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Review

From Cognitive Substitution to Cognitive Amplification: Artificial Intelligence, Higher-Order Learning and Real-World Readiness in Online Postgraduate Public Health Education—A Scoping Review

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Abstract

Background: Online postgraduate (PG) public health education must develop higher-order competence and readiness for practice. Generative artificial intelligence (genAI) may enhance feedback, simulation and scaffolding, but may also substitute for learner reasoning. This review examined pedagogical conditions supporting higher-order learning and how AI interacts with them to influence competence and real-world readiness in online PG public health education. Methods: Following JBI guidance and PRISMA-ScR, PubMed and Scopus were searched for literature published from 2010 to 2026, with the final search conducted on 20 August 2026. Eligible sources addressed higher-order learning, authentic learning, competence or professional readiness in PG public health education, or provided transferable evidence from health professions and higher education settings. Of 5777 records identified, 253 duplicates were removed and 5524 screened. Data were charted using a structured evidence matrix and stratified into direct, transferable, synthesis, and contextual evidence layers. Results: Of 401 records undergoing detailed eligibility and analytic-role assessment, 338 were retained. Core evidence comprised 92 studies: 27 direct and 65 transferable; 32 syntheses provided triangulation. AI featured in 11.1% of direct versus 87.7% of transferable studies. Applied competence/skills occurred in 59.8%, synthesis/integration in 44.6%, critical thinking in 26.1%, and real-world cases/scenarios in 51.1%. Practice/workplace transfer was more prominent in direct than in transferable evidence (66.7% vs. 13.8%). Direct AI evidence in PG public health was limited, and heterogeneity across studies constrained direct comparison and precluded quantitative pooling. Conclusions: Higher-order learning depended more on pedagogical architecture than modality or AI adoption. AI may amplify cognition when preserving learner reasoning, verification, and judgement, but may substitute for cognition when generated outputs replace these processes. No external funding was received for this review.

Keywords: artificial intelligence; generative artificial intelligence; Master of Public Health; postgraduate education; online learning; higher-order thinking; authentic learning; competency-based education; professional readiness

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1. Introduction

Public health practice increasingly requires professionals to operate within complex, interconnected, and rapidly changing systems. Practitioners must interpret heterogeneous evidence, recognise uncertainty, integrate epidemiological and contextual information,

understand interactions between social, environmental and health system determinants, engage diverse stakeholders and make defensible decisions where no single technically correct solution exists. Preparing graduates for this environment therefore requires PG public health education to extend beyond knowledge acquisition towards analysis, synthesis, systems thinking, critical judgement and the application of knowledge in authentic professional contexts [1–3].

This requirement is particularly important for Master of Public Health (MPH) and related PG programmes. Although competency frameworks differ across jurisdictions, contemporary public health education increasingly emphasises applied capabilities such as evidence-informed decision-making, communication, leadership, collaboration, systems thinking, programme planning and evaluation. The educational objective is consequently not simply that graduates know public health, but that they can mobilise knowledge to address complex population-health problems [1–4].

The expansion of online PG education complicates this objective. Online delivery has increased access and flexibility and has become an established component of PG health professions education. However, the educational question is no longer whether disciplinary content can be delivered online. The more consequential question is whether online learning environments can reliably develop the higher-order capabilities required for professional practice [5–8].

This distinction is important because delivery modality and pedagogy are not synonymous. An online programme may reproduce didactic knowledge transmission through recorded lectures and conventional assessments, or it may incorporate authentic cases, simulations, projects, community engagement, collaborative problem solving, iterative feedback and reflective learning. The educational effectiveness of online PG public health education may therefore depend less on its digital modality than on the cognitive and experiential demands embedded within its instructional design [1,7–13].

Artificial intelligence introduces a further transformation. Generative AI and large language models can produce explanations, analyses, code, scenarios, feedback, summaries and written products within seconds. In education, these capabilities create opportunities for personalised tutoring, simulation, formative feedback, adaptive practice and rapid generation of authentic learning scenarios. They may be particularly valuable in online programmes, where scalable opportunities for interaction and feedback have historically been difficult to provide [14–16].

The same capabilities, however, create a fundamental pedagogical problem. Many of the outputs that genAI can produce, including analyses, interpretations, arguments, recommendations, statistical code, and professional documents; have traditionally been used as observable evidence that a learner has performed the underlying cognitive work.

When AI performs substantial portions of that work, the relationship between the quality of an educational product and the competence of the learner who submits it becomes less certain.

This raises concerns regarding cognitive offloading. Delegating routine cognitive activity to external tools is not inherently undesirable; professional practice has always incorporated technologies that extend human capability. The educational risk arises when the activity delegated to AI is itself the capability the learner is expected to develop. A system that assists a competent practitioner may therefore have a different educational effect when used by a novice who has not yet developed the reasoning that the system is replacing [17,18].

The challenge is especially consequential in public health. Generative outputs concerning disease patterns, environmental risks, programme effectiveness or policy options may appear plausible while containing inaccurate evidence, fabricated references, inappropriate

assumptions, or recommendations that fail to account for local context and equity. Public health graduates therefore require not only the ability to use AI but also the epistemic capacity to interrogate it.

Much of the rapidly expanding literature on AI in health professions education has focused on adoption, attitudes, perceived usefulness, AI literacy or technological capability. These are important implementation considerations, but positive attitudes towards AI do not demonstrate improved critical thinking, reasoning or professional competence. Similarly, successful completion of an AI-assisted task cannot automatically be interpreted as evidence that the learner possesses the capability represented by the final product [14–19].

A further evidence problem concerns disciplinary transferability. Medicine, nursing, dentistry and other health professions have generated substantial literature on AI-supported simulation, virtual patients, clinical reasoning and feedback. These studies can illuminate pedagogical mechanisms relevant to public health, but PG public health differs from many clinical disciplines in the scale and character of its reasoning. Public health frequently requires population-level analysis, systems thinking, policy judgement, stakeholder negotiation and decision-making under social, organisational and political constraints. Evidence from adjacent health professions must therefore be distinguished from evidence generated directly within PG public health education [15,19].

A synthesis is consequently required that connects three bodies of literature that have largely developed separately: evidence concerning effective PG public health pedagogy; evidence concerning online and authentic learning; and the emerging evidence concerning AI-supported higher-order learning. Given the heterogeneity of educational interventions, populations, study designs, and outcome constructs across these intersecting studies, a scoping review was considered appropriate to map the breadth and characteristics of the evidence, clarify transferable pedagogical mechanisms, and identify evidence gaps rather than estimate a single intervention effect.

This scoping review therefore examined how online PG public health education can develop higher-order learning and real-world readiness in the AI era. Rather than asking only whether AI improves educational outcomes, the review examined the pedagogical conditions under which higher-order capability develops and how AI interacts with those conditions. The review was conceptualised around PG public health learners and relevant transferable learner populations (population), higher-order learning, competence and professional readiness in relation to AI-supported and established pedagogies (concept), and online, blended and digitally mediated PG education (context).

Review Questions

The review addressed four questions:

1. Which pedagogical approaches are associated with higher-order learning and competence development in online or digitally mediated PG public health education?
2. How are authentic learning, professional application, and real-world readiness developed and assessed within PG public health education?
3. What does transferable evidence from health professions and higher education indicate about the effects of AI-supported learning on critical thinking, reasoning, judgement, communication, and applied competence?
4. Under what pedagogical conditions does AI appear to amplify learner cognition, and under what conditions might it substitute for the cognitive processes that education is intended to develop?

2. Materials and Methods

2.1. Review Design

A scoping review methodology was selected because the review questions encompassed heterogeneous educational interventions, study designs, populations, outcome measures, and emerging technologies. The purpose was to map the extent and characteristics of the evidence, identify pedagogical mechanisms and evidence gaps, and develop an integrative conceptual account rather than estimate a single pooled intervention effect. The review was conducted in accordance with updated JBI methodological guidance for scoping reviews [20] and reported in accordance with the PRISMA extension for Scoping Reviews (PRISMA-ScR) [21]. The review was not prospectively registered, and no formal review protocol was published or made publicly available.

2.2. Eligibility Framework

Eligibility was structured around population, concept and context. The principal population comprised learners enrolled in PG public health education, particularly MPH and closely related PG programmes. Because direct empirical evidence concerning AI-supported higher-order learning in this population was expected to be limited, a predefined transferable evidence layer included learners in health professions and higher education settings where interventions evaluated comparable cognitive or professional capabilities. The principal concept was the development of higher-order learning and professional capability. Relevant outcomes included critical thinking, reasoning, problem solving, systems thinking, synthesis, judgement, decision-making, communication, metacognition, applied competence and transfer of learning into authentic or professional contexts. The context encompassed online, blended and digitally mediated PG education together with pedagogical approaches capable of informing online curriculum design. AI-supported learning included generative AI, large language models, intelligent tutoring, conversational agents, AI-supported simulation, virtual patients, automated feedback and related applications where AI formed part of the educational process. Studies concerned solely with attitudes towards AI, awareness, familiarity, readiness to adopt AI or psychometric validation of AI-readiness instruments were not considered learner outcome evidence unless they also evaluated substantive educational outcomes. Studies in which AI was used only as an analytic tool, for example, to predict student performance, were excluded from the AI educational intervention evidence. Studies published from 2010 onward were deliberately retained so that pedagogical mechanisms established before the widespread availability of generative AI could serve as a historical comparator. This pre-genAI evidence was used to determine whether authentic learning, scaffolding, reflection, and professional transfer were established features of higher-order public health education before AI-mediated learning, rather than effects attributable to AI itself.

Eligible sources were published from 2010 to 2026 and were restricted to English-language publications at the full paper review stage. Eligible sources included peer-reviewed primary research and evidence syntheses relevant to the review questions, together with programme-level, conceptual and contextual sources where these contributed to interpretation of educational mechanisms or the evidence architecture. Sources were excluded when they did not address the predefined population, concept, or context or did not provide evidence relevant to higher-order learning, authentic learning, competence, or professional readiness. Eligible sources were subsequently assigned an analytic role according to their proximity to the review questions and function within the synthesis. The 2010–2026 period was selected to capture both the established evidence base for digitally mediated postgraduate education and the subsequent emergence of generative AI-supported learning.

2.3. Information Sources and Search Strategy

PubMed and Scopus were searched for literature published from 2010 to 2026 using a structured strategy designed to capture PG public health education, online and digitally mediated learning, AI, higher-order cognition, competency development, and professional readiness. The final database search was concluded on 20 August 2026. The 2010 start date intentionally captured a substantial pre-genAI evidence base for comparison with the emerging AI-era literature. Search concepts used controlled vocabulary, where available, and free text terms covering public health and MPH education; PG and professional education; online, blended and digital learning; AI and genAI; critical thinking, reasoning and higher-order cognition; authentic and experiential learning; competency; and workforce or professional readiness. Database-specific syntax was adapted for PubMed and Scopus. No language filter was applied at the database search stage; English-language eligibility was applied during full-paper review. PubMed and Scopus were selected to provide biomedical/public health and broad multidisciplinary coverage within the resources of this single-author review. ERIC, PsycINFO, CINAHL, ACM Digital Library, and IEEE Xplore were not searched; reference lists of key syntheses and eligible sources were checked for candidate literature as a supplementary mitigation strategy. Records were exported, deduplicated, and screened in Covidence systematic review software (Veritas Health Innovation, Melbourne, Australia, 2026). Scopus AI (Elsevier, Amsterdam, The Netherlands; accessed September 2026) was used only as a supplementary discovery aid, not as an independent bibliographic database or separately countable search stream. Its interactive interface provided clickable/selectable fields and user input options through which relevant concepts could be selected or entered to refine exploratory discovery. A complete sequential history of these selections/inputs and the unique candidate yield was not prospectively logged and cannot be reconstructed reliably. Candidate records considered for inclusion were bibliographically verified and assessed against the predefined eligibility criteria. Supplementary Material S1 provides the PubMed strategy and executable Scopus reconstructions preserving the recorded terms and intended concept block logic, together with the search date, applied limits, and reproducibility note; the raw historical Scopus query history export and family-specific retrieval counts were not retained and have not been retrospectively imputed. Accordingly, neither the number of records uniquely identified through Scopus AI nor the complete sequence of prompts, selectable fields, and user inputs can be reported reliably. The Scopus AI pathway was supplementary to the conventional database searches and should not be interpreted as an independently reproducible search stream. No retrospective AI-specific record count or interaction history was inferred from the retained search documentation.

2.4. Study Selection

All records were imported into Covidence, where duplicate records were identified and removed. Title and abstract screening and subsequent detailed eligibility assessment were undertaken by the author; no records were excluded on eligibility grounds by automated screening tools. Covidence was used for record management, deduplication, and screening workflow. Screening decisions were based on the population–concept–context (PCC) framework and the predefined distinction between direct public health and transferable evidence. The searches yielded 5777 records before deduplication. After removal of 253 duplicate records, 5524 unique records underwent title and abstract screening, of which 5123 were excluded. The remaining 401 records proceeded to detailed eligibility and analytic role assessment. Of these, 63 were excluded, and 338 sources were retained in at least one analytic role. The screening strategy deliberately distinguished between direct and transferable evidence. Records involving PG public health education were prioritised

for the direct evidence stream, whereas studies conducted in adjacent health professions or higher education populations were retained when their educational interventions or outcomes could inform mechanisms through which higher-order learning or professional competence develops. Because report-level retrieval status was not independently recorded for every record entering detailed eligibility assessment, separate counts for reports sought for retrieval and reports not retrieved could not be reconstructed reliably and were therefore not retrospectively imputed. Accordingly, this stage is reported as detailed eligibility assessment rather than as a conventional PRISMA "full-text reports assessed" count. Sources retained following eligibility assessment were subsequently classified according to their proximity to the review questions and function within the synthesis. Screening, eligibility assessment, and analytic role classification were conducted by a single reviewer; no independent duplicate screening, independent verification subset, or inter-rater reliability statistic was available. To support internal consistency, the same predefined PCC criteria and evidence layer definitions were applied throughout; borderline classifications were rechecked against source records, and analytic role assignments were reconciled against the structured evidence matrix and narrative synthesis. These procedures improve auditability but do not substitute for independent duplicate review. No retrospective independent verification subset was undertaken because the screening and charting workflow had been completed by the sole reviewer and no second reviewer had been prospectively engaged; this remains an unresolved limitation, and the consistency procedures described above should not be interpreted as a reliability check.

2.5. Evidence Layer Classification

A layered evidence architecture was used to avoid treating heterogeneous sources as methodologically equivalent.

- Direct core evidence comprised primary studies evaluating learner, competency, applied practice or professional readiness outcomes within PG public health education or closely aligned PG public health contexts.
- Direct supporting evidence comprised public health curriculum evaluations, programme descriptions, competency studies and contextual evidence that informed interpretation but did not provide equivalent learner outcome efficacy evidence.
- Core transferable evidence comprised primary studies from health professions or relevant higher education settings evaluating pedagogical mechanisms and higher-order outcomes directly transferable to the review question.
- Transferable supporting evidence informed implementation, mechanisms, or educational context without carrying the same weight as core learner outcome studies.

Evidence syntheses were separately classified as high-value or supporting syntheses according to methodological design and proximity to the review outcomes. Conceptual frameworks and contextual sources were retained where they contributed to interpretation but were not counted as primary outcome evidence. This approach produced a principal primary study synthesis of 92 studies, comprising 27 direct and 65 transferable core studies. Operationally, 'core' required a primary empirical study with learner-level higher-order competence, applied practice, or readiness outcomes that directly informed a review question; 'supporting' sources informed curriculum, implementation, mechanism, or context without equivalent learner outcome evidence. 'Direct' required a PG public-health/MPH or closely aligned PG public health context, whereas 'transferable' denoted an adjacent health professions or higher education population with a relevant pedagogical mechanism and outcome construct. The full coding rubric and source level matrix for all 92 core studies are provided in Supplementary Material S4.

2.6. Data Mapping

Data were charted by the author using a structured evidence matrix developed around the review questions and PCC framework. As this was a single-author scoping review, data charting was not performed independently in duplicate. Extracted information was checked against the source publications during synthesis to support consistency of classification. No investigators were contacted for additional or missing data. Extracted variables included study identification, educational context, population, design, delivery modality, pedagogical approach, AI integration and function, higher-order learning outcomes, authentic learning characteristics, competency or professional readiness outcomes, and direction of findings. Pedagogical categories included case- and problem-based learning, simulation and virtual patients, experiential or field learning, project and capstone learning, flipped or blended learning, online/asynchronous learning, interprofessional or team-based learning, and explicit scaffolding or metacognitive approaches. AI functions were coded according to the educational role performed, including tutoring or assistance, simulation or virtual interaction, feedback or debriefing, data analysis or coding support, reasoning scaffolds, and content or scenario generation. The complete coding rubric and source-level evidence charting matrix are provided in Supplementary Material S4. No independent duplicate extraction or reliability statistics were available; consistency was supported through repeated source-level checking and reconciliation of coding against the evidence tables and synthesis.

2.7. Outcome Coding

Higher-order outcomes were coded into conceptually related domains, including critical thinking, reasoning, problem solving, systems thinking, decision-making or judgement, metacognition or reflection, synthesis or integration, communication, and applied competence or skills. Authentic learning features were separately coded to identify real-world cases or scenarios, simulation or role play, practicum or community engagement, project or capstone outputs, interprofessional tasks, and explicit workplace or professional transfer. Competency and readiness outcomes included competency attainment, self-efficacy or confidence, workplace/practice transfer, professional behaviour, and explicit workforce or practice readiness. Because these constructs frequently co-occurred, categories were treated as non-mutually exclusive.

2.8. Direction of Findings

Direction of findings was coded conservatively as positive, mixed or nuanced, null/equivalent, negative/risk signal, or not determinable from the available evidence. Positive coding required evidence of favourable learner or competence outcomes rather than favourable perceptions of AI alone. Mixed coding was applied where improvements in some outcomes were accompanied by null findings, limitations or potential cognitive risks in others. Where the available record did not permit responsible determination of the direction of findings, no effect was imputed.

2.9. Critical Appraisal

Formal methodological quality or critical appraisal of individual sources was not undertaken because the purpose of the scoping review was to map the breadth, characteristics, and pedagogical mechanisms of a heterogeneous evidence base rather than determine pooled intervention effectiveness. The evidence layer classification was used to distinguish sources according to their analytic function and proximity to the review questions and should not be interpreted as a formal assessment of methodological quality or risk of bias. Study design was nevertheless retained in the evidence matrix and used descriptively

to contextualise interpretive credibility: controlled/comparative studies, uncontrolled pre/post evaluations, qualitative studies, programme reports and self-reported outcomes were not treated as methodologically equivalent. This descriptive contextualisation is not a retrospective quality score, and mapped frequencies or favourable directions are not interpreted as causal estimates of effectiveness. The characteristics and findings of 27 direct core studies are presented in Table 1, while Table 2 situates these studies within the broader evidence base by comparing key pedagogical characteristics, higher-order outcomes, authentic learning features, and competence/readiness outcomes across the 27 direct and 65 transferable core studies. The study-design information reported for the 27 direct core studies in Table 1 was further synthesised into descriptive design categories in Table 3. This stratification is provided to contextualise the methodological composition of the direct evidence base and should not be interpreted as a formal methodological quality or risk-of-bias grading.The categories are descriptive and do not constitute a formal quality hierarchy. A comparable retrospective design stratification was not imposed on the 65 transferable studies where design descriptors were not recorded with sufficient consistency in the source level coding matrix; doing so would require post hoc inference beyond the prespecified charting fields.

Table 1. Characteristics and key findings of the 27 core studies providing direct evidence from PG public health education.

Study	Country/ Setting	Population/ Sample	Design	Pedagogy/Exposure	Higher-Order/ Readiness Outcome	Principal Finding
Mengesha et al., 2026 [22]	Australia	PG health science students; $n = 78$	Mixed-methods pre/post evaluation	Scaffolded GenAI in epidemiol-ogy/research critical appraisal assessment	Metacognition; critical appraisal; responsible AI use	GenAI understanding and perceived effective use capability improved ($p < 0.001$); themes included metacognitive engagement, authentic learning tension, and ethical ambiguity.
Roohi et al., 2026 [23]	Iran	MPH students; $n = 8$	Pilot course/case study	Fully online GenAI-assisted biostatistics using R; project-based assessment	Applied analytical problem solving; interpretation	All students applied key concepts despite little prior programming/biostatistics experience; GenAI supported conceptual clarification and coding problem solving.
Thandla et al., 2024 [24]	USA	Graduate global health students; $n = 28$	Comparative educational evaluation	Student papers compared with ChatGPT-4o papers generated from identical prompts	Information literacy; evidence verification; judgement	AI papers were generally rated inferior or similar; 54% of 729 AI references were authentic, and only 14.4% were both authentic and relevant.
Richardson et al., 2026 [25]	USA	MPH students; $n = 60$ qualitative participants; survey n varied	Mixed-methods curriculum evaluation	Evidence-based MPH core delivered online and in person	Competency attainment; self-efficacy; workforce relevance	Competency self-ratings increased; 52% rated the curriculum very/extremely effective; qualitative findings emphasised workforce relevance and skill self-efficacy.
Sneed et al., 2025 [9]	USA	Online MPH students; typically 10–28/ semester	Course implementa-tion/evaluation	14-week asynchronous community engagement course with applied assignments and practitioner input	Metacognition; community engagement skills; authentic application	Course design explicitly linked theory with authentic public health practice; intentional interaction and applied tasks were central to skill development.
Hemingway et al., 2024 [26]	USA	Current/recent MPH students; $n = 80$	Pre/post online training evaluation	One-hour self-paced online programme evaluation training	Programme evaluation knowledge; self-efficacy	Mean knowledge increased from 2.13 to 3.24 and self-efficacy from 2.92 to 3.44; attitudes also improved.

Table 1. *Cont.*

Study	Country/ Setting	Population/ Sample	Design	Pedagogy/Exposure	Higher-Order/ Readiness Outcome	Principal Finding
Cunnington et al., 2023 [6]	USA	Public health students; $n = 39$	Comparative course evaluation	Practice-based teaching delivered in-person, virtual or hybrid	Competency; problem solving; teamwork; workforce readiness	Virtual and hybrid delivery achieved similarly high competency outcomes to in-person teaching; students linked practice-based teaching directly to workforce readiness.
Claiborne et al., 2021 [27]	USA	Dental hygiene and MPH students; $n = 86$ enrolled	Pre/post interprofessional evaluation	Online case-based interprofessional applied learning activity	Systems thinking; interprofessional competence; career relevance	Interprofessional socialisation and values improved; 64% agreed that the acquired skills would assist their careers.
Milic et al., 2018 [5]	Serbia	Master's public health students; $n = 69$	Comparative educational trial	Blended biostatistics versus traditional delivery	Biostatistics competence; knowledge	Blended learners achieved higher final statistics scores (89.65 vs. 78.21) and knowledge test scores (35.89 vs. 22.56), both $p < 0.001$.
Duffy et al., 2017 [28]	USA	Graduate health sciences students including MPH; $n = 319$	Mixed-methods evaluation	Six-week asynchronous online interprofessional activity	Social determinants reasoning; interprofessional competence; behaviour	Teams including an MPH student demonstrated greater awareness of social determinants of health (OR 2.04, 95% CI 1.13–3.66).
Angus et al., 2016 [29]	Australia	MPH students; n = NR	Curriculum implementation/preliminary evaluation	Five online Indigenous public health modules integrated into core MPH subjects	Competency development; deeper knowledge construction; judgement	Case-based, scaffolded and flipped design ensured exposure to Indigenous public health competencies and supported deeper knowledge construction.
Zolo et al., 2025 [30]	South Africa	UCT MPH alumni; $n = 10$	Qualitative descriptive evaluation	Systems-focused, multidisciplinary and case-based global surgery course	Systems thinking; professional identity; career impact; readiness	Themes included paradigm shift, multidisciplinary learning, career advancement and practitioner advocate identity; graduates were characterised as practice-ready change agents.
Wang et al., 2025 [31]	China	Full-time MPH post-graduates; n = NR	Programme implementation/outcome report	MPH integrated with standardised public health physician training	Practical ability; occupational competence	Integrated training was explicitly designed to strengthen practical ability and job competence.
Ramaswamy et al., 2019 [10]	USA	Graduate public health learners; 142 enrolments, 127 master's level	Curriculum evaluation using Kirkpatrick framework	Applied implementation science courses using cases, systems/design thinking, and quality improvement	Applied competence; transfer to authentic practice products	Students subsequently applied methods in practicums, master's papers and special studies, demonstrating transfer beyond the course.
Papadopoulos et al., 2013 [11]	Canada	MPH students; focus group n = NR	Capstone educational evaluation	Business plan capstone integrating all 36 Canadian public health competencies	Synthesis; evidence-informed decisions; stakeholder engagement	Students integrated epidemiological evidence, multiple information sources, stakeholder needs and implementation feasibility within a real-world programme plan.
Villanueva et al., 2011 [12]	USA	Graduate MPH students and preceptors; three cohorts	Pre/post practicum evaluation	Required 120 h community-based practicum within service/PBL curriculum	Real-world problem solving; competence; collaboration	Students reported greater ability to address real-world problems; preceptors were satisfied with student competence and project completion.
Galway & Cameron, 2020 [7]	Canada	Master's level Environmental and Occupational Health students; small cohort	Pre/post course survey	Online flipped classroom MPH course	Critical thinking; knowledge/skills; engagement	Learning outcomes were achieved, while the course promoted critical thinking and engagement in online graduate public health education.

Table 1. *Cont.*

Study	Country/ Setting	Population/ Sample	Design	Pedagogy/Exposure	Higher-Order/ Readiness Outcome	Principal Finding
Corvin et al., 2017 [1]	USA	MPH students; >200 across three pilots	Multi-cohort curriculum implementation/evaluation	Integrated interdisciplinary core with experiential learning and critical thinking assignments	Systems thinking; problem solving; competency	Preliminary CPH pass rate was 88% among transformed core students versus 71% in the traditional core and 70% nationally.
Walker et al., 2021 [8]	USA	MPH/MSPH and Executive MPH students; 17 course sections	Mixed-methods modality evaluation	Online, hybrid, and in-person sections across five courses	Learning; engagement; confidence in learning objectives	Online delivery was equivalent to in-person delivery for learning, satisfaction, and engagement; confidence in achieving learning objectives increased across modalities.
McHale et al., 2025 [4]	USA	MPH leadership concentration; *n* = NR	Curriculum case study with alumni/employer feedback	Problem-based learning across five leadership courses	Systems thinking; strategic decision-making; leadership; readiness	Alumni and employer feedback indicated workplace readiness and leadership capacity gains from applied interdisciplinary PBL.
Stolow & Lederer, 2023 [32]	USA	MPH students; *n* = 102	Qualitative content analysis	Required foundational programme planning course	Transferable career skills; programme planning competence	In total, 87.3% identified new transferable career skills, and 93.1% reported a positive change in their perception of programme planning.
Kruger et al., 2023 [33]	USA	MPH and PharmD students; *n* = 133	Observed intervention plus post-survey	Two-hour interprofessional innovation sprint	Problem solving; collaboration; self-efficacy	A total of 92% met observed interprofessional competencies; collaboration and problem-solving outcomes were also positively reported.
Garbers et al., 2022 [2]	USA	Columbia MPH students; *n* = 1902 respondents	Retrospective six-year curriculum evaluation	Integrated MPH Core with active/interdisciplinary learning	Integration of concepts; application to field experience	A total of 81.7% reported easily integrating concepts across core modules; similar proportions reported applying core learning to subsequent coursework and field experience.
Zwanikken et al., 2014 [3]	Vietnam, China, South Africa, Mexico, Sudan and Netherlands	MPH graduates; 37.5% response rate	Graduate outcome/impact study	MPH programmes oriented to LMIC public health needs	Competency application; workplace performance; leadership; societal impact	A total of 69% reported leadership change and 80% new responsibilities; graduates attributed substantial competency application and workplace impact to MPH training.
Anderson et al., 2011 [34]	USA	MPH students/ community partners; *n* = NR	Programme implementation report	Service learning progressively embedded into elective, practicum and internship	Experiential learning; community engagement; practice readiness	Service learning strengthened community-campus partnerships, increased student community service, and enriched practice-oriented learning.
Ramos-Gomez et al., 2024 [35]	USA	Paediatric dentistry/MPH alumni; *n* = 20/22	12-year qualitative follow-up	Dual degree MPH principles applied after graduation	Long-term practice transfer; leadership; prevention orientation	All interviewed alumni considered the MPH highly worthwhile and reported applying public-health principles in practice, leadership, research, and teaching.
Hosseinzadeh et al., 2022 [13]	Australia	International MPH health promotion students; *n* = 79	Pre/post intervention study	Case-scenario-based teaching	Critical thinking; multiple solution problem solving; communication	Critical thinking scores improved significantly ($p < 0.001$); critical thinking predicted 78.6% of total marks after adjustment.

Abbreviations: AI, artificial intelligence; CPH, Certified in Public Health; GenAI, generative artificial intelligence; MPH, Master of Public Health; MSPH, Master of Science in Public Health; NR, not reported in the retrieved record; PBL, problem-based learning; UCT, University of Cape Town.

Table 2. Comparative evidence map of the 92 core studies: direct PG public health evidence versus transferable evidence.

Domain	Characteristic	Direct Evidence *n* = 27, *n* (%)	Transferable Evidence *n* = 65, *n* (%)	All Core Studies *N* = 92, *n* (%)
AI integration	AI-integrated studies	3 (11.1)	57 (87.7)	60 (65.2)
Pedagogy	Online/asynchronous	11 (40.7)	9 (13.8)	20 (21.7)
	Scaffolded/metacognitive	9 (33.3)	29 (44.6)	38 (41.3)
	Case-/problem-based	6 (22.2)	12 (18.5)	18 (19.6)
	Simulation/virtual patient	0 (0.0)	21 (32.3)	21 (22.8)
	Interprofessional/team-based	6 (22.2)	10 (15.4)	16 (17.4)
	Experiential/practicum/field	5 (18.5)	4 (6.2)	9 (9.8)
	Flipped/blended	2 (7.4)	7 (10.8)	9 (9.8)
Higher-order outcome	Applied competence/skills	16 (59.3)	39 (60.0)	55 (59.8)
	Critical thinking	3 (11.1)	21 (32.3)	24 (26.1)
	Reasoning	0 (0.0)	9 (13.8)	9 (9.8)
	Synthesis/integration	9 (33.3)	32 (49.2)	41 (44.6)
	Decision-making/judgement	2 (7.4)	15 (23.1)	17 (18.5)
	Metacognition/reflection	3 (11.1)	15 (23.1)	18 (19.6)
	Communication	3 (11.1)	18 (27.7)	21 (22.8)
	Systems thinking	3 (11.1)	1 (1.5)	4 (4.3)
Authentic learning	Real-world cases/scenarios	14 (51.9)	33 (50.8)	47 (51.1)
	Simulation/role-play	0 (0.0)	21 (32.3)	21 (22.8)
	Practicum/field/community	6 (22.2)	7 (10.8)	13 (14.1)
	Workplace/professional transfer	16 (59.3)	2 (3.1)	18 (19.6)
Readiness/competence	Competency attainment	15 (55.6)	35 (53.8)	50 (54.3)
	Practice/workplace transfer	18 (66.7)	9 (13.8)	27 (29.3)
	Self-efficacy/confidence	4 (14.8)	18 (27.7)	22 (23.9)

Table 3. Descriptive design stratification of the 27 direct core studies.

Descriptive Design Category	*n*	Studies Represented/Basis
Pre/post intervention or training evaluation	6	Studies explicitly reported as pre/post or mixed-methods pre/post evaluations.
Comparative/modality evaluation or trial	4	Studies explicitly comparing educational approaches, modalities, or AI-generated versus student outputs.
Qualitative evaluation/content analysis	3	Qualitative descriptive, content-analysis or long-term qualitative follow-up designs.
Mixed-methods evaluation without a primary pre/post or comparative label	2	Mixed-methods curriculum or interprofessional evaluations.
Retrospective/graduate outcome or impact evaluation	2	Retrospective curriculum evaluation and graduate outcome/impact study.
Course/curriculum/programme implementation, case study or applied evaluation	10	Pilot, course, curriculum, capstone, programme implementation and applied intervention/evaluation reports not classified above.
Total	27	All direct core studies in Table 1.

2.10. Synthesis

Given heterogeneity in interventions, populations, designs and outcomes, studies were synthesised descriptively rather than statistically pooled. Frequencies were used to summarise pedagogical mechanisms, higher-order outcomes, authentic learning characteristics and competence/readiness outcomes across direct and transferable evidence; categories were non-mutually exclusive. The synthesis proceeded in three stages: direct PG public health evidence identified mechanisms associated with higher-order learning and professional transfer; transferable evidence examined how AI interacted with comparable mechanisms and outcomes; and the two layers were integrated. The pre-generative-AI literature provided a comparator for identifying pedagogical mechanisms that pre-dated

widespread genAI use. This enabled the final interpretive distinction between cognitive amplification, where AI supports learning while preserving learner responsibility for reasoning and judgement, and cognitive substitution, where AI performs cognitive activity that constitutes the intended learning outcome. The amplification/substitution distinction was developed as an interpretive conceptual framework from the mapped evidence; it was not prospectively specified or validated as a causal model and is used to organise hypotheses about learner cognitive responsibility rather than to rank AI tools or establish comparative effectiveness.

3. Results

3.1. Study Selection and Evidence Architecture

The database searches identified 5777 records. After removal of 253 duplicates, 5524 unique records underwent title and abstract screening, of which 5123 were excluded. The remaining 401 records proceeded to detailed eligibility and analytic role assessment. Of these, 63 were excluded, and 338 sources were retained in at least one analytic role (Figure 1). Because report-level retrieval status was not independently recorded for every record entering detailed eligibility assessment, separate counts for reports sought for retrieval and reports not retrieved could not be reconstructed reliably and were not retrospectively imputed. The 338 retained sources were subsequently classified according to their proximity to the review questions and function within the synthesis. These comprised 27 direct core primary studies, 33 direct supporting sources, 65 core transferable primary studies, 181 transferable supporting sources and 32 evidence syntheses. The principal primary learner-outcome evidence base therefore comprised 92 studies: 27 direct and 65 transferable core studies. Source-level characteristics and findings relevant to the review questions are presented in the accompanying evidence tables, while the narrative synthesis below summarises patterns across the direct and transferable evidence layers.

The retained literature was stratified according to its proximity to the review question and evidentiary function. The principal learner outcome evidence base comprised 92 primary studies: 27 studies providing direct evidence from PG public health education or closely aligned contexts and 65 providing transferable evidence from health professions or higher education settings. Thirty-two high-value systematic reviews, meta-analyses or other evidence syntheses were retained for triangulation. The remaining sources contributed supporting programme, curriculum, competency, implementation, conceptual or contextual evidence and were not treated as equivalent to primary learner outcome studies.

3.2. Characteristics of the Direct PG Public Health Evidence

The 27 direct studies encompassed MPH and related PG public health programmes, courses, practicums, capstones, interprofessional activities, competency-based curriculum reforms and graduate outcome evaluations (Table 1) [1–13,22–35]. Eleven (40.7%) included online or asynchronous learning; six (22.2%) used case- or problem-based learning; six (22.2%) incorporated interprofessional or team-based learning; five (18.5%) included experiential, practicum, field or community-based learning; and nine (33.3%) incorporated explicit scaffolding or metacognitive structuring. Only three (11.1%) explicitly incorporated AI. The pre-genAI direct evidence included authentic application, scaffolding, integration, reflection, and workplace-transfer approaches, providing a temporal comparator for the subsequent AI-era evidence.

3.3. Higher-Order Learning and Competence in PG Public Health

Applied competence or skills were identified in 16 of 27 direct studies (59.3%) and competency attainment in 15 (55.6%). Synthesis/integration occurred in nine (33.3%),

critical thinking in three (11.1%), systems thinking in three (11.1%), communication in three (11.1%), metacognition/reflection in three (11.1%), and decision-making/judgement in two (7.4%). Authentic learning was prominent: 14 studies (51.9%) used real-world cases or scenarios, 6 (22.2%) included practicum, field, or community experiences, and 18 (66.7%) identified practice/workplace transfer as an outcome. Longitudinal and graduate outcome studies further documented competency application, new responsibilities, leadership development, and sustained use of public health principles after graduation.

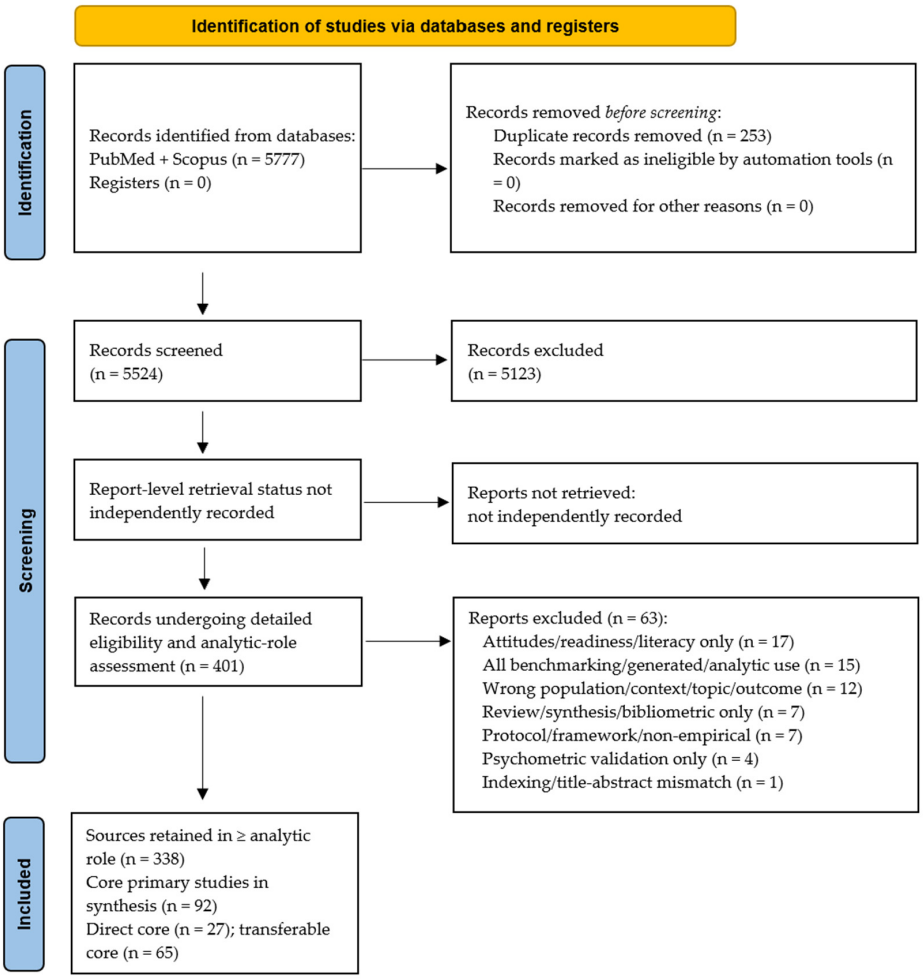


Figure 1. PRISMA-ScR flow diagram for the study selection and analytic classification. Note: Separate counts for "reports sought for retrieval" and "reports not retrieved" were not independently recorded and could not be reconstructed reliably; these fields are therefore shown as not independently recorded. This is a deviation from complete PRISMA-ScR flow reporting.

3.4. Online Delivery and Authentic Public Health Learning

The direct evidence did not indicate an inherent disadvantage of online or blended delivery. Studies comparing online, hybrid, and in-person public health education generally reported comparable learning or competency outcomes when designs incorporated active and practice-oriented learning [5–8]. Authentic cases, flipped learning, interdisciplinary collaboration, applied assignments, projects, and community- or practice-based activities were associated with outcomes extending beyond knowledge acquisition to competency, critical thinking, self-efficacy, problem solving, and workforce preparedness [1,6–12,29,34].

3.5. Comparison with the Transferable Evidence

The 65 transferable studies substantially expanded the AI-supported evidence (Table 2). AI was integrated into 57 of 65 transferable studies (87.7%) versus 3 of 27 direct studies

(11.1%). Applied competence/skills were similarly represented (60.0% vs. 59.3%), as was competency attainment (53.8% vs. 55.6%). Transferable studies more often addressed simulation/virtual patients (32.3% vs. 0%), critical thinking (32.3% vs. 11.1%), and decision-making/judgement (23.1% vs. 7.4%). In contrast, direct public health evidence more often demonstrated workplace/professional transfer (59.3% vs. 3.1% as an authentic learning characteristic; 66.7% vs. 13.8% as an outcome). Table 3 summarises the design labels reported in Table 1 and is not a formal methodological quality or risk-of-bias grading.

3.6. AI-Supported Higher-Order Learning

Across the core evidence base, 60 of the 92 studies incorporated AI. AI-supported interventions included genAI tutors, chatbots, virtual patients, simulated professional interactions, AI-supported feedback and debriefing, decision-support scaffolds, data analysis or coding assistance, and AI-enhanced assessment. Within the 57 AI-integrated transferable studies, AI educational functions were non-mutually exclusive. GenAI tutor/assistant was coded in 46 studies (34 positive, 10 mixed/nuanced, 1 null/equivalent and 1 risk/negative); feedback/debriefing/assessment in 36 (26 positive, 10 mixed); decision-support/reasoning scaffold in 35 (24 positive, 10 mixed and 1 null/equivalent); simulation/virtual agent in 14 (10 positive, 4 mixed); coding/data analysis support in 6 (3 positive, 1 mixed, 1 null/equivalent and 1 risk/negative); and content/question generation in 3 (2 positive, 1 mixed). These overlapping descriptive counts do not establish comparative causal effectiveness between AI functions. Favourable outcomes were most commonly observed when AI was incorporated into structured educational activities requiring learners to remain cognitively active. These included case-based learning, Socratic questioning, simulation, role play, metacognitive scaffolding, iterative feedback, diagnostic or decision-making exercises, and structured problem solving [15,16,18,19,22,23]. Across the 92 core studies, applied competence or skills were identified in 55 studies (59.8%), synthesis or integration in 41 (44.6%), critical thinking in 24 (26.1%), communication in 21 (22.8%), metacognition or reflection in 18 (19.6%), decision-making or judgement in 17 (18.5%), reasoning in nine (9.8%), and systems thinking in four (4.3%). Descriptively, favourable findings frequently co-occurred with structured educational activities that required learners to remain cognitively active; because AI functions overlapped and study designs and outcomes were heterogeneous, this pattern should not be interpreted as evidence that these functions caused superior outcomes.

3.7. Direction of Findings and Cognitive Offloading

The direction of findings across the core evidence base was not uniformly positive. Of the 92 core studies, 61 were coded as showing predominantly positive findings, 18 showed mixed or nuanced findings, 3 showed broadly null/equivalent findings, and 1 showed a predominantly negative or cognitive risk signal; the direction of findings could not be determined for 9. Improvements in engagement, confidence, efficiency, or product quality did not consistently coincide with gains in reasoning or knowledge, and some studies identified weaknesses in individualisation, problem-to-plan integration, verification, or independent cognitive processing [15,17–19,24].

3.8. Integrated Evidence Model

Across both evidence layers, higher-order learning was most consistently associated with active application of knowledge to authentic problems through scaffolding, cases, simulation, projects, field experiences, community engagement, collaboration, feedback, and reflection. The pre-genAI comparator demonstrated that these mechanisms were present before widespread genAI adoption. Integration of the pre-genAI and AI-era evidence generated an interpretive distinction between cognitive amplification and cognitive

substitution. When AI expanded opportunities for practice, simulation, feedback, comparison, and iterative reasoning while learners retained responsibility for interpretation, verification, and judgement, this pattern was classified as cognitive amplification. When AI generated the reasoning, decisions, or products constituting the intended learning activity, this pattern was classified as a risk of cognitive substitution. These contrasting conditions are operationalised in Table 4 and integrated in Figure 2.

Table 4. AI as cognitive amplification versus cognitive substitution according to learner cognitive responsibility.

AI Educational Function	Amplification Condition	Substitution Risk	Relevant Outcome
Tutor/scaffold	Learner must explain and