competencies, and content development may indirectly contribute to strengthening these aspects of smart education systems.

The causal relationships identified in the study also highlight the importance of integrated communication with students (A7) and access to technology (A9) as supporting elements in the development of smart education ecosystems. These factors help create a more interactive and inclusive learning environment where students can actively participate in digital learning processes.

From an educational perspective, the findings highlight the importance of strengthening digital competencies among teachers and students. Educational institutions should invest in continuous professional development programs that help educators acquire both technical and pedagogical skills necessary for teaching in digital environments. Training programs focusing on digital pedagogy, instructional design, and the effective use of educational technologies can significantly improve the quality of smart education systems.

Furthermore, the development of high-quality digital learning content should be considered a strategic priority. Interactive multimedia resources, adaptive learning materials, and student-centred instructional designs can enhance learner engagement and support more effective knowledge acquisition.

At the institutional level, the results emphasise the importance of developing appropriate technological infrastructure and governance mechanisms. Educational institutions must ensure reliable access to digital platforms, learning management systems, and communication technologies that support online and blended learning.

In addition, the implementation of intelligent monitoring and evaluation systems can help institutions track learning outcomes, identify areas for improvement, and ensure the quality of digital education programs. Institutional policies should therefore promote the integration of digital technologies into teaching, learning, and assessment practices.

The findings also have important implications for educational policy and strategic planning. Governments and educational authorities should prioritise investments in digital infrastructure and technology access in order to reduce inequalities in educational opportunities. Policies that promote digital inclusion and equitable access to educational technologies are essential for the successful implementation of smart education systems.

Moreover, policymakers should support the development of national digital education strategies that encourage collaboration between educational institutions, technology providers, and policymakers. Such strategies can help ensure that technological innovations are effectively integrated into educational systems while addressing issues such as data security, privacy protection, and ethical use of digital technologies.

Overall, the results demonstrate that empowering smart education requires a holistic, systemic approach that integrates technological infrastructure, digital competencies, pedagogical innovation, and supportive institutional policies. Understanding the causal relationships among these factors can help educators, administrators, and policymakers design more effective strategies for the development of smart education in the digital era.

Conclusion

The rapid development of digital technologies has significantly transformed educational systems worldwide, accelerating the transition toward smart and technology-enhanced learning environments. In this context, understanding the key factors that empower smart education has become an important research and practical challenge. The aim of this study was to identify the critical factors influencing the empowerment of smart education and to analyse the causal relationships among these factors using the fuzzy DEMATEL method.

Based on a comprehensive literature review, an initial set of twenty potential factors influencing smart education empowerment was identified. Through expert evaluation and refinement, this list was reduced to nine key enabling factors representing technological, pedagogical, organisational, and social dimensions of smart education systems. The fuzzy DEMATEL analysis was then applied to examine the cause-and-effect relationships among these factors.

The results indicate that teachers' and students' technical skills, technological infrastructure, and the creation of attractive digital learning content are among the most influential drivers in the system. These factors play a critical role in enabling other elements of smart education and significantly influence the development of effective digital learning environments. In particular, the findings highlight that improving digital competencies and ensuring access to appropriate technological infrastructure are essential prerequisites for the successful implementation of smart education initiatives.

In contrast, factors such as social and security skills, online monitoring systems, and interactive communication with students were identified primarily as effect factors within the system. This suggests that improvements in infrastructure, digital competencies, and digital learning resources may indirectly enhance these elements of smart education environments.

The study contributes to the existing literature by providing a causal framework for understanding the interrelationships among factors influencing the empowerment of smart education. Unlike previous studies that primarily identify individual determinants, this research demonstrates how these factors interact within a broader system and highlights the key drivers that influence other components of digital learning ecosystems.

From a practical perspective, the findings suggest that educational institutions and policymakers should prioritise investments in digital infrastructure, teacher training, and the development of high-quality digital learning content. Strengthening digital competencies among educators and students can significantly enhance the effectiveness of technology-enhanced learning environments. At the same time, institutional governance mechanisms and monitoring systems should support the integration of digital technologies into teaching and learning processes.

Despite its contributions, this study has several limitations. First, the analysis is based on expert evaluations, which may reflect subjective judgements and may not fully represent all perspectives within the educational sector. Second, the number of experts involved in the evaluation process was limited. Future research could expand the sample of experts and apply alternative analytical approaches to validate the findings. Further studies may also explore the application of other multi-criteria decision-making methods or empirical data to examine the relationships among smart education factors in different educational contexts.

Overall, the findings of this study highlight the importance of adopting a systemic and integrated approach to the development of smart education. By understanding the causal relationships among technological, pedagogical, organisational, and social factors, educational stakeholders can design more effective strategies to support digital transformation and improve the quality of education in the digital era.

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Examining the Adoption of Natural Language Processing in HR Practice: An Empirical Investigation Using TAM

Abstract

This paper discusses how employees respond to and embrace the idea of using chatbots to perform their human resources tasks and roles. This paper aims to investigate the Technology Adoption Model (TAM) constructs and two external factors to identify employees' attitudes toward and acceptance of chatbots for HR functions. A closed-ended questionnaire with a 7-point Likert scale was developed with a clear structure to collect data from a diverse group of professionals, including HR managers, administrative staff, and other employees who interact with HR functions in their organisations from various sectors within the Delhi-NCR region, including the IT, finance, and manufacturing industries. The cross-sectional data collected from 237 respondents for this study were analysed through Partial Least Squares Structural Equation Modelling (PLS-SEM). The results of the study revealed a significant positive influence of Perceived Ease of Use (PEOU) and Technology Enthusiasm (TE) on Perceived Usefulness (PU). However, PU alone was not a significant determinant of employees' attitudes towards chatbot adoption.

Keywords: TAM, chatbots, Technology Adoption Model, technology enthusiasm, HR functions, perception

Introduction

Over the years, numerous advances have attained a stage where technology has been blended with Human Resource Management (HRM) and related terminologies of HRM Systems (HRIS), Digital HRM (DHRM), Automated HR (AHR), Enterprise Resource Planning (ERP), Internet of Things (IoT) and data mining (Bondarouk, 2017; Nawaz & Gomes, 2017; Stone, 2015). Regarding AI potential, it is crucial to underscore that AI chatbots, especially ChatGPT, are considered versatile software for HR automation and enhancing the candidate experience (Allal-Chérif et al., 2021; Kshetri, 2021). Using Machine Learning (ML) techniques and Natural Language Processing (NLP), these chatbots reply to the conversation in a way that is close to the human interaction, and they can be widely used in different fields of HR functions, including recruitment, onboarding and engagement of the employees (Merlin & Jayam, 2018). The vigour of information technology innovations in business has become increasingly evident. As these technologies advance, they are poised to bring about more drastic changes to the natural world of human resource management within organisations, enhancing work efficiency, staff morale, and organisational performance (Anitha & Shanthi, 2021; Jitgosol et al., 2019).

In recent years, there has been growing research and discussion on the use of chatbots in organisations, especially those serving as support for internal operations and HRM (Carter & Knol, 2019; Dutta et al., 2023). These are the AI-based chatbots he added, designed to make HR processes less time-consuming, employees happier, and organisations work more efficiently (Taule et al., 2022). With the use of NLP and other machine learning techniques, chatbots can perform various functions, including answering general employee queries and even handling most recruitment processes,

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freeing HR professionals to undertake more strategic tasks (Dodda et al., 2025). The proposed application of conversational AI and HR Chatbots for international human resource development (IHRD) offers opportunities to increase productivity and excellent prospects for efficiency in the process (Andreas, 2024).

The existence of a gap in the theoretical understanding of the need to identify the essence of moving AI-powered chatbots into HR functions allows us to conclude that the discussed research is highly justified. Although the Technology Acceptance Model has been widely used in previous studies to generalise to technological tools, its predictive ability remains lower in new, human-interactive AI contexts, such as HR chatbots, where the essence of emotional, behavioural, and sustainability-related variables can be critical. Current models pay little attention to the roles of employee mindset, technological enthusiasm, and environmental awareness in adoption decisions within the organisational context. This paper helps narrow that gap by building on TAM by incorporating context-relevant constructs and empirically showing that conventional predictors, such as perceived usefulness, might not be sufficient to explain user attitudes toward HR applications. Given the growing use of AI in recruitment, onboarding, and employee engagement, it is important and well-timed to develop a more sophisticated, humanistic theoretical framework; thus, the present research can be a valuable input to the literature on technology adoption.

Despite the great potential chatbots might have for improving and automating various processes in the Human Resources department, many factors remain unclear about their use by employees and human resources managers. Chatbots are still at the stage of exploration in organisations whereby they are only beginning to apply them and this comes with many challenges some which are; usability, reliability, privacy issues all of which may impact the acceptance of use of chatbot among users and thus there is potential for the future development and usage of chatbots (Jaiswal et al., 2025; Rahmani & Kamberaj, 2021; Sakib, 2024). Therefore, understanding the factors that shape employees' perceptions of using and embracing chatbots in a given context is significant. Since this concern was the research focus, the current study sought to understand employees' acceptance of chatbots and the critical factors driving it within the technological context, particularly in the execution of Human Resource activities. The study will also seek to establish the factors that make this a new research topic that has been explored minimally. From this study, developers of chatbots and organisations can benefit by understanding key antecedents of an HR-based chatbot model for employees.

Recent scholarship on algorithmic management highlights how AI systems reshape employee autonomy and monitoring (Sharma & Sengupta, 2024), while research on digital employee experience emphasises the role of chatbots in shaping perceptions of fairness and support (Strohmeier, 2022). Additionally, prior studies have examined TAM in general technology adoption; few have examined how enthusiasm for technology and environmental concern shape acceptance of HR chatbots. This study addresses that gap by extending TAM to include these variables to explain employee attitudes toward HR practice.

Historical Background

To provide conceptual clarity, the literature review is structured into four themes: (1) AI & Chatbots in HRM, technology adoption model and determinants of AI acceptance, extending the framework with Technology Enthusiasm (TE) and Environmental Concern (EC) to ensure a logical flow from general developments in HR technology to the specific constructs examined in this study.

AI & Chatbots in HRM

In the present, rapidly evolving global environment, deploying AI in HRM is considered one of the most critical and rapidly evolving trends replacing popular strategies for managing workforces (Alkhalailah & Mjlae, 2023). Organisations are shifting towards greater reliance on AI, aided by the emerging phenomenon of chatbots, which mimic user engagement by using NLP and ML algorithms to replicate human-like conversations with users (Majumder & Mondal, 2021). AI-powered tool chatbots provide organisations with suitable and well-organised interfaces to facts and facilities for internal matters and administrative purposes (Brandtzaeg & Følstad, 2017). This conversational software provides facilities for a range of HR functions, including application sorting, interview scheduling, responding to frequently requested inquiries, and supporting onboarding and employee engagement (DiRomualdo et al., 2018; Majumder & Mondal, 2021). Chatbots are also seen as a reputation symbol for the organisations as they are the cause of a good image of the company in the market, establishing it as an organisation actively implementing innovative solutions, and showcasing the company's commitment to its employees as a key priority to help attract talented workers and ensure high levels of their engagement (Majumder & Mondal, 2021). Technology Enthusiasm reflects employees' proactive attitudes toward innovation, which has been shown to accelerate the adoption of AI tools in HR contexts (Berner et al., 2023). Environmental Concern, meanwhile, aligns with sustainability-driven HR practices, where digital tools reduce resource use and support eco-friendly operations (Åberg, 2017).

Technology Acceptance Model (TAM)

The TAM model proposed by Davis (1985) is widely cited in various literatures as an ideal model for explaining individuals' acceptance behaviour towards technology. It is an established theory for understanding user approval and their acceptance of technology. Originally, the TAM model was founded on two of the well-known theories from the social psychology domain, namely the 'Theory of Planned Behaviour' and the 'Theory of Reasoned Action', which were then developed by Ajzen and Fishbein in 1980 based on their earlier research work (Fishbein & Ajzen, 1975). TAM has been refined and included repeatedly by other analysts, and it postulates that users' perceptions and attitudes towards technology are very important for their actual use of the technology (Venkatesh & Bala, 2008; Venkatesh & Davis, 2000).

In the context of TAM, two key components, PU and PEOU, are particularly helpful in determining technology acceptance, as they are the significant variables in the model (Davis, 1989; Marangunić & Granić, 2015). The Technology Acceptance Model focuses on four internal factors, consisting of PEOU, PU, ATU, and BI, regarding the actual utilisation of new technologies. The external factors considered as part of the decision-making procedure help formulate the intent to adopt any technology. At the same time, the two outcome variables incorporated are usage and behavioural intention, as posited by Venkatesh et al. (2003). BI measures actual usage and, at the same time, serves as the dependent variable in the PU and PEOU models. TAM was then refined to TAM2 in a 2000 study by Venkatesh and Davis, and subsequently to TAM3, incorporating additional variables, by Venkatesh and Bala in 2008. It is widely accepted across domains due to its flexibility and the inclusion of external variables. The TAM has been dynamic and provides a robust theoretical foundation for the acceptance of technology by extant and expected users across diverse domains and environments. About 40–50% of people's readiness to embrace technology may be accounted for by ATU, PU, and PEOU, which collectively form the core TAM variables (Park, 2009).

Attitude Towards Usage (ATU)

In TAM, 'Attitude Towards Usage (ATU)' is the sum of the user's beliefs regarding the positive or negative disposition they hold towards a specific technology that might affect their likelihood of using that technology (Davis, 1989; Liébana-Cabanillaset al., 2014). ATU refers to the user's personal preference and subjective evaluations about a particular technology, which is a complex concept. Previous research also revealed a favourable, significant association between individual attitude and ultimate behaviour (Bhatt & Shiva, 2020; Yang, 2012).

H1: Attitude Towards Usage (ATU) has a positive influence on employees' Behavioural Intention (BI) towards chatbots.

Behavioural Intention (BI)

Since Behavioural Intention (BI) forecasts a person's future behaviour, this construct serves as a key component of TAM (Davis, 1989). One of the two main concepts in the 'TAM' is behavioural intention, which describes a person's goal to utilise a specific technology or system (Davis, 1989). Intention is the likelihood of the intended behaviour wherein an individual will perform a given behaviour (Fishbein & Ajzen, 1975). While various factors, including attitudes towards a new technology and external stimuli, can influence behavioural intention, TAM, which is based in the cognitive response area of human psychology, primarily focuses on two major constructs: PU and PEOU (Hampshire, 2016). The hypothesis, as mentioned below, has been tested in various studies and has consistently been found to yield an absolute positive, significant correlation between a person's behaviour and attitude (Bhatt & Shiva, 2020; Yang, 2012).

H2: Behavioural Intention (BI) has a positive influence on the Actual Usage (AU) of chatbots by employees.

Environmental Concern (EC)

Attitudes, awareness and responses to environmental issues include the kinds of interactions users can exhibit toward new technology or software in terms of their environmental concern. Prior studies have shown that people with higher Levels of environmental concern exhibit more positive environmental attitudes and behaviours (Bhatt & Shiva, 2020; Yoon, 2018). Environmental concerns primarily focus on their ability to add value to the sustainability process. Chatbots have the potential to free people from physical facilities and material resources, thereby positively impacting energy conservation and reducing CO_2 emissions (berg, 2017).

H3: Environmental Concern (EC) has a positive influence on Attitude Towards Usage (ATU) of chatbots.

Technology Enthusiasm (TE)

Technology anxiety and technology enthusiasm are widely accepted as constructs that help to describe how people perceive and interact with technology (Anderberg et. al., 2019). Technology integration that is appropriate for users, development, and implementation is a significant step towards widespread acceptance. Berner et al. (2023) emphasise that all these attitudes are important in the development of a person's relationship with technology. Not only do they mention the application or the interaction with the specific technology, but they also impact the extent and type of usage or adoption of new technological procedures. Technology acceptance, usage and interest have also been associated with the personality (Berner et al., 2023). Hence, the given hypotheses have been constructed based on the literature review.

H4: Technology Enthusiasm (TE) has a positive influence on the Perceived Ease of Use (PEOU) of chatbots.

H5: Technology Enthusiasm (TE) has a positive influence on the Perceived Usefulness (PU) of chatbots.

Perceived Ease of Use (PEOU)

Perceived Ease of Use '(PEOU)', being a sub-factor of TAM, refers to the amount of effort that a user anticipates in order to operate any technology or IT application (Davis et al., 1989). 'PEOU' significantly and positively impacts the ATU and BI (Park et al., 2015), as the technology that is easy to use is often perceived as useful by the users (Davis et al., 1989). Users' perceptions of chatbots were strongly shaped by their perceived usefulness and user-friendliness (Kasilingam, 2020). The literature found that it is convenient for customers to obtain product or service information through chatbots and to engage in customer interactions, due to constructs such as PU and PEOU (Pillai & Sivathanu, 2020; Selamat & Windasari, 2021). Chatbot technology has been anticipated to be easy to use, influencing PU in various other ways, such as shopping and education (Al-Abdullatif, 2023; Kasilingam, 2020).

H6: Perceived Ease of Use (PEOU) has a positive influence on employees' Attitude Towards Usage (ATU) of chatbots.

H7: Perceived Ease of Use (PEOU) has a positive influence on the Perceived Usefulness (PU) of chatbots.

Perceived Usefulness (PU)

Perceived Usefulness PU is stated as one's belief that a particular application or technology would likely increase one's performance and efficiency to perform their job (Davis et al., 1989). Some researchers have highlighted that information systems have the potential to generate content that enhances Perceived Usefulness (Huang & Chueh, 2021; Lee & Lehto, 2013). The researchers have further posited that PU is a significant factor influencing the adoption of a particular technology (Elmorshidy et al., 2015; Selamat & Windasari, 2021). PU also affects user attitudes and behaviours, as prior research has shown that PU is consequential for user attitudes and behaviour towards the use of chatbots (Elmorshidy et al., 2015; Gümüş & Çark, 2021; Murtarelli et al., 2023).

H8: Perceived Usefulness (PU) has a positive influence on employees' Attitude Towards Usage (ATU) of chatbots.

Research Methodology

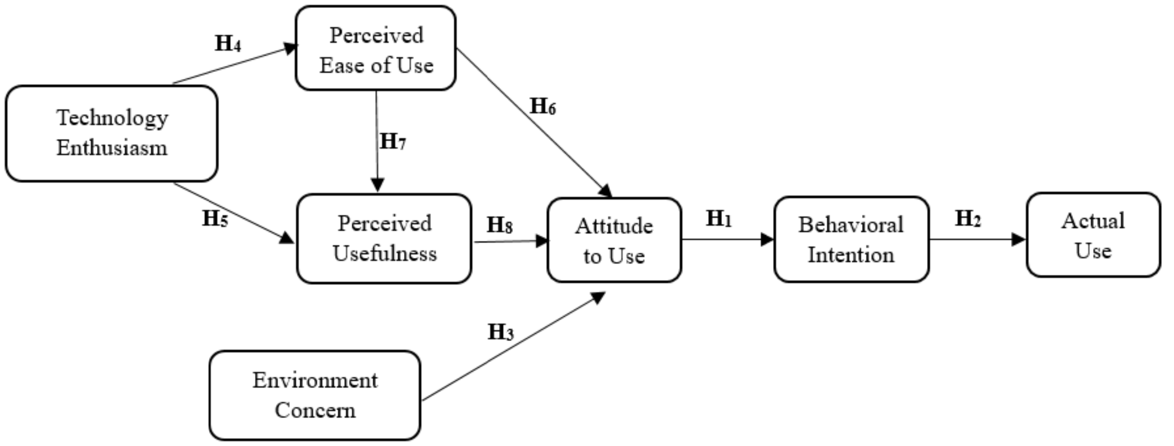
Research Design

This study employs a multi-indicator model that incorporates many reflective components to evaluate various latent variables in the technology acceptance model of chatbots in human resource management. The data was collected from a diverse group of professionals, including HR managers, administrative staff, and employees from support functions like payroll staff, training coordinators, and IT support personnel who regularly interact with HR systems. Their inclusion ensured a broader perspective on chatbot adoption beyond HR specialists. who interact with HR functions in their organisations from various sectors within the Delhi-NCR region, including the IT, finance, and manufacturing industries. These sectors were deliberately chosen because they represent industries with high levels of HR automation, diverse workforce structures, and varying degrees of exposure to digital HR practices, making them suitable for testing chatbot adoption across different organisational contexts. The collected data are cross-sectional. The study was conducted from January, 2024 to May, 2024. This study follows a descriptive research design.

Measurement Scales

To elicit first-hand information from the target respondents, a 7-point Likert-scale closed-ended questionnaire with a clear structure was developed,

Figure 1
Conceptual Model



Note. Figure shows the conceptual framework of the study. The model builds on TAM and UTAUT, linking Perceived Ease of Use and Perceived Usefulness to Attitude Towards Usage, which in turn influences Behavioral Intention and Actual Usage. It shows how different factors are connected through hypotheses (H1–H8).

as shown in the appendix. The questionnaire had two parts: Section I was a demographic section that asked respondents about themselves, and Section II comprised test questions presented on a range of scales. All used scales were standardised, but a few modifications were made to align with the study's research objective. A panel of three HR academics and two industry practitioners reviewed the items to ensure contextual relevance. In addition to the survey, a post-survey focus group discussion (FGD) was conducted with HR managers, employees, and academic experts.

Sampling & Data Collection

The current study used a snowball sampling technique, which enabled access to a diverse range of respondents, initially reaching out to 400 potential respondents via online platforms such as WhatsApp groups and email. Only those respondents who answered affirmatively to the screening question confirming prior use of HR chatbots were allowed to proceed with the survey. Of these 400, 256 responded, and after data cleaning, 237 responses were retained for analysis, exceeding the suggested number of respondents by G*Power. Therefore, the final sample size of 237 was considered to be sufficient and adequate for this study.

Data Analysis

The normal distribution was missing among the data collected for this study. Nevertheless, when the data are not normally distributed, PLS-SEM is deemed appropriate (Henseler, 2010). Therefore, based on the data and the level of the conceptual model, the researchers adopted SmartPLS software (Ringle et al., 2024) to assess construct validity and reliability and analyse the data to test the above-stipulated hypotheses.

Demographics of Respondents

The present study encompassed respondents aged twenty and older, with 64.55% men and 35.45% women. Additionally, 40.5% of respondents reported an income between five lakh and ten lakh, 32.9% reported an income below five lakhs, and the remainder reported an income above 10 lakhs. These demographics suggest a diverse range of chatbot users, each with varying understandings and behavioural intentions regarding chatbot usage (as depicted in Table 1 given below).

Measurement Model Assessment

This study employed the recommendations provided by Hair et al. (2019) and Hair et al. (2020) to assess the model results. The first step while assessing the measurement model is to check for construct validity. To retain any item within the model, its loading should be above 0.708 (Hair et al., 2020). As shown in Table 2 given below, each item's loading score is above the threshold limit.

Subsequently, we evaluated internal consistency reliability by computing the Composite Reliability and Cronbach's alpha for each construct. Thus, all constructs exceeded the mandatory threshold of 0.70 (Hair et al., 2020; Henseler et al., 2009). Subsequently, construct convergence was assessed by calculating the AVE for all constructs, which exceeded the suggested limit of 0.5 (Hair et al., 2019; Hair et al., 2020). This shows us that each of the constructs studied accounts for at least 50 per cent of the variance between the items. Also, discriminant validity is tested through HTMT in Table 3.

Structural Model Assessment

After measuring the model, the path coefficients were tested to assess the hypothesised relationships linking employees' BI to their use of chatbots. Also, to verify the concluding theoretical and empirical implications of the suggested model, Q^2 Stone-Geisser's value of the main constructs of the study was estimated. It was discovered that the Q^2 values were greater than zero, which confirms that the given model performs fairly well in predicting the above-said constructs (Henseler et al., 2009). The coefficient of determination, R^2, indicated that the explanatory variables explained a substantial amount of variance

Table 1
Respondents' Demographic Profile

	Characteristics	Frequency (N = 237)	Percentage
Gender	Male	153	64.55
	Female	84	35.45
Age	20–30 years	103	43.46
	30–40 years	91	38.40
	Above 40 years	43	18.14
Annual Income (Rs.)	Less than 5 lacs	78	32.91
	5–10 lacs	96	40.50
	Above 10 lacs	63	26.59

Table 2
Discriminant Validity – Heterotrait Monotrait Ratio (HTMT)

Construct	Coding	Indicator Loading	Cronbach's Alpha	Composite Reliability (rho_a)	AVE
Attitude Towards Usage	ATU1	0.887	0.941	0.951	0.85
	ATU2	0.935			
	ATU3	0.927			
	ATU4	0.939			
Actual Usage	AU1	0.959	0.957	0.957	0.92
	AU2	0.957			
	AU3	0.962			
Behavioural Intention	BI1	0.937	0.913	0.913	0.852
	BI2	0.931			
	BI3	0.901			
Environmental Concern	EC1	0.895	0.904	0.908	0.839
	EC2	0.932			
	EC3	0.921			
Technology Enthusiasm	TE1	0.9	0.936	0.939	0.84
	TE2	0.937			
	TE3	0.919			
	TE4	0.909			
Behavioural Intention	PEOU1	0.875	0.928	0.931	0.775
	PEOU2	0.903			
	PEOU3	0.868			
	PEOU4	0.888			
	PEOU5	0.868			
Perceived Usefulness	PU1	0.836	0.936	0.939	0.798
	PU2	0.923			
	PU3	0.906			
	PU4	0.932			
	PU5	0.866			

Table 3
Discriminant Validity – Heterotrait Monotrait Ratio (HTMT)

	AU	ATU	BI	EC	TE	PEOU	PU
AU							
ATU	0.384						
BI	0.611	0.382					
EC	0.443	0.551	0.513				
TE	0.378	0.308	0.285	0.494			
PEOU	0.689	0.331	0.423	0.312	0.455		
PU	0.38	0.389	0.353	0.437	0.345	0.347	

Note. AU: Actual use; ATU: Attitude Towards Use; BI: Behavioural Intention; EC: Environment Concern; TE: Technology Enthusiasm; PEOU: Perceived Ease of Use; PU: Perceived Usefulness.

in the endogenous constructs, reflecting the model's in-sample predictive or explanatory capacity (Hair et al., 2019). The minimum acceptable R^2 threshold depends on the study context, and even lower values can be considered acceptable within the scope of PLS-SEM analysis.

To test the proposed hypotheses, bootstrapping with 5,000 subsamples was performed, and in Table 5, all path coefficients were significant at $p < 0.05$, except for one coefficient, with the values of f^2. Among the eight hypotheses in this study, six appear significant at the 1% level, while one appears significant at the 5% level (Table 4).

TE significantly and positively impacts PEOU ($\beta = 0.428$, $p < 0.01$) and PU ($\beta = 0.228$, $p < 0.01$). So, H4 and H5 hypotheses were duly supported by the result. The PEOU in Hypothesis H6 ($\beta = 0.142$, $p < 0.05$) has a positive and significant influence on employees' ATU of chatbots, as it assists them with various tasks, such as HR, IT support and other organisational issues. Thus, it suggests that chatbots, which employees perceive as easy to use, will lead them to adopt a positive attitude towards them. Similarly, Hypothesis H7 is accepted at the 1% significance level, indicating that PEOU has a significant and positive impact on PU ($\beta = 0.227$, $p < 0.01$). At last, PU also has a positive impact on ATU but failed to be accepted ($\beta = 0.162$, $p = 0.055$), thus H8 was rejected.

Discussion

This study extends the Technology Acceptance Model (TAM) to examine chatbot adoption in HRM, enriching domains such as AHR, HRIS, ERP, DHRM, IoT, and data mining, and confirms TAM's effectiveness in predicting user attitudes toward AI-based HR tools by integrating perceived usefulness, ease of use, environmental concern, and technology enthusiasm as key determinants (Bai et al., 2022; Hmoud & Várallyai, 2020; Khan et al., 2024; Yoo et al., 2018). In fact, environmental concern compels HR managers and the organisation to adopt this technology, such that Chatbots are also considered a reputation icon for organisations because they aim to enhance the firm's favourable image, especially in the eyes of the public (Majumder & Mondal, 2021).

This research expands the classical Technology Acceptance Model by presenting a contextualisation aligned with AI-based HR practices, thereby enhancing the theoretical impact. In contrast to traditional TAM applications, which place the most significant focus on perceived usefulness and ease of use, the current study incorporates Technology Enthusiasm and Environmental Concern as important boundary conditions that influence employee cognition and intentions to adopt chatbots. This result adds to the theory by suggesting the transition of performance-focused to experience-focused adoption of technology in organisations. Additionally, the research offers a subtle insight into the functioning of AI-based tools in the socio-organisational context, thereby taking TAM a step further toward humanisation and sustainability-focused design. The empirically tested extensions provided by the research enable the development of a theoretically enriched model that can serve as a framework for further research investigating the adoption of AI in HRM, as well as other areas of service in this field.

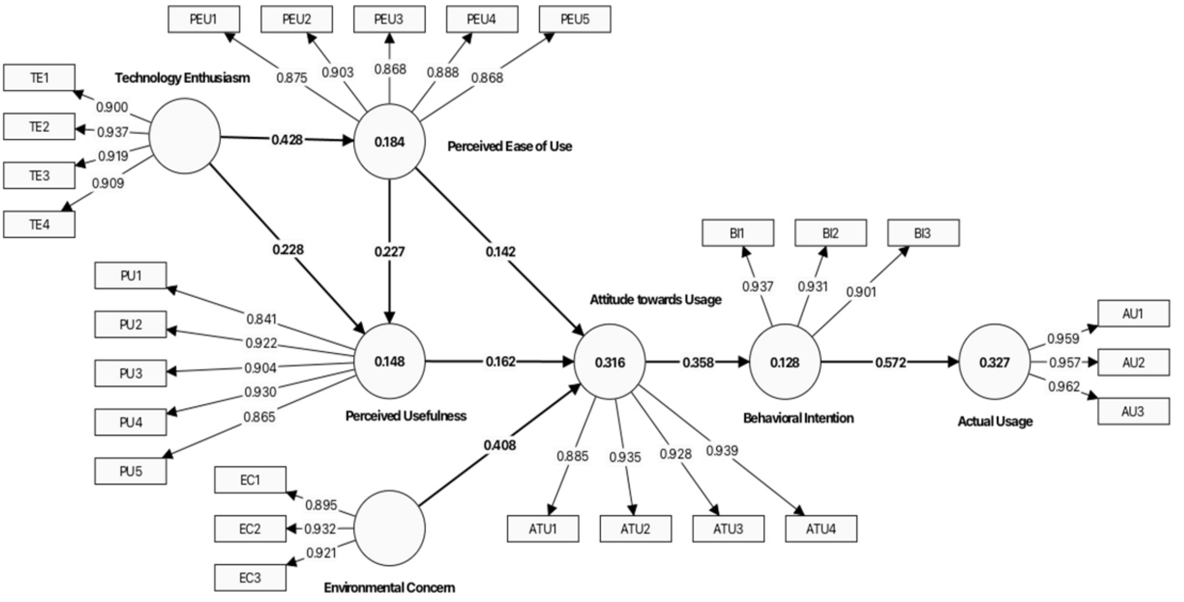
In this research study, PEOU has been established as one of the key constructs of the TAM model that positively affects employees' attitudes, which is in line with the findings of Nemukula (2023), and subsequently influences employees' behavioural intention towards chatbot usage. A smooth user experience and interface can substantially contribute to the two perceived factors: ease of use and usefulness. Chatbot features that PU has improved the sample participants' attitudes towards the implementation of chatbots, with employees reporting a more positive attitude towards the application of chatbots. The employees' BI positively influences the AU of NLP-based chatbots. For HR practice, this means that managers should focus on building employees' behavioural intention through training, communication, and trust-building initiatives,

Table 4
Hypothesis Testing and Relationship With Variables

		β	T statistics	CI 0.95	Significance	VIF Inner	R^2	Q^2	f^2
H1	ATU -> BI	0.358	5.969***	[0.238-0.474]	Yes	1	0.316	0.251	0.147
H2	BI-> AU	0.572	11.699***	[0.475-0.664]	Yes	1	0.128	0.127	0.487
H3	EC -> ATU	0.408	4.994***	[0.25-0.571]	Yes	1.245	–	–	0.196
H4	TE -> PEOU	0.428	6.376***	[0.293-0.56]	Yes	1	–	–	0.225
H5	TE -> PU	0.228	2.878***	[0.068-0.377]	Yes	1.225	–	–	0.05
H6	PEOU -> ATU	0.142	1.996**	[0.001-0.281]	Yes	1.157	0.184	0.173	0.025
H7	PEOU -> PU	0.227	3.091***	[0.079-0.373]	Yes	1.225	–	–	0.049
H8	PU -> ATU	0.162	1.918	[-0.009-0.316]	No	1.273	0.148	0.093	0.03

Note. *** significant at 1%; ** significant at 5%; AU: Actual use; ATU: Attitude Towards Use; BI: Behavioural Intention; EC: Environment Concern; TE: Technology Enthusiasm; PEOU: Perceived Ease of Use; PU: Perceived Usefulness.

Figure 2
Testing the Structural Equation Model



Note. Figure represents the hypothesized pathways among the constructs of the structural equation model depicting the directional relationships specified in the study.

as these directly translate into actual chatbot use in daily HR tasks such as recruitment, onboarding, and employee query handling. This study showed that enthusiasm for technology significantly and positively impacts PEOU and PU. It assists in closing the existing literature gap on chatbots, with a specific focus on the concept's applicability in the enterprise environment, particularly for the implementation of selected elements of HRM processes.

This study contributes to refining technology adoption models by showing that ease of use and enthusiasm are stronger drivers of chatbot adoption than perceived usefulness alone. By adding Technology Enthusiasm and Environmental Concern, the model is extended to HR-specific practices. This highlights how proactive attitudes and sustainability concerns shape employees' acceptance of digital HR tools.

Theoretical Implications and Practical Implications

The current study advances existing knowledge regarding factors affecting the perceived efficiency of chatbots in the workplace, drawing on TAM and an amended UTAUT model that incorporates attitudinal and perceptual factors. Hence, this study employs various constructs such as AU, ATU, BI, EC, TE, PEOU and PU to provide a comprehensive view of co-integration relationships. In addition, to make our conceptual model more precise, they incorporated the variable known as Technology Enthusiasm to expand the knowledge concerning these relationships. The inclusion of TE adds a significant layer to the existing theory by highlighting employees' proactive attitudes towards technological innovations. From an HR perspective, fostering enthusiasm for technology can be achieved by integrating chatbot demonstrations into orientation programs, encouraging peer-to-peer support, and positioning chatbots as tools that reduce administrative burden, thereby allowing HR staff to focus on strategic functions.

Overall, the findings highlight that ease of use and enthusiasm are stronger drivers of chatbot adoption than perceived usefulness alone. HR managers should prioritise intuitive chatbot design, emphasise sustainability benefits to appeal to employees' environmental concerns, and ensure ethical data handling to build trust. These measures will help organisations achieve smoother adoption and maximise the efficiency gains of chatbot integration in HR practice.

Study Limitations and Its Future Scope

The present study did not use any qualitative research methodology; it used only the quantitative method. As PLS-SEM is a quantitative research approach, it is always beneficial to complement it with qualitative data collected from interviews or focus groups to understand the nature of the problem, user attitudes and experiences interacting with chatbots. Therefore, it would be useful for the subsequent research in the same field to use qualitative or, correspondingly, mixed research methods to avoid some of the shortcomings of the quantitative approach discovered in this work. Although the model focuses on TAM with two external variables, future research should incorporate constructs such as trust in AI, privacy concerns, perceived risk, and organisational support to capture the full complexity of HR chatbot adoption. Another limitation of this study was that only 237 respondents participated. Future research based on these constructs should consider increasing the sample size, which will help improve external validity and total internal validity according to the most desirable statistical metrics.

The appendix is available in the online version of the journal.

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Employee Commitment and Total Quality Management as Mediators between Leadership Styles and Innovation

Abstract

The paper analyses the structural relationships among transformational (TLF) and transactional (TL) leadership styles, employee commitment (ECM), Total Quality Management (TQM), and Innovation (INNO). This paper aims to examine the impact of transformational and transactional styles on TQM and ECM; the impact of ECM on TQM; and the impact of ECM and TQM on INNO. The study uses a sample of 100 respondents employed in private-sector organisations in North Macedonia and applies the PLS-SEM method for data analysis. The analysis shows that the transformational leadership style positively impacts both TQM and ECM, whereas transactional leadership has no significant impact on them. Both TQM and ECM positively impact innovation. This study indicates that the more transformational leadership characteristics leaders exhibit, the higher the level of employee commitment and the greater the implementation of Total Quality Management, which in turn leads to increased innovation. This paper extends the empirical literature in the field and benefits the private sector through improved process management.

Keywords: transformational leadership style, transactional leadership style, employee commitment, innovation, Total Quality Management

Introduction

In today's rapidly changing environment, organisations increasingly struggle to survive using traditional practices. Changes over the past decades have significantly influenced how organisations address both internal and external challenges. Recent global developments have further intensified the difficulties organisations face in maintaining financial stability and effective management. To gain a competitive advantage, businesses must increasingly focus on Total Quality Management (TQM). Total Quality Management practices have been shown to contribute directly to business performance growth (Khalfallah et al., 2025). In this context, leadership plays a crucial role in implementing management practices, fostering employee commitment, and promoting innovation.

Research and practice indicate that leadership and employee commitment are essential for the successful implementation of TQM. TQM is widely considered a management philosophy that emphasises employee involvement, continuous improvement, and customer satisfaction. This perspective is also supported by classical authors such as Juran (1988), Deming (1986), and Crosby (1979), who highlighted the importance of customer satisfaction, supplier relationships, continuous process improvement, quality planning, and following clear standards. However, leadership remains a challenge in many modern organisations and requires sustained attention. Kotter and Heskett (1992) were among the first to demonstrate that effective leadership is a critical factor in successful organisational change. Among the most widely studied leadership styles are transformational and transactional leadership, as discussed by Bass (1990) and Yukl (2002). Over the past decade, empirical research has extensively examined these leadership styles in relation to various organisational outcomes.

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A key question remains: what are the effects of TQM on innovation? Does implementing TQM foster greater innovation, given that it reflects an organisational mindset focused on continuous improvement? This study aims to investigate the roles of transformational and transactional leadership styles in shaping employee commitment and TQM, and their impact on organisational innovation.

Several empirical studies have examined the impact of leadership on TQM (Argia & Ismail, 2013; Das et al., 2011; Kumar & Sharma, 2018; Teoman & Ulengin, 2018). Other studies link TQM to improvements in organisational performance (Al-Qahtani et al., 2015; Anil & Satish, 2016; Kalfallah et al, 2025; Demirbag et al., 2006; Fotopoulos & Psomas, 2010; Ngambi & Nkemkiafu, 2015; Qasrawi et al., 2017; Twaissi et al., 2025; Valmohammadi, 2011). Some studies also examine the relationship between TQM and innovation (Ahinful et al., 2024; Antunes et al., 2021). Previous research conceptualises TQM as a set of practices and highlights the important role of leadership and people management in driving innovation (Hoang et al., 2006). Although TQM practices and employee commitment have been found to mediate the relationship between leadership and innovation, empirical evidence remains inconclusive regarding which pathway exerts a stronger influence.

This study extends existing research by using structural equation modelling to compare the indirect effects of leadership on innovation through TQM practices and employee commitment, to identify the dominant pathway. Furthermore, no empirical study has simultaneously examined leadership, employee commitment, TQM, and innovation within a single structural equation modelling framework. This study addresses this gap using a sample from a Western Balkan country, North Macedonia, which remains underrepresented in empirical research on these variables. Countries in this region face an increasing need to adopt modern managerial practices that support long-term sustainability.

The research questions guiding this study are as follows:

- What impact do leadership styles have on employee commitment and the implementation of TQM practices?
- Does employee commitment enhance innovation?
- Does TQM contribute to greater innovation?
- Which pathway exerts a stronger influence on innovation: the indirect effect of leadership through TQM practices or through employee commitment?
- The remainder of the paper is structured as follows. The next section presents the literature review, followed by the theoretical framework and research model. The methodology is then described, followed by the empirical results, discussion, conclusions, limitations, and directions for future research.

Literature Review and Hypotheses

Businesses are operating in an environment characterised by rapid, continuous change that affects all organisational processes. Managing such change requires effective leadership, which plays a central role in shaping employee commitment and guiding organisational practices.

Leadership styles play a very important role in shaping organisational behaviour and achievement. The two approaches most studied by researchers are transformational and transactional leadership, presented by Bass (1990). Transformational leadership focuses on motivating employees, communicating a shared vision, and fostering organisational innovation. In contrast, transactional leadership is based on clear instructions and structured processes, and on monitoring and managing performance through rewards. These two leadership styles have been studied extensively in relation to organisational performance, commitment, and innovation. Other leadership approaches, such as servant leadership, have also been discussed in the literature; however, this study focuses on transformational and transactional leadership because of their strong empirical basis.

The classical authors in the field of Total Quality Management, namely Deming (1986), Juran (1988), and Crosby (1979), have made distinct yet complementary contributions to the Field. Deming emphasised continuous process improvement, highlighting the importance of the overall system rather than focusing solely on individual employees, and the role of supplier collaboration and error reduction. Juran focused on quality planning, quality control, and continuous improvement. Meanwhile, Crosby stressed the importance of doing things right the first time and preventing errors through clearly defined standards.

In addition to these foundational contributions, contemporary approaches have further developed the concept of TQM, including the EFQM Excellence Model. The EFQM model emphasises leadership, people management, continuous improvement, and organisational learning as key drivers of organisational performance (Fonseca, 2022).

Given the evolution of the TQM concept and its broad scope, empirical studies often operationalise TQM using selected dimensions depending on the research context. In particular, studies focusing on employee perceptions tend to emphasise internal organisational practices that are directly observable by employees. In line with this perspective, this study conceptualises TQM along three main dimensions: (1) organisational commitment to quality, (2) continuous improvement practices, and (3) employee involvement in quality-related initiatives.

Accordingly, TQM is expected to play a key role in linking leadership and employee commitment with organisational innovation. Continuous quality improvement, as a core dimension of TQM, enables organisations to meet customer expectations while simultaneously gaining a competitive advantage

(Baftijari et al., 2020). Effective TQM implementation, supported by strong leadership and reinforced by employee commitment, is therefore essential for enhancing organisational innovation and performance.

Previous research highlights the significant role of leadership styles in implementing TQM principles (Bouranta, 2021; Kumar & Sharma, 2018; Teoman & Ulengin, 2018). Bouranta (2021), using structural equation modelling, found a positive, statistically significant effect of transformational leadership on TQM implementation, whereas transactional leadership did not show a significant effect. Similarly, Kumar and Sharma (2018), employing multiple regression analysis on primary data collected in India, reported that leadership styles positively influence continuous improvement practices. Importantly, the authors recommended examining employee commitment as a potentially influential variable in future research. A similar study by Argia and Ismail (2013) also found a positive impact of transformational leadership on TQM.

Based on this literature, the following hypotheses are proposed:

H1: Transformational leadership positively influences TQM implementation.

H2: Transactional leadership positively influences TQM implementation.

Previous research (Emini et al., 2023) highlights the important role of leadership in fostering organisational learning, which in turn supports innovation within organisations. Furthermore, several empirical studies demonstrate a strong positive relationship between transformational leadership and employee commitment (Al-Amin, 2017; Azim et al., 2019; Chin et al., 2019; Jiatong et al., 2022; Milhem et al., 2019). An empirical study in Nigeria also found a positive impact of transformational leadership on employee commitment, while transactional leadership showed a negative effect (Abasilim et al., 2019). In contrast, Mahfouz (2019) reported a positive effect of transactional leadership on employee commitment.

Drawing on prior findings, the following hypotheses are formulated:

H3: Transformational leadership positively influences employee commitment.

H4: Transactional leadership negatively influences employee commitment.

However, the empirical evidence regarding Hypothesis H4 is mixed, with some studies reporting non-significant effects and others reporting negative relationships. Therefore, this hypothesis tests the nature of this relationship within the context of the present study.

The relationship between TQM and innovation has also attracted the attention of researchers. Prajogo and Sohal (2001) argue that TQM and innovation share common foundations, including continuous improvement and an open organisational culture. It is important to note that, as one of the main principles of TQM, continuous improvement is widely considered a form of incremental innovation rather than an opposition to it. Therefore, organisations that implement TQM practices are expected to demonstrate higher levels of innovation. In their empirical study, Prajogo and Sohal (2003) found a positive impact of TQM on innovation using structural equation modelling. However, other studies have reported non-significant results, indicating that empirical evidence remains limited and inconclusive.

Based on this discussion, the following hypothesis is proposed:

H5: TQM implementation positively influences organisational innovation.

Employee commitment is also considered a key driver of innovation. Emini and Zeqiri (2025) suggest that employee learning and development positively influence organisational processes and enhance performance, including innovation. Sedighi et al. (2022) found that employee commitment promotes knowledge sharing, which in turn supports innovation. Similarly, Khassawneh (2022) emphasises that leadership fosters employee dedication and knowledge sharing, ultimately contributing to innovation. Additional studies indicate that employee commitment enhances innovative behaviour within organisations (Hakimian et al., 2016; Nguyen et al., 2019; Xerri & Brunetto, 2013).

Accordingly, the following hypothesis is proposed:

H6: Employee commitment positively influences organisational innovation.

Although prior research has examined individual relationships among leadership, employee commitment, TQM, and innovation, these constructs have largely been studied separately. By integrating transformational and transactional leadership with employee commitment and TQM within a comprehensive mediation framework, this study contributes to a deeper understanding of the mechanisms through which leadership influences organisational innovation.

To address this research gap, the following mediation hypotheses are proposed:

H7: Employee commitment mediates the relationship between transformational leadership and organisational innovation.

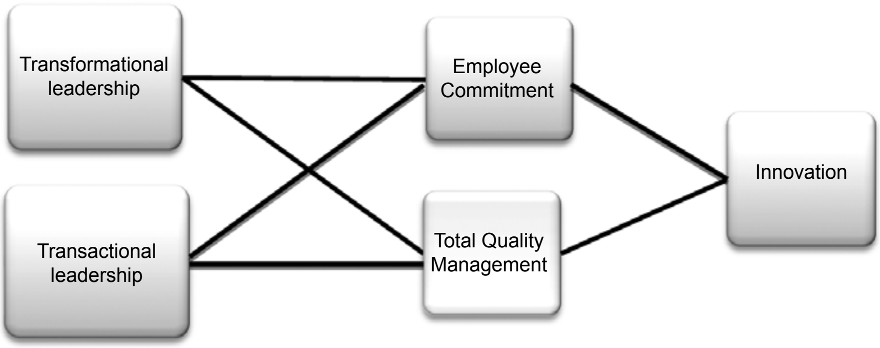
H8: Employee commitment mediates the relationship between transactional leadership and organisational innovation.

H9: TQM implementation mediates the relationship between transformational leadership and organisational innovation.

H10: TQM implementation mediates the relationship between transactional leadership and organisational innovation.

This study aims to identify the most effective pathway through which leadership contributes to innovation, recognising that leadership style, employee commitment, and TQM are interrelated dimensions that jointly enhance organisational performance. Figure 1 illustrates the conceptual research model and the hypothesized relationships among transformational leadership, transactional leadership, employee commitment, TQM, and innovation.

Figure 1
Theoretical Framework



Research Methodology

Research Design

This study employs a quantitative, cross-sectional research design to examine the relationships among transformational leadership, transactional leadership, employee commitment, TQM implementation, and organisational innovation.

Sampling and Data Collection

The study employed a non-probability convenience sampling approach. The questionnaire was distributed electronically via official institutional channels, including the Chamber of Commerce of the Republic of North Macedonia and affiliated business networks. The respondents consisted of employees working in private sector organisations. Given their direct involvement in internal organisational processes, they can be considered competent to assess leadership practices, employee commitment, and quality management activities. Although the respondents may not have been formally trained in quality management systems, the study focuses on employees' perceptions of organisational practices such as leadership behaviour, continuous improvement, and employee involvement, which can be reliably assessed from an employee's perspective.

This approach is consistent with prior empirical research that frequently relies on employee perceptions and self-reported data to assess organisational practices (Hair et al., 2019).

Questionnaire

The questionnaire was divided into five sections. The first section included questions regarding the participants' demographic profiles. A descriptive question regarding ISO 9001 certification was also included to provide contextual information about the organisations. It is important to note that ISO 9001 certification is not treated as equivalent to Total Quality Management (TQM) in this study. Rather, it is used solely as a background indicator of formal quality systems and was not included as a variable in the empirical model.

The second section focused on leadership styles and was adapted from Bass et al. (1996). Specifically, transformational and transactional leadership styles were examined. The third section addressed employee commitment within the organisation, while the fourth section focused on Total Quality Management (TQM). In this study, TQM was conceptualised as a multidimensional construct reflecting key principles such as quality orientation, continuous improvement, and employee involvement. To operationalise this construct, three items were selected to capture these core dimensions. Specifically, the items measure (1) the organisation's commitment to quality, (2) the presence of continuous improvement practices, and (3) the extent to which employees are encouraged to contribute suggestions and initiatives. This approach provides a parsimonious yet theoretically grounded representation of TQM suitable for structural equation modelling.

The final section covered organisational innovation, focusing on the extent to which organisations are open to new ideas, support changes and improvements, and encourage employee involvement in innovation-related processes (Hurt et al., 1997; Prajogo & Sohal, 2003). To operationalise the construct in this study, three items were used: openness to new ideas, support for change and improvement, and employee involvement in the innovation process.

In addition to demographic questions, the questionnaire included five-point Likert-scale items to measure each variable. For each construct, three items were used to ensure reliable and robust measurement.

Table 1 provides an overview of the variables included in the PLS-SEM model, along with their descriptions based on the questionnaire items adapted from the original sources.

The study sample consisted of 100 respondents employed in the private sector in the Republic of North Macedonia. A multivariate approach was employed to examine the multidimensional relationships among the variables using PLS-SEM. PLS-SEM is a multivariate statistical technique used to analyse complex relationships between variables without requiring normally distributed data (Hair et al., 2019). As noted by Hair et al. (2019), this method is particularly suitable for small sample sizes and focuses on maximising the explained variance of the dependent variables.

Table 1
Variable Description

Variable code	Variable name	Description (employee perspective)	Adapted by
TLF	Transformational Leadership Style	Assessment of the extent to which leaders motivate employees, encourage innovative thinking, and communicate a clear organisational vision and goal	Bass et al. (1996)
TL	Transactional Leadership Style	Assessment of the extent to which leaders monitor performance, enforce work standards, and provide rewards based on the achievement of objectives	Bass et al. (1996)
ECM	Employee Commitment	Assessment of the extent to which employees feel committed to the organisation and its goals	Mowday et al. (1979)
TQM	Total Quality Management	Assessment of the extent to which the organisation demonstrates commitment to quality, applies continuous improvement practices, and encourages employee involvement in quality-related activities	Grandzol & Gershon (1998); Yusuf et al. (2007)
INNO	Innovation	Assessment of the extent to which the organisation supports new ideas, encourages innovation, and adapts to changes in the market and technology	Hurt et al. (1997); Prajogo & Sohal (2003)

The sample size is therefore adequate to ensure sufficient statistical power to detect the relationships examined in the model.

To assess the significance of the path coefficients, a bootstrapping procedure with 5,000 resamples and a 95% confidence interval was performed using SmartPLS 4.1.4. SPSS was employed to generate descriptive statistics.

Sample Characteristics

Table 2 presents the demographic and organisational characteristics of the study sample. The sample consisted of 100 employees, with 32% male and 68% female respondents. Most participants were in the 34-44-year-old (50%) or 25-34-year-old (30%) age group. Regarding work experience, 48% reported more than 6 years, while 18% reported less than 1 year. Regarding ISO 9001 certification, 46% indicated that their organisation is ISO 9001 certified, 21% reported no certification, and 33% were unsure.

PLS-SEM Model

Figure 2 presents a visualisation of the PLS-SEM model illustrating the hypothesised relationships among the study variables (see Table 1 for variable descriptions).

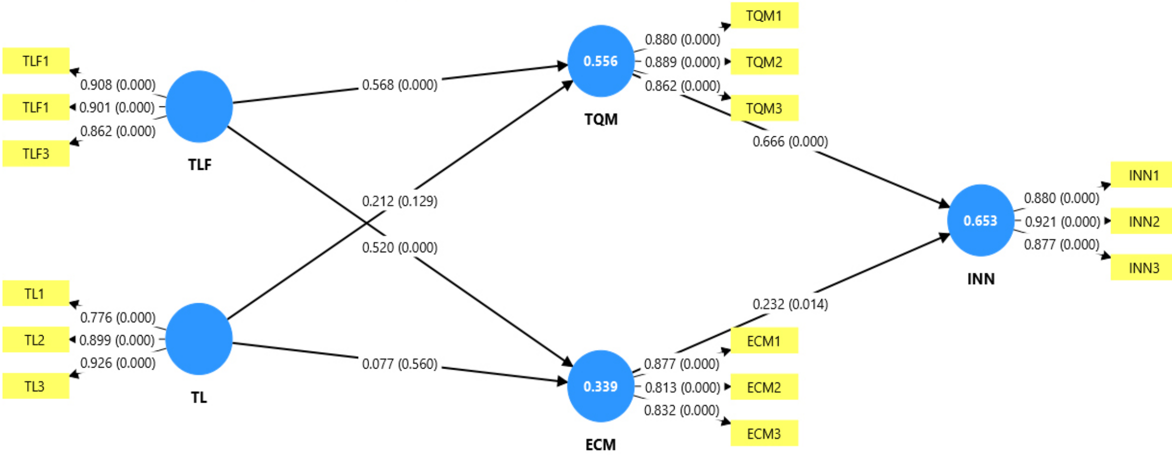
The arrows in the figure represent the structural paths, indicating the effects of leadership styles on ECM and TQM, the influence of ECM on TQM, and the effects of both ECM and TQM on INNO.

Table 2
Descriptive Statistics

Variable	Category	Frequency (*n*)	Percentage (%)
Gender	Male	32	32
	Female	68	68
Age	25–34 years	30	30
	35–44 years	50	50
	45–54 years	7	7
	55+ years	3	3
	Below 25 years	10	10
Work Experience	1–3 years	19	19
	4–6 years	15	15
	More than 6 years	48	48
	Less than 1 year	18	18
Quality Certification	Yes (ISO 9001)	46	46
	No	21	21
	Not sure	33	33

Figure 2

PLS-SEM Visualisation



Note. TLF = Transformational Leadership; TL = Transactional Leadership; TQM = Total Quality Management; ECM = Employee Commitment; INN = Innovation.

Measurement Model Evaluation

To prevent common method bias (CMB), several measures were implemented during the design and distribution of the questionnaire. The questionnaire was anonymous, items for each variable were presented in separate sections, and a Likert scale was used to ensure consistency.

Table 3 presents the outer loadings and variance inflation factor (VIF) values for all measurement items. As shown, all items exhibit outer loadings above the recommended threshold of 0.70, indicating that the indicators reliably measure their respective constructs (Hair et al., 2019). Furthermore, all VIF values are below 3.3 (Kock, 2015), suggesting that common method bias is not a concern in this model.

Table 4 presents the VIF values for all structural paths in the model. All values are below the critical threshold of 3, ranging from 1.335 to 2.610, indicating that multicollinearity is not a concern. This confirms that the relationships identified between constructs are reliable and not biased by overlapping information among predictor variables. The results complement the indicator reliability assessment shown in Table 3, supporting the robustness of the measurement model.

Table 3

Measurement Model Results: Outer Loadings and Variance Inflation Factors (VIF) (Items → Constructs)

Constructs	Item	Outer loadings	VIF
Transformational Leadership (TLF)	TLF1 <- TLF	0.901	2.679
	TLF2 <- TLF	0.908	2.543
	TLF3 <- TLF	0.862	1.974
Transactional Leadership (TL)	TL1 <- TL	0.776	1.593
	TL2 <- TL	0.899	2.475
	TL3 <- TL	0.926	2.748
Total Quality Management (TQM)	TQM1 <- TQM	0.857	2.396
	TQM2 <- TQM	0.880	2.090
	TQM3 <- TQM	0.889	2.195
Employee Commitment (ECM)	ECM1 <- ECM	0.862	1.513
	ECM2 <- ECM	0.877	1.905
	ECM3 <- ECM	0.813	2.036
Innovation (INNO)	INNO1 <- INNO	0.832	2.303
	INNO2 <- INNO	0.880	2.831
	INNO3 <- INNO	0.921	2.169

Table 4
VIF Values for Structural Paths (Constructs → Constructs)

	VIF
ECM -> INN	1.335
TL -> ECM	2.610
TL -> TQM	2.610
TLF -> ECM	2.610
TLF -> TQM	2.610
TQM -> INN	1.335

Table 5 presents the reliability and validity of the constructs using Cronbach's alpha, composite reliability, and average variance extracted (AVE). The values of Cronbach's alpha, *rho_a*, and *rho_c* exceed the recommended threshold of 0.70 (Hair et al., 2020), indicating satisfactory internal consistency. In addition, all AVE values are above 0.50, confirming the convergent validity of the constructs.

This can be explained by the fact that TQM and innovation are theoretically related constructs, as TQM involves continuous process improvement, which is closely associated with organisational innovation. Henseler et al. (2015) note that for conceptually related constructs, higher HTMT values may be expected, and that concerns regarding discriminant validity arise primarily when HTMT values approach or exceed 1 (Table 6).

Another method to measure the discriminant validity of the model is the Fornell-Larcker criterion (Fornell & Larcker, 1981). The Fornell-Larcker rule is that the square root of the AVE for a construct should be greater than its correlations with other constructs. As shown in Table 7, all constructs meet the Fornell-Larcker criterion, which means that the discriminant validity is confirmed and the constructs are distinct from each other.

Table 8 shows the model fit values. In PLS-SEM, many authors consider the SRMR and NFI values important for assessing model fit (Hair et al., 2019; Sivo et al., 2006; West et al., 2012). The SRMR value

Table 5
Composite Reliability

	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
TLF	0.870	0.876	0.920	0.793
TL	0.838	0.873	0.902	0.756
TQM	0.850	0.851	0.909	0.769
ECM	0.803	0.877	0.878	0.707
INN	0.873	0.876	0.922	0.798

Note. TLF = Transformational Leadership; TL = Transactional Leadership; TQM = Total Quality Management; ECM = Employee Commitment; INN = Innovation.

Table 6
Heterotrait-Monotrait (HTMT)

	Heterotrait-monotrait ratio (HTMT)
INN <-> ECM	0.630
TL <-> ECM	0.555
TL <-> INN	0.824
TLF <-> ECM	0.651
TLF <-> INN	0.881
TLF <-> TL	0.906
TQM <-> ECM	0.560
TQM <-> INN	0.906
TQM <-> TL	0.766
TQM <-> TLF	0.851

Table 7
Fornell-Larcker Criterion

	ECM	INN	TL	TLF	TQM
ECM	0.841				
INN	0.566	0.893			
TL	0.485	0.715	0.869		
TLF	0.580	0.771	0.785	0.891	
TQM	0.501	0.783	0.658	0.734	0.877

Note. ECM = Employee Commitment; INN = Innovation; TL = Transactional Leadership; TLF = Transformational Leadership; TQM = Total Quality Management.

Table 8
Model Fit

	Saturated model	Estimated model
SRMR	0.082	0.094
d_ULS	0.813	1.062
d_G	0.406	0.445
Chi-square	243.738	254.703
NFI	0.786	0.777

Note. SRMR = Standardized Root Mean Square Residual; d_ULS = Unweighted Least Squares Discrepancy; d_G = Geodesic Discrepancy; Chi-square = Chi-square statistic; NFI = Normed Fit Index.

in this case is 0.094, which is acceptable according to the rule of thumb (< 0.010), while the NFI exceeds the threshold of 0.70, suggesting an acceptable and suitable model.

Empirical Results

Table 9 presents the coefficients of determination (R^2) for each endogenous construct of the structural model. The R^2 value for employee commitment is 0.34, indicating that 34% of the variance in ECM is explained by leadership styles. The R^2 value for innovation is 0.65, suggesting that 65% of the variance in INN is explained by leadership styles, TQM, and ECM.

Table 9
R Square

Endogenous construct	R-square	R-square adjusted
ECM	0.339	0.325
INN	0.653	0.646
TQM	0.556	0.547

Furthermore, the R^2 value for TQM is 0.56, meaning that transformational and transactional leadership styles explain 56% of its variance.

Table 10 presents the structural relationships among the variables. The structural coefficients (β) indicate the magnitude of the effects, while the p-values indicate their statistical significance.As shown in Table 10, transformational leadership positively affects TQM, with a coefficient of $\beta = 0.57$ and a statistically significant p-value (p < 0.001). In contrast, transactional leadership has no statistically significant effect on TQM. Thus, Hypothesis 1 is supported, whereas Hypothesis 2 is rejected.

Transformational leadership als o has a strong and statistically significant influence on employee commitment (ECM), with $\beta = 0.520$ ($p < 0.001$), whereas transactional leadership does not exhibit a statistically significant effect on ECM. Hence, Hypothesis 3 is supported, and Hypothesis 4 is rejected.

Furthermore, both TQM and ECM positively affect innovation. Specifically, TQM has a strong positive impact on innovation ($\beta = 0.666$, $p < 0.001$), while ECM also exerts a positive and statistically significant effect ($\beta = 0.232$, $p = 0.014$). Therefore, Hypotheses 5 and 6 are supported.

The mediation results indicate that both TQM and ECM mediate the relationship between leadership styles and innovation. Specifically, transformational leadership has a positive and statistically significant indirect effect on innovation through employee commitment ($\beta = 0.121, t = 1.966, p = 0.049$). Therefore, Hypothesis 7 is supported. In contrast, transactional leadership does not have a statistically significant indirect effect on innovation through employee commitment ($\beta = 0.018, t = 0.021, p = 0.591$); therefore, this mediation effect is not supported.

Moreover, transformational leadership shows a statistically significant indirect effect on innovation through TQM ($\beta = 0.378, t = 3.740, p < 0.001$), supporting the mediating role of TQM. However, the indirect effect of transactional leadership on

Table 10
Structural Relationships

Hypothesis	Path	β	*t-value*	*p-value*	Result
H1	TLF -> TQM	0.568	4.295	0.000	supported
H2	TL -> TQM	0.212	1.519	0.129	rejected
H3	TLF -> ECM	0.520	4.024	0.000	supported
H4	TL -> ECM	0.077	0.582	0.560	rejected
H5	TQM -> INN	0.666	8.589	0.000	supported
H6	ECM -> INN	0.232	2.467	0.014	supported
H7	TLF -> ECM -> INN	0.121	1.966	0.049	supported
H8	TL -> ECM -> INN	0.018	0.021	0.591	rejected
H9	TLF -> TQM -> INN	0.378	3.740	0.000	supported
H10	TL -> TQM -> INN	0.141	1.466	0.143	rejected

Note: TLF = Transformational Leadership; TL = Transactional Leadership; ECM = Employee Commitment; TQM = Total Quality Management; INNO = Innovation.

innovation through TQM is not statistically significant ($\beta = 0.141$, $t = 1.466$, $p = 0.143$); thus, Hypothesis 10 is rejected.

Discussion

The results obtained using the PLS-SEM method answer the research questions and confirm several theoretical expectations. Transformational leadership (TLF) has a positive and statistically significant impact on employee commitment (ECM), whereas transactional leadership does not show a significant effect. These findings are consistent with previous studies (Abasilim et al., 2019; Clinebell et al., 2013).

Similarly, transformational leadership has a positive, statistically significant effect on TQM implementation, whereas transactional leadership does not. These results are in line with prior research (Bouranta, 2021; Kumar & Sharma, 2018; Teoman & Ulengin, 2018).

Regarding the impact of TQM and employee commitment on innovation, both variables exhibit positive, statistically significant effects, supporting earlier findings (Hakimian et al., 2016; Nguyen et al., 2019; Prajogo & Sohal, 2003; Xerri & Brunetto, 2013).

To address the key question raised in the literature regarding whether leadership influences innovation primarily through TQM or through employee commitment, the results indicate that TQM exerts a stronger effect. This is evident both in its mediating role between transformational leadership and innovation and in its direct contribution to innovation (see Table 5).

Overall, these findings provide not only empirical contributions but also practical implications for organisations seeking to adapt to a rapidly changing business environment and achieve long-term sustainability. The PLS-SEM results suggest that fostering innovation requires a combination of effective leadership and well-structured internal processes that support continuous improvement.

Limitations

This study has several limitations. First, the sample includes respondents from only one country, the Republic of North Macedonia, which may limit the generalisability of the findings. Future research could expand the sample to include other countries in the Western Balkans or beyond to provide a broader understanding of the relationships examined.

Second, the use of convenience sampling may weaken the external validity of the results, as the sample may not fully represent the broader population. Future studies should consider using probabilistic sampling techniques to improve generalisability.

Third, the relatively small sample size, although appropriate for PLS-SEM analysis, may limit the robustness of the findings. Future research with larger samples could provide more stable estimates.

Additionally, this study focuses on selected dimensions of TQM rather than capturing the full scope of Total Quality Management, which may influence innovation in different ways.

Finally, the study relies on self-reported data, which may be subject to respondent bias. Future research could incorporate multiple data sources to enhance the validity of the findings.

Conclusion

This study examined the impact of transformational and transactional leadership styles on the implementation of Total Quality Management (TQM) practices and employee commitment. It also investigated the impact of employee commitment on TQM, as well as the effects of TQM and employee commitment (ECM) on innovation in private enterprises in the Republic of North Macedonia. The empirical analysis confirmed the suitability of the proposed model, and the results were subsequently presented and interpreted.

The main findings indicate that transformational leadership is essential for fostering Total Quality Management and employee commitment within organisations. Moreover, a positive relationship was identified among employee commitment, TQM, and innovation.

The results of the PLS-SEM model further reveal that the mediating effect of leadership on innovation through TQM is stronger than the pathway mediated by employee commitment. This finding highlights TQM practices as the primary mechanism through which leadership enhances organisational innovation.

Future Research Directions

Future studies could expand the sample to include other Balkan countries in order to enhance the generalisability of the findings. Another promising avenue for research would be to compare the impact of Total Quality Management and employee commitment on innovation across the manufacturing and service sectors, with the aim of identifying which factors exert the strongest influence in each context.

This topic could also be explored within the public sector to determine whether similar patterns emerge. Furthermore, future research could examine the impact of artificial intelligence (AI) on TQM practices and innovation, particularly in developing countries such as North Macedonia, where the adoption of digital technologies may lag behind that in more developed economies.

The appendix is available in the online version of the journal.

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Integrating Human Capital Management and Ambidextrous Business Process Management: A Conceptual Review and Framework

Abstract

Contemporary organisations operate in an increasingly complex and volatile environment, demanding greater flexibility than traditional Business Process Management (BPM). One of the biggest challenges is balancing exploitative and explorative activities, a duality that has given rise to integrated models such as ambidextrous BPM (ABPM). Organisational success in this context depends not only on structures and technologies, but also on the strategic role of human capital and human resource management (HRM) practices. This paper aims to identify the challenges and opportunities facing HR departments in supporting ABPM. The analysis focuses on four key areas: managing multigenerational teams, fostering cognitive diversity, strengthening employees' mental resilience, and shaping an organisational culture conducive to ambidexterity. To address these dimensions, the study draws on a literature review based on Scopus and Web of Science databases. The article concludes by proposing a conceptual framework that links HRM practices with the demands of ABPM. This integrative perspective offers an original contribution to BPM and HRM domains, emphasising the role of human capital as a key enabler of organisational ambidexterity in dynamic and uncertain environments.

Keywords: BPM, ABPM, human capital, human capital management (HCM), ambidexterity, diversity, social aspects, resilience, human resource management (HRM)

Introduction

The growing complexity and unpredictability of the organisational environment, marked by rapid technological advancement and mounting pressure for innovation, are signs of Industry 4.0/5.0 and represent a transformative shift in the way organisations are managed. This shift demands that organisations adopt strategies that enable dynamic adaptation to changing conditions (Sliż & Jackowska, 2024).

The challenge for researchers and practitioners today is to understand how human resource management can be aligned with organisational strategies while simultaneously supporting the conflicting demands of exploitation and exploration (Junni et al., 2015). This question becomes even more relevant when considering the complexity of human behaviour and the strategic importance of employees' knowledge, engagement, and motivation.

Despite growing interest in this area, the literature still falls short in addressing the role of HR in implementing ambidextrous strategies at the process and business process management level. Current research offers limited insights into how HR can support process-level ambidexterity.

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This article aims to identify the challenges and opportunities for the contemporary strategic approach of HRM (Human Resource Management) in the context of implementing and supporting ambidexterity in BPM. This approach can be thought of as human capital management (HCM).

At this point, a conceptual clarification between Human Resource Management (HRM) and Human Capital Management (HCM) is required. Although the two terms are often used interchangeably in the literature, they represent partially overlapping yet analytically distinct perspectives. HRM traditionally refers to the configuration of policies, practices, and systems aimed at managing people within organisations (Armstrong & Taylor, 2023; Boxall & Purcell, 2016), and can therefore be used synonymously with HR practices in this text. In contrast, HCM emphasises the strategic, value-creation dimension of people management, viewing employees not merely as resources to be administered but as capital assets that generate future economic and strategic returns (Becker et al., 2001; Juchnowicz, 2014).

In this article, HRM is treated as the operational and systemic domain of people-management practices, whereas HCM represents its strategic and investment-oriented logic, particularly relevant in the context of ambidextrous Business Process Management (BPM). Thus, the term HCM will be used to refer to the strategic role of human capital as a driver of the exploration–exploitation balance, while HRM will denote the organisational mechanisms and managerial practices through which this strategic intent is enacted. This distinction allows the paper to integrate both perspectives without conflating their analytical levels.

In this light, the study explores four HCM-driven areas crucial for ambidextrous BPM: multigenerational team management, cognitive diversity and flexibility workgroups, psychological resilience and Psychological Capital, and organisational culture supportive of ambidexterity.

This leads to the main research question (RQ):

RQ: What are the key challenges facing modern strategic HCM in implementing the principles of ambidexterity within BPM?

The paper is conceptual and is intended to stimulate future empirical research aimed at testing its assumptions and propositions. To explore the issue, the article employs a conceptual literature review drawing on the Web of Science and Scopus databases. It contributes to the ABPM discourse by addressing a persistent gap – namely, the relative paucity of research focusing on human capital issues in ABPM – by providing an initial conceptualisation of HCM in ABPM, identifying strategic opportunities for integrating HR with ambidextrous BPM (ABPM) in response to the complex challenges of the 21st century, and outlining directions for subsequent empirical verification.

This article adopts a conceptual review design aimed at integrating dispersed insights from the BPM, ambidexterity, and human capital literature into a coherent analytical framework. Rather than testing empirical relationships, the paper develops a theoretically grounded model that systematises the microfoundations of ambidextrous BPM and delineates directions for future empirical validation.

Theoretical Foundations of the Human Capital–ABPM Framework

HRM in Ambidextrous Business Process Management (ABPM) lies in the foundational tension between exploration and exploitation in organisational processes (March, 1991), further developed within the ambidexterity literature (O'Reilly & Tushman, 2013). In BPM settings, this duality translates into the simultaneous requirement to maintain operational reliability and efficiency while continuously adapting and reconfiguring processes (Sliż & Jackowska, 2024). Process ambidexterity should therefore not be reduced to a structural or technological design challenge. Rather, it constitutes a human capital–based capability, as employees enact and balance both logics in their day-to-day process execution (Gibson & Birkinshaw, 2004). Human Capital Management perspective shifts the analytical focus from structural separation toward the microfoundations of ambidexterity. ABPM environments redefine expectations toward employees engaged in process work (Armstrong & Taylor, 2023; Baron & Armstrong, 2007), requiring them to:

- switch between competing work logics (cognitive switching) (Hoang et al., 2025; Rosing & Zacher, 2017);
- tolerate heightened ambiguity and stress (mental resilience) (Demerouti et al., 2001; Jia et al., 2024);
- integrate diverse knowledge domains (learning and knowledge sharing) (Marin Idarraga et al., 2025; Wang et al., 2024);
- collaborate effectively within heterogeneous teams (diversity management) (Ahammad et al., 2019; Kassotaki, 2022).

These changing performance requirements provide the conceptual bridge to the theoretical lenses supporting the proposed framework. At the strategic level, the model is anchored in the Resource-Based View (RBV), which conceptualises sustainable competitive advantage as rooted in valuable, rare, and difficult-to-imitate resources (Barney, 1991). The configuration of human competencies, tacit knowledge, collaborative routines, and relational capital constitutes such a resource bundle. Ambidextrous BPM may therefore be interpreted as the outcome of a distinctive human capital configuration rather than a mere reflection of formal process architecture. Extending this reasoning, the Dynamic Capabilities perspective emphasises the organisation's capacity to integrate and reconfigure resources in response to environmental turbulence (Teece, 2007; Teece et al., 1997). The capability to oscillate between standardisation and adaptation represents a microfoundational expression of dynamic capability at the process level. Within the proposed framework, the four HR/HCM levers operate precisely as enabling mechanisms for activating this switching capability in everyday process work.

The psychological dimension of ABPM is illuminated through the Job Demands–Resources (JD-R) model. Ambidextrous process environments generate simultaneous efficiency pressures (exploitation) and experimentation imperatives (exploration). When job and personal resources are insufficient, overload and disengagement may follow (Demerouti et al., 2001; Schaufeli & Bakker, 2004). Psychological resilience and the components of Psychological Capital (PsyCap) (Luthans et al., 2007a) thus function as critical personal resources enabling sustained performance under complexity. Recent empirical findings demonstrate that ambidextrous HR practices strengthen PsyCap, thereby enhancing creativity and performance outcomes (Zhao et al., 2022).

A central foundational element of the model is multigenerational team management (generational composition and coordination), conceptualised within the Diversity Management paradigm. Teams represent the primary locus where exploitation and exploration are reconciled. From the RBV standpoint, human capital acquires strategic value not solely at the individual level but as a configuration of complementary competencies within teams (Barney, 1991). Multigenerational teams may enhance cognitive variety by combining experiential process knowledge and stability orientation with exploratory learning and innovation capacity.

Yet diversity effects remain conditional. As established in diversity research, heterogeneity, conceptualised as ‘variety’, may enhance problem-solving quality, whereas heterogeneity, conceptualised as ‘separation’, may generate conflict and reduce cohesion (Harrison & Klein, 2007; van Knippenberg et al., 2004). Social Identity Theory explains such dynamics through processes of in-group and out-group categorisation (Hogg, 2016; Tajfel & Turner, 1979). In ABPM contexts, generational diversity does not automatically translate into ambidexterity. Rather, its value depends on deliberate orchestration through HR practices.

Properly coordinated multigenerational collaboration can generate cognitively energising, non-routine solutions often driven by younger employees, while simultaneously preserving validated quality standards grounded in the tacit knowledge of more experienced staff. Consequently, multigenerational team management is treated not as a demographic attribute but as a designed HRM mechanism encompassing role alignment, mentoring and reverse mentoring, structured knowledge transfer, managerial support, and conflict-resolution processes. From the perspective of dynamic capabilities, sustained knowledge integration enables process reconfiguration. From the JD-R perspective, effective coordination mitigates cognitive and emotional strain, thereby strengthening both operational reliability and readiness for innovation.

The final integrative dimension is organisational culture and the leadership context. Upper Echelons Theory (Hambrick & Mason, 1984) argues that strategic choices and balancing mechanisms reflect top managers’ cognitive frames (Hambrick, 2007). Ambidexterity research underscores the necessity of a context combining discipline and flexibility (O’Reilly & Tushman, 2013). A culture that legitimises both operational rigour and experimentation, therefore institutionalises the remaining HRM levers and sustains ambidextrous performance (Gibson & Birkinshaw, 2004).

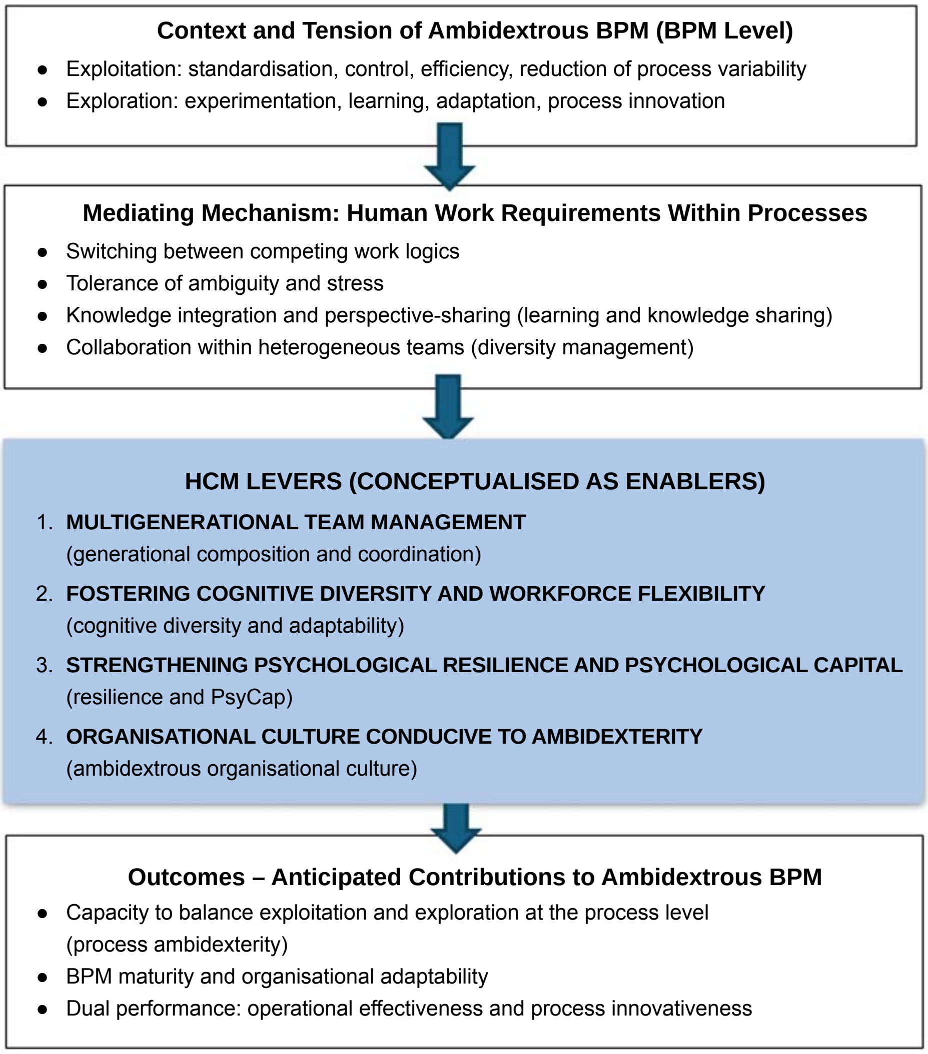
Recent empirical evidence further confirms that high-performance HR practices promote organisational ambidexterity, which mediates the relationship between HR systems and innovation outcomes (Wang et al., 2024). Accordingly, the four HR/HCM levers constitute a coherent set of microfoundations of ambidextrous BPM, grounded in resource-based, adaptive, and psychological theories and integrated through culture and leadership (Varandas et al., 2024).

The conceptual framework (Figure 1) thus integrates ambidextrous BPM with core human capital levers. The model begins with the fundamental tension between exploitation and exploration, identifies the resulting requirements for human work within processes (dual demands, switching between work logics, knowledge integration), and subsequently indicates four HCM domains as key mechanisms that enable the institutionalisation of ambidexterity at the process level. In this way, the transition from general ambidexterity theory to specific HRM solutions becomes theoretically structured and analytically transparent.

The Method

Given the study’s conceptual and integrative aims, a structured conceptual literature review was adopted. This approach was considered appropriate because the paper does not seek to estimate the prevalence of specific effects or test empirical relationships, but rather to synthesise dispersed insights from Business Process Management, organisational ambidexterity, and Human Capital Management into a coherent conceptual framework. The search was conducted in the Scopus and Web of Science databases. The search strategy was based on combining three groups of concepts: (1) BPM/process management, (2) ambidexterity/exploration–exploitation, (3) HCM/HRM/people dimension. A limited number of queries were used to cover the core of the problem (e.g., BPM + ambidexter), as well as the link between ABPM and the HRM/human capital dimension. Additionally, clarifying queries were run when necessary to capture literature on people and work (including culture, leadership, psychological capital, diversity and generations). The search time frame spanned

Figure 1
The Model of the Human Capital Enablers – ABPM Conceptual Framework



2000–2025. Given the study's conceptual and framework-building character, the review should not be understood as a full systematic literature review but rather as a structured conceptual review supported by a supplementary search.

A key element of the procedure was an analysis focused on 'people challenges'. From each publication, excerpts were extracted describing: (a) tensions and constraints on the part of employees, teams, or managers (e.g., role conflicts, cognitive load, resistance to change, barriers to collaboration), (b) organisational conditions that exacerbate or reduce these tensions (culture, leadership, HR systems), and (c) implications for balancing exploration and exploitation in processes. Next, thematic synthesis was applied, treating the 'challenge' as the unit of analysis: codes referring to similar problems were grouped into categories, which were then organised into coherent challenge areas. As a result, the review led to the identification of four overarching domains of people-related challenges for ABPM, which form the structure of the article's findings: (1) managing multigenerational teams, (2) leveraging and integrating cognitive diversity, (3) strengthening employees' mental resilience to ambidexterity tensions, and (4) shaping an organisational culture conducive to ambidexterity. These domains were then used to develop a conceptual framework that links ABPM requirements to HRM practices and human capital resources.

Navigating the Complexity: Human Resources in Ambidextrous BPM

The concept of ambidexterity is extensively discussed in the literature (Helbin & Van Looy, 2021; Lis et al., 2018; O'Reilly & Tushman, 2011; Sliż, 2022; Sliż & Jackowska, 2024). From the BPM perspective, it could be defined as the capacity to balance commodity, traditional BPM (exploitative BPM) with more innovative, adaptive approaches (explorative BPM). Expanding on this view, it can be stated that ambidexterity involves addressing both structural and systemic dimensions that allow an organisation to improve its core operational processes while simultaneously pursuing experimentation and breakthrough innovation. From the perspective of added value, this is a state in which resource, knowledge, and innovation management are balanced in two areas: first, where value is currently being generated, and second, where the organisation is actively seeking opportunities to create new value (Sliż, 2022, 2024).

However, ambidexterity cannot be achieved solely through structural solutions. Its effectiveness depends significantly on how organisations manage their human resources. In this regard, organisational context becomes crucial, particularly when analysed through the lens of the 5P Model of HRM: Philosophy, Policies, Programmes, Practices, and Processes. Among the five elements, Processes are especially important, as they integrate both BPM and HRM into a coherent HCM system (Pryor et al., 2007). Organisations may adopt structural forms of ambidexterity, where exploitative and explorative efforts are separated spatially or functionally, or they may pursue contextual ambidexterity, which embeds both modes of activity within the same workflows or roles. This strategic choice primarily shapes the expected role of leaders and employees from the perspective of organisational goals and strategies. It also influences how individuals are selected, motivated, and how teams are managed, while acknowledging the broad spectrum of employees' backgrounds across generations, cultures, and belief systems.

Considering this, it is essential to examine how the existing literature frames the relationship between ambidexterity and various HR-related factors. A review of the literature on team ambidexterity reveals a strong emphasis on shaping organisational ambidexterity through internal conditions. Research has focused on the role of organisational cultures in empowering employees (Caniëls et al., 2017), different orientations that support either task-focused or social forms of organisational ambidexterity (Lee et al., 2019), and psychological capital, such as self-efficacy, hope, optimism, and resilience (Venugopal et al., 2019). Another stream of research focuses on leadership, exploring how strategic clarity, vision, and the alignment between individual and organisational values affect ambidextrous capacity (O'Reilly & Tushman, 2011). Research also investigates the links between managerial ambidexterity and organisational ambidexterity (Mom et al., 2019), as well as the influence of tenure on organisational ambidexterity (Knight & Cuganesan, 2020). Scholars are also examining management styles that foster organisational ambidexterity (Salas Vallina et al., 2019; Swart et al., 2019). Furthermore, the relationship between HR department strategies and organisational ambidexterity is being explored (Jørgensen & Becker, 2017).

The next sections of this article explore four selected HRM domains that are particularly relevant to supporting ambidextrous BPM: multigenerational team management, cognitive diversity and flexibility, psychological resilience and Psychological Capital, and organisational culture supportive of ambidexterity.

Generational Dynamics in ABPM

The current analysis identifies generational differences in orientation toward exploration and exploitation (Scuotto et al., 2020); however, it requires further theoretical elaboration across three dimensions: (1) motivational, (2) cognitive, and (3) implementation-related, particularly in relation to HR practices supporting ABPM.

First, generational differences should be explicitly linked to the exploration–exploitation logic (March, 1991; O'Reilly & Tushman, 2013). Prior research suggests that older cohorts (Baby Boomers and, to some extent, Generation X) have more strongly internalised norms of organisational stability, loyalty, and operational optimisation. Within ABPM environments, their accumulated experiential capital, procedural organisational memory, and capabilities in process standardisation may reinforce the exploitative dimension. In contrast, younger cohorts (Generations Y and Z) tend to demonstrate greater acceptance of variability, shorter iterative learning cycles, higher digital fluency, and a stronger developmental orientation, all of which are more closely associated with exploratory activities (Berraies, 2023; Woods, 2016).

However, consistent with the findings of Herlina and Syahchari (2023), generational affiliation alone does not determine ambidextrous behaviour. Accordingly, the generational dimension in ABPM should not be interpreted deterministically, but rather as a moderator of the effectiveness of HR practices (Mom et al., 2019; Prieto-Pastor & Martin-Perez, 2015). This perspective implies a shift from 'managing generations' toward designing organisational conditions under which different cohorts can activate complementary cognitive and motivational resources.

Second, further conceptual refinement is required in the analysis of motivational differences. Drawing on Regulatory Focus Theory (Higgins et al., 2001), employees with a prevention focus – more frequently observed in older cohorts – may naturally reinforce exploitative logic by prioritising quality, risk mitigation, and compliance with standards. Conversely, a promotion focus – more often associated with younger cohorts – supports exploration, experimentation, and process reconfiguration. Importantly, ABPM requires the ability to switch between these orientations rather than entrenching generational stereotypes. This places HRM in the role of architect of contextual ambidexterity (Gibson & Birkinshaw, 2004).

Third, the generational dimension should be more explicitly translated into HCM implications for ABPM. At the level of process role design, ABPM teams may deliberately combine procedural expertise (e.g., process owners, standardisation specialists) with experimental roles (e.g., innovation sprint leaders), while avoiding rigid age-based role allocation. Rotational mechanisms and bidirectional mentoring are critical in this regard. Concerning learning systems, research on ambidextrous HR practices (Ahammad et al., 2019; Wang et al., 2024; Zhao et al., 2022) indicates that high-performance HR systems enhance ambidexterity through organisational learning. From a generational perspective, this requires differentiated developmental approaches: knowledge transfer programmes, expert coaching, and mentoring roles for senior cohorts; and experimental projects, learning-by-doing, digital platforms, and real-time feedback for younger cohorts. Such differentiation strengthens knowledge integration as conceptualised in the dynamic capabilities framework (Teece, 2007). With respect to intergenerational conflict management, Social Identity Theory suggests that generational differences may foster in-group/out-group categorisation (Hogg, 2016; Tajfel & Turner, 1979). Under conditions of tension between exploration and exploitation, this may escalate cognitive conflict. HR interventions should therefore focus on cultivating a shared process identity anchored in ABPM objectives rather than generational affiliation. Finally, leadership perceptions have been shown to be moderated by employee age (Berraies, 2023; Kim, 2019). Ambidextrous leaders in ABPM contexts should integrate structural clarity (supporting exploitation) with participatory autonomy (supporting exploration), adapting communication styles to cohort-specific expectations.

The integration of the generational perspective into ABPM should therefore rest on the assumption that age moderates the effectiveness of HR practices and mechanisms of contextual ambidexterity rather than deterministically shaping employee behaviour. Whether individuals engage more strongly in exploitation (standardisation, control, optimisation) or exploration (experimentation, process redefinition) depends primarily on role design, learning architecture, and leadership style. Nevertheless, multigenerational composition may provide complementary microfoundations of ABPM: senior cohorts often strengthen exploitative capacity through accumulated experience and stability orientation, whereas younger cohorts – particularly Generation Z – may reinforce exploratory capacity through iterative learning readiness, digital competence, and openness to innovation.

Building upon prior research on generational management (Herlina et al., 2023; Stevanovski et al., 2024), the following tendencies may be observed. Baby Boomers demonstrate a stronger exploitative orientation consistent with classical definitions of exploitation as process refinement and control (March, 1991). Empirical findings indicate that the effects of ambidextrous HR practices may be less pronounced among older cohorts (Berraies, 2023; Scuotto et al., 2020), potentially reflecting stronger preferences for structured leadership and formalised processes within contextual ambidexterity frameworks (Gibson & Birkinshaw, 2004). Generation X exhibits greater autonomy and capacity to balance exploration and exploitation, supported by research on individual ambidexterity and role switching (Rosing & Zacher, 2017; Tempelaar & Rosenkranz, 2019), while the JD-R model highlights the importance of designing adequate job resources to manage dual demands (Demerouti & Bakker, 2023; Demerouti et al., 2001). Generation Y (Millennials) exhibits a stronger exploratory orientation and openness to innovation, in line with evidence that age moderates the relationship between distributed leadership and ambidextrous innovation (Berraies, 2023) and with promotion-focused motivational tendencies (Higgins et al., 2001). However, insufficient process structure may destabilise ambidextrous balance, underscoring the importance of aligning HR practices with ambidexterity (Mom et al., 2019; Wang et al., 2024). Generation Z, although still underrepresented in empirical ABPM research, aligns with emerging studies on ambidextrous employee behaviour in digitally mediated environments (Hoang et al., 2025) and heightened cognitive load associated with exploration–exploitation tensions (Rao & Mattarelli, 2024). Their higher sensitivity to uncertainty and search for meaningful work suggest the need to strengthen Psychological Capital (PsyCap) as a protective resource (Luthans et al., 2007a; Zhao et al., 2022). Recent research further indicates that digital forms of ambidexterity and participatory, purpose-driven HR practices are particularly salient for Generation Z (Herlina & Syahchari, 2023; Stevanovski et al., 2024) while intergenerational analyses confirm that cohort effects are strongly conditioned by organisational context and role design (Herlina et al., 2023). This reinforces the argument that generational affiliation should be conceptualised as a contingent factor within ABPM rather than a primary explanatory mechanism.

In summary, a refined approach to generational dynamics in ABPM should: (1) move beyond the stereotypical attribution of exploration to younger cohorts and exploitation to older ones; (2) conceptualise generational affiliation as a moderator of HR practice effectiveness; and (3) explicitly embed generational diversity within the microfoundations of ABPM as an element of human capital configuration.

Managing Diverse Teams in ABPM: Towards Cognitive Diversity and Flexibility

While generational differences represent one form of diversity, cognitive differences, understood as different ways of perceiving, processing information, and interpreting situations, also play an important role in shaping both exploratory and exploitative behaviours of organisational members (Rao & Mattarelli, 2024). It should be noted that direct empirical evidence linking cognitive diversity specifically to Ambidextrous Business Process Management remains limited. Therefore, the following argument should be understood as an evidence-informed conceptual extrapolation from research on cognitive diversity, motivational orientation, individual ambidexterity, and team-level innovation.

The objective is not to assert that these relationships have been fully validated in ABPM contexts, but rather to identify mechanisms by which cognitive diversity and cognitive flexibility may facilitate balancing exploration and exploitation in process work.

A useful theoretical lens is Walter Mischel's cognitive theory (Mischel, 1968), which provides a valuable theoretical basis for understanding individual differences in employee behaviour. According to this theory, human behaviour is not constant and universal; on the contrary, it is strongly dependent on the specific characteristics of a situation and on how a person perceives it. Mischel identifies five key variables that determine individual reactions in specific conditions: perceived competence, interpretation of goals and tasks, expected results of actions, the value assigned to those results, and a set of norms and standards. In an ABPM context, these factors determine how individuals engage with change, uncertainty, or routine processes.

At the individual level, this concept allows us to understand and manage diversity in terms of (van Knippenberg et al., 2004):

- Perception and interpretation of organisational situations – while some employees perceive BPM as a development and innovation opportunity, others experience it as a threat to stability, autonomy, or job security. Each employee may interpret the same organisational structures, initiatives, or management communications differently – e.g., an organisational culture that fosters support, a leader's role, or changes in processes.
- Attitudes towards change – ambidextrous organisations require constant adaptation to activities of a different nature – exploitative and exploratory. For some, change is a threat, a source of fear and uncertainty, while for others it is a challenge and a stimulus to action.
- Motivational orientation – promotion-focused and prevention-focused (Higgins et al., 2001). Promotion-oriented employees are more likely to engage in exploratory activities, while prevention-oriented employees are more likely to engage in exploitative activities. In the context of ambidextrous business process management, the issue is the ability to adapt one's motivational orientation to the requirements of a given task, i.e., to shift from a promotion orientation to a prevention orientation or vice versa. While everyone naturally tends to favour one motivational orientation, a key task for a leader is to develop cognitive flexibility that enables the conscious adjustment of one's mindset to changing organisational conditions.

At the group and intergroup level, the cognitive concept plays a role primarily in:

- Recognising and overcoming stereotypes – in ABPM teams, exploratory tasks (innovative, creative) are rated as 'more important' and 'more prestigious' than exploitative tasks (routine, repetitive). Such attitudes can weaken team cohesion and hinder cooperation (García-Granero et al., 2018),
- Shaping a fair team culture – it is necessary to build a sense of balance, recognition and trust in relation to both types of activities. When team members feel that both their exploratory and exploitative work is appreciated and rewarded, their commitment and mutual cognitive trust increase (García-Granero et al., 2018).
- Creating space for dialogue and cooperation, not competition – dualism does not mean competition between approaches, but rather their complementarity. That is why it is so important to promote norms and behaviours that support open communication, exchange of views, and mutual learning.

Until now, the separation of tasks through functions, spaces, and structures has been preferred, but now the challenge is to combine exploratory and exploitative tasks, which requires cognitive flexibility. This is why the application of the cognitive concept in ambidextrous business process management (ABPM) is crucial, as effective switching between tasks of different natures – exploratory (innovative, risky, requiring openness) and exploitative (routine, focused on efficiency and optimisation) requires awareness of one's own beliefs and ways of interpreting reality, as well as the ability to modify them flexibly and alternate between them depending on the context.

The cognitive concept therefore provides leaders with additional knowledge, but also presents them with challenges in terms of team management in an ABPM environment. From the perspective of the proposed framework, leaders may need to recognise the cognitive, motivational, and emotional differences between team members and adapt their actions, people, and other elements of the organisational system. Possible leadership and HRM responses may include:

- Supporting employees in the process of changing beliefs about ambidextrous business process management (ABPM) through design thinking, mindfulness, job crafting/job rotation, and identifying personal and organisational resources that support cognitive adaptability. These resources include individual factors such as competence, autonomy, and control (Laureiro-Martínez et al., 2015), role identity (Tempelaar & Rosenkranz, 2019), learning orientation (Kauppila & Tempelaar, 2016), and organisational factors such as building a sense of belonging, leadership styles (Kauppila & Tempelaar, 2016; Smith & Tushman, 2005), organisational culture (Caniëls et al., 2017) and structure (Mom et al., 2019; Tempelaar & Rosenkranz, 2019), which have a direct impact on engagement in various tasks.
- Incorporating cognitive concepts into recruitment and job-matching processes.
- Fostering psychological safety within the team in order for cognitive flexibility to develop,

employees must have space to express their opinions, test new solutions, and make mistakes without fear of negative consequences (Edmondson, 1999).

Designing BPM without taking the cognitive structures of the people who carry out processes into account carries the risk of a lack of commitment or a mismatch with personal motivations and capabilities.

Mental Resilience as a Pillar of Ambidextrous BPM

An ambidextrous organisation is one that successfully combines two seemingly contradictory approaches: maintaining stable, efficient operations while simultaneously fostering innovation to ensure future readiness. Achieving such processual ambidexterity requires more than structural adjustments or procedural redesign – it fundamentally depends on people. Specifically, it requires employees who are able to (Lee et al., 2019; Luthans et al., 2007b): perform routine tasks efficiently, remain open to change and novel challenges, cope effectively with stress and uncertainty, and continuously learn and adapt to evolving conditions.

Human Capital Management (HCM) plays a pivotal role in cultivating the competencies, attitudes, and psychological resilience necessary for employees to function in both exploitative and explorative modes. Key HR interventions within an HCM approach include the following (Luthans & Youssef-Morgan, 2017): recruiting individuals with high cognitive flexibility and openness to change, fostering a psychologically safe work environment that encourages experimentation without fear of failure, designing roles and responsibilities that deliberately integrate both stable and innovative components, shaping an organisational culture that simultaneously supports operational efficiency and continuous innovation, delivering training programmes aimed at developing Positive Psychological Capital (PsyCap) – namely resilience, hope, optimism, and self-efficacy.

PsyCap is a higher-order construct which encompasses self-efficacy, optimism, hope, and resilience. It has emerged as a key enabler of ambidextrous performance. Notably, this concept is both measurable and developable, positioning it as a strategic intangible asset for organisations seeking to sustain dual-process operations under uncertainty (Luthans & Youssef-Morgan, 2017). Empirical research demonstrates that employees with higher PsyCap exhibit improved job satisfaction, innovation, and behavioural flexibility – all of which are critical in BPM environments characterised by the simultaneous demands of exploitation and exploration (Avey et al., 2009; Luthans et al., 2007a).

Ambidextrous Business Process Management (ABPM) is the organisational capability to pursue operational excellence and innovation in parallel. However, this capability does not arise from systems, structures, or technologies alone, but it is created and sustained by people who are strategically selected, supported, and developed through HRM (Avey et al., 2011). Thus, in the era of ABPM, HRM is no longer merely a supportive function. It becomes a strategic partner, a key architect of organisational adaptability and resilience in an increasingly volatile and complex world.

As organisations adapt to the accelerating volatility, uncertainty, complexity, and ambiguity (VUCA) of the business environment, the ability to implement Ambidextrous Business Process Management (ABPM) has emerged as a strategic imperative. While technological solutions and agile structures are enablers, the true driver of ambidextrous process capability is human capital (Beal et al., 2013).

ABPM thrives on dynamic capabilities that allow organisations to simultaneously standardise and innovate across their value chains. This duality places a cognitive and emotional burden on employees, who must fluidly shift between different process logics, respond to change, and maintain high performance under pressure. Therefore, the success of ABPM critically hinges on the psychological readiness and adaptive strength of the workforce.

HR practices that include structured PsyCap training (e.g., based on the BASIC Ph model or Reivich & Shatté's tools), resilience coaching, and psychological safety frameworks (Edmondson, 1999) empower employees to withstand the tension of dual-process demands. Empirical research confirms that PsyCap-enhancing interventions significantly improve innovative performance, adaptive problem-solving, and stress resistance, which are key attributes of ABPM-enabling talent (Abbas & Raja, 2015).

Moreover, studies by Yu et al. (2022) and Lee et al. (2019) reveal that SHRM practices focused on psychological development mediate the relationship between organisational design and performance through PsyCap. Specifically, Ambidextrous Organisational Cultures (AOC) that promote both control and autonomy have a greater impact on job outcomes when mediated by PsyCap. This suggests that ABPM maturity is not achievable without parallel investment in human resilience and psychological agility. In ABPM systems, where processes oscillate between routine standardisation (exploitation) and creative disruption (exploration), employees' ability to cope with uncertainty and manage dual cognitive frames becomes a strategic differentiator. Here, mental resilience acts as a lubricant of ambidexterity, reducing friction in transitions between process types and enabling continuous value delivery despite ambiguity. Consequently, the proposed framework suggests a possible extension of HR's role from administrative support to resilience engineering – designing roles, teams, and development programmes that embed adaptive capacity into daily operations (Luo et al., 2021).

Integrating PsyCap into Human Capital strategies enables BPM practitioners and HR leaders to co-create a workforce that is not only efficient but also innovative and capable of sustaining long-term ambidexterity. Such integration can be operationalised through Ambidextrous HR Practices (AHRPs), which blend stability (performance management, SOPs) with learning agility (innovation labs, job crafting). These practices provide the behavioural infrastructure for ABPM to function reliably in unstable conditions (Luthans et al., 2007b).

In conclusion, Ambidextrous BPM requires ambidextrous people, and these people are built through deliberate human capital investments in psychological resources. From this perspective, Human Capital Management may shift from transactional functions to transformative resilience-building, embedding PsyCap into selection, development, performance, and culture systems. The sustainability of ABPM, particularly in VUCA conditions, depends not only on design but on people: resilient, agile, and empowered to thrive in duality.

Cultural Transformation: Orchestrating Change Management in ABPM

Another critical component in the human-centric approach to BPM is the organisational culture. Numerous authors emphasise the importance of this aspect for the successful implementation and outcomes of BPM in organisations (Hribar & Mendling, 2014; Rosemann & de Bruin, 2005). Conversely, other studies indicate that an inappropriate organisational culture is one of the main factors contributing to BPM implementation failure (Rosemann & vom Brocke, 2015; Trkman, 2010). Previous research has focused on the attributes of a culture conducive to effective BPM (Jesus et al., 2010; vom Brocke & Schmiedel, 2011; Zairi, 1997). The main attributes of this culture identified as CERT model are (Schmiedel et al., 2014): customer orientation, which comprises: 1a) orientation on the external customer and 1b) orientation on the internal customer; excellence, including continuous improvement and innovation; responsibility, distinguished as: responsibility for results and commitment to improving processes and their results; teamwork, encompassing formal structures and informal cooperation. These values foster alignment, discipline, and process consistency, which are characteristics especially relevant to exploitative BPM. However, in the context of ambidextrous BPM, these traits are insufficient on their own. Recent research emphasises that organisational culture significantly influences the success of BPM ambidexterity. Helbin and Van Looy (2023) introduced the FADE model, which complements CERT by including: failure acceptance – tolerance for risk and mistakes; agility – openness to change and responsiveness; disruptiveness – support for radical innovation; ecosystem thinking – cross-boundary collaboration and co-creation.

Together, these models reflect a dual cultural orientation, which supports both operational control and creative exploration. Complementing this, scholars emphasise the role of tolerance for ambiguity, shared identity, and the meta-competence of 'learning to learn' as essential for navigating the dual demands of exploration and exploitation. Additionally, elements such as social capital and leadership ambivalence (the ability to hold and manage conflicting strategic logics) are recognised as key to enhancing organisational adaptability in dynamic environments (Helbin & Van Looy, 2021).

Given that the organisational culture is a critical factor in the success of the BPM approach, any significant deviation from the desired culture model should be addressed. Despite its relevance, the transformation of organisational culture toward BPM principles remains an underexplored area in the literature. As part of our research, we identified a set of methods for shifting the organisational culture towards the BPM approach, analogous to the Lean approach, as exemplified by effective process management. These methods include (Balle & Balle, 2010; Balle & Balle, 2014; Piątkowski, 2009; Shook, 2010; Walentynowicz & Szreder, 2022):

- Establishing a new set of organisational values and promoting them broadly, ideally directly by the top management.
- Effectively communicating the vision of change and the new organisational culture, again ideally by the top management.
- Top-down leadership example, where both top-level and lower-level managers adhere to the new principles and organisational values.
- Changing leadership and decision-making styles to be more participative, especially in problem-solving, process improvement, and organisational development.
- Actively involving frontline employees in the company's transformation process, particularly in process analysis and improvement.
- Ensuring that employees gain positive experiences by participating in organisational improvement processes or by directly consuming their positive effects.
- Developing employees' understanding of the purpose and meaning of their work, especially through process-oriented persuasion and teaching appropriate methods for organisational improvement by their supervisors (coaching).
- The positive influence of group members on individuals (the associative effect), where through actions described in points 6 and 7, individual employees become ambassadors of the new way of functioning in the organisation and encourage others to join these processes.

These practices can be seen as key levers of cultural change management aimed at aligning organisational behaviours with the demands of ABPM. This makes culture not only a context for ABPM, but a strategic lever in its implementation.

Discussion

This study explored the potential integration of Human Resource Management and Human Capital Management (HCM) into Ambidextrous Business Process Management (ABPM), with particular focus on the human factors that enable organisations to simultaneously exploit existing processes and explore innovative ones. Based on a structured literature review and empirical insights, the analysis was framed around four key dimensions: multigenerational team management, cognitive diversity and flexibility, psychological resilience and Psychological Capital, and organisational culture.

Based on the theoretical insights, the following HR development directions in the context of ABPM are proposed:

- Diverse generational preferences and values: Studies indicated that different generations of employees may have varying preferences, values, and expectations regarding work and management style. This can influence the approach to BPM and the organisation's adaptation to changing market conditions.
- Need for flexibility and innovation: Younger generations, such as Generation Z, are often more inclined towards innovation, flexibility, and quick response to changes in the business environment. Conversely, older generations may prefer stability and traditional approaches. Organisations must balance these preferences to support ambidextrous BPM.
- Diversity in skills and experiences: Different generations can bring diverse skills, experiences, and perspectives to the BPM management process. Leveraging this diversity can be crucial for creating ambidextrous teams capable of both standardisation and innovation. Psychological resilience, operationalised through the development of Positive Psychological Capital (PsyCap), emerges as a foundational enabler of ABPM by equipping employees with the adaptive capacity to navigate between exploitative efficiency and exploratory innovation. Strategic Human Capital Management must therefore evolve into a resilience-oriented architecture, embedding PsyCap-enhancing practices into HRM systems to sustain ambidextrous process capability in VUCA environments.
- Communication and knowledge management: Effective management of different generations of employees requires appropriate communication and knowledge management. Younger generations may be more oriented towards communication technologies and social media, while older generations may prefer traditional forms of communication. Organisations must find a balance to leverage their full potential and enhance ambidexterity as a driver of organisational performance.
- Employee education and development: Effective management of different generations of employees in the BPM context requires investment in employee education and development. Training programmes and leadership development should take generational differences into account and adapt to diverse preferences and learning styles. Some research emphasises the importance of training and development programmes tailored to different generational preferences in BPM practices. For example, a study by Kim (2019) evaluated the effectiveness of training interventions designed to bridge intergenerational gaps in BPM skills and mindset.
- A new role of leadership as a partner and promoter of the democratic style: These are to be systemic actions on the part of the employer to reduce communication obstacles by lowering rigid and formal organisational ties, and thus by ensuring the decisive maintenance of the cultural dimensions of low power distance for younger generations. However, any cultural shift must also consider the expectations of older employees and avoid overly intrusive or automatic application of new assumptions (Alghamdi, 2018).
- A conscious effort is needed to shape an organisational culture that supports a tailored approach to BPM, which recognises the unique contribution of every employee.

This article invites a deeper investigation into the differentiated impact of selected Human Capital Management (HCM) determinants on the dual dimensions of ambidexterity within the context of Ambidextrous Business Process Management (ABPM). It remains unclear which of the four contextual drivers (namely multigenerational team management, cognitive diversity and flexibility, psychological resilience and Psychological Capital, and organisational culture and leadership supportive of ambidexterity) contributes more to supporting exploration, and which better reinforces exploitation. Distinguishing these effects may yield valuable insights into how HCM practices strategically align these seemingly opposing domains. These relationships warrant empirical validation through structured analysis, such as exploratory and confirmatory factor analysis, to assess the distinct correlations between HCM configurations and the dual logic of process ambidexterity.

However, this study does not provide a comprehensive systematic review of the literature. Rather, it presents a structured conceptual synthesis designed to integrate theory and develop frameworks. As a result, certain relevant empirical studies may be omitted, especially those outside the intersecting domains of business process management (BPM), ambidexterity, and human capital management (HCM).

Conclusion

This article contributes to the ongoing dialogue between BPM and HCM by proposing a conceptual framework that links strategic HR practices with the dual demands of process exploitation and exploration. Rather than treating people as passive participants in process execution, it places them at the centre. They are key to building the flexibility and responsiveness that ambidextrous process management requires.

The research offers practical guidance for organisations aiming to embed ambidexterity into their operational routines. To achieve this, they need to:

- design HR systems that strengthen psychological resilience and learning orientation,
- treat generational and cognitive diversity as a source of process flexibility,
- foster a cultural environment that balances structure with openness to change,
- change HR's role from a support function to a strategic enabler of behavioural adaptability.

At the same time, this research opens several questions for further investigation. It raises the question of which specific HR practices most effectively support exploratory initiatives, and which contribute more to maintaining process efficiency. Empirical testing across sectors and organisational contexts would help to clarify how HCM can best support the balance between innovation and stability.

The authors are aware that the research and discussion presented in this article do not fully close the identified knowledge gap.

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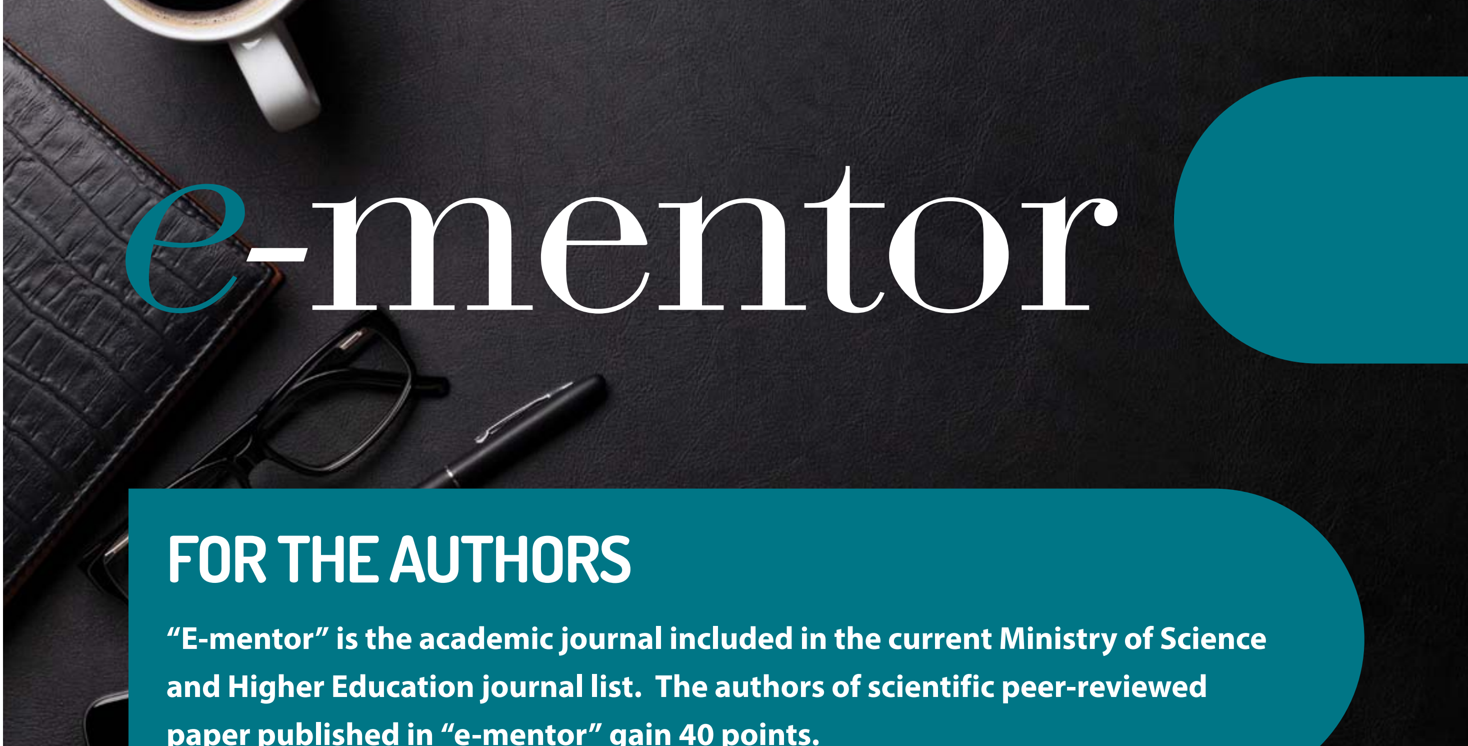

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