Supplementary Table S1. Complete Characteristics of the 26 Studies Included in the Systematic Synthesis

The table enumerates the complete peer-reviewed corpus retained after re-auditing the review against the stated eligibility criteria. Non-peer-reviewed professional, policy, or industry sources cited in the main manuscript are contextual only and are not counted among the 26 included studies. Quality score: 1 point for each of four criteria (clear objectives, appropriate methodology, transparent data collection/analysis, direct relevance); retention threshold ≥3/4.

No.	Study	Year	Design / method	Educational context	Focus	Key contribution to synthesis	Theme	Quality	DOI
1	Bervell & Arkorful	2020	Empirical survey / model testing	Distance tertiary education; tutors	LMS-enabled blended learning utilization	Facilitating conditions and voluntariness are important to LMS use behavior in distance education.	LMS adoption / facilitating conditions	4/4	https://doi.org/10.1186/s41239-020-0183-9
2	Boland	2020	Case study / diffusion analysis	Higher education institutions	Diffusion and adoption of LMS	Successful LMS diffusion depends on stakeholder communication, social channels, early adopters, and deliberate implementation planning.	Organizational readiness / diffusion	4/4	https://doi.org/10.1186/s13731-020-00139-z
3	Tinmaz & Lee	2020	Cross-cultural survey; non-parametric analysis	Fully online university course; German and Spanish students	LMS design preferences	Culture and study level influenced LMS design preferences more strongly than age or gender, supporting user-sensitive LMS design.	User experience / personalization	4/4	https://doi.org/10.1186/s40561-020-00141-8
4	Ifenthaler & Yau	2020	Systematic literature review	Higher education	Learning analytics and study success	Learning analytics can support study success and identify at-risk learners, although large-scale causal evidence remains limited.	Learning analytics	4/4	https://doi.org/10.1007/s11423-020-09788-z
5	Hellings & Haelermans	2022	Randomized controlled experiment	Blended programming course; Moodle-based environment	Learning analytics dashboard	Dashboard access improved online course performance indicators, while overall final-exam effects were limited and heterogeneous.	Learning analytics / feedback	4/4	https://doi.org/10.1007/s10734-020-00560-z
6	Anthony et al.	2022	Systematic review and synthesis	Higher education	Blended learning adoption and implementation	Adoption is shaped by technology acceptance, system quality, pedagogical design, and institutional/administrative practices.	Institutional implementation	4/4	https://doi.org/10.1007/s10758-020-09477-z
7	Alzahrani & Seth	2021	Survey; structural equation modeling	UK higher education students	Continuous LMS use and satisfaction	Information quality and self-efficacy significantly influenced satisfaction with continued LMS use; social and prior-experience factors also mattered.	Technology acceptance / satisfaction	4/4	https://doi.org/10.1007/s10639-021-10492-5
8	Mohammadi et al.	2021	Qualitative study; 100 semi-structured interviews; thematic analysis	Afghan universities; management, lecturers and students	Challenges and factors influencing LMS use during COVID-19	Successful LMS implementation depends on addressing user, organizational, infrastructure, support, and training challenges.	Organizational readiness / barriers	4/4	https://doi.org/10.1007/s10639-021-10517-z
9	Guzmán-Valenzuela et al.	2021	Bibliometric and content analysis	Higher education	Learning analytics research and challenges	Learning analytics is rapidly growing but remains at risk of privileging analytics over learning and pedagogical complexity.	Learning analytics / pedagogy	4/4	https://doi.org/10.1186/s41239-021-00258-x
10	Rets et al.	2021	Qualitative interviews with distance learners	Distance university students	Perceived usefulness of learning analytics dashboards	Learner-centered design and alignment with distance learners' needs are critical to perceived usefulness of dashboards.	Learning analytics / user acceptance	4/4	https://doi.org/10.1186/s41239-021-00284-9
11	Alduraywish et al.	2022	Interpretive structural modelling with literature and expert input	Saudi higher education institutions	Critical success factors for LMS diffusion	IT policy/infrastructure, staff skills/training, human competencies, and top-management support are key drivers of LMS diffusion.	Institutional support / leadership	4/4	https://doi.org/10.1007/s10639-021-10621-0
12	Susnjak et al.	2022	Systematic review plus dashboard design	Higher education	Learning analytics dashboards	Most dashboards rely on descriptive analytics; predictive/prescriptive analytics and actionable learner feedback remain underdeveloped.	Learning analytics / AI	4/4	https://doi.org/10.1186/s41239-021-00313-7
13	Turnbull et al.	2022	Comparative policy analysis	20 universities in four countries	LMS governance policies	Dedicated LMS policies should address accounts, courses, ownership, support, usage, protection, and the human dimensions of LMS governance.	Institutional governance	4/4	https://doi.org/10.1007/s11528-022-00752-7
14	Lavidas et al.	2022	Survey; variance-based structural equation modeling	378 faculty members from 20 Greek universities	Faculty intention to use LMS	Attitude, perceived usefulness/ease of use, technological complexity, self-efficacy, and subjective norm explain faculty LMS intention.	Technology acceptance / faculty	4/4	https://doi.org/10.1007/s40692-021-00217-5
15	Kaliisa & Dolonen	2023	Design-based research; interviews with university teachers	Seven blended university courses	Teacher-facing learning analytics dashboard	Teacher involvement, agency, and interpretable participation/discourse indicators support dashboard adoption in practice.	Learning analytics / teacher support	4/4	https://doi.org/10.1007/s10758-022-09598-7

16	Lehmann et al.	2023	Cross-sectional survey; SEM/path analysis	485 university students in Germany	Mandatory digital learning acceptance	Technology acceptance during mandatory digital learning is shaped by interacting personal and technology-related determinants.	Technology acceptance	4/4	https://doi.org/10.1007/s40692-022-00244-w
17	Khaldi et al.	2023	Systematic literature review	Online higher education	Gamification in e-learning	Points, badges, leaderboards, levels and feedback dominate; personalization and theoretically grounded gamification remain key needs.	Gamification	4/4	https://doi.org/10.1186/s40561-023-00227-z
18	Jin et al.	2023	Exploratory design study; interviews	University students in online learning	AI applications for self-regulated learning	Students value AI support for self-regulation when pedagogical and psychological needs are explicitly considered.	Artificial intelligence / adaptive support	4/4	https://doi.org/10.1186/s41239-023-00406-5
19	Rangel-de Lazaro & Duart	2023	Systematic literature review	Online higher education	Mobile learning applications	Mobile learning supports flexible access, interaction, collaboration, and learning effectiveness in online higher education.	Mobile learning	4/4	https://doi.org/10.7821/naer.2023.7.1287
20	Ilić et al.	2023	Literature review	E-learning and online education	Intelligent techniques in e-learning	AI and intelligent techniques can improve personalization and performance, but their educational impact depends on appropriate integration into e-learning processes.	Artificial intelligence / intelligent e-learning	4/4	https://doi.org/10.1007/s10462-023-10508-1
21	Sanchez et al.	2024	Comparative evaluation of 45 LMSs	Higher education	LMS platform features and quality	Interoperability, accessibility, communication, learning tools, productivity, and security provide a multidimensional basis for comparing LMS quality.	LMS functionality / interoperability	4/4	https://doi.org/10.1007/s44217-024-00143-5
22	Paulsen & Lindsay	2024	Systematic literature review	Higher education	Student-facing learning analytics dashboards	Dashboard design is shifting toward pedagogically informed, student-focused approaches using broader data and more actionable affordances.	Learning analytics / learner-centered design	4/4	https://doi.org/10.1007/s10639-023-12401-4
23	Vaarma & Li	2024	Machine-learning empirical study	Finnish higher education	Dropout prediction using LMS data	Moodle activity provides meaningful predictive information for degree dropout alongside transcript and demographic variables.	Learning analytics / machine learning	4/4	https://doi.org/10.1016/j.techsoc.2024.102474
24	Simon et al.	2025	Structured qualitative interviews	University teachers and students in Hong Kong	LMS use and underutilization	LMS use expanded during the pandemic, but barriers and underutilized functions remain; end-user perspectives are central to effective adoption.	LMS use / organizational practice	4/4	https://doi.org/10.1007/s10758-024-09734-5
25	Mella-Norambuena et al.	2025	PRISMA systematic review	University faculty	Models underlying faculty LMS use	TAM is the dominant framework; LMS use is shaped by personal, technological, social, and institutional variables, with moderate predictive power.	Technology acceptance / faculty	4/4	https://doi.org/10.1007/s40692-024-00336-9
26	Buabeng-Andoh	2025	Survey; structural equation modeling	Student-teachers	Continuous use of mobile LMS	Satisfaction and confirmation strongly influence continuous intention to use mobile LMS; combining TAM and ECM improves explanatory power.	Mobile LMS / continuance	4/4	https://doi.org/10.1007/s44217-025-00447-0

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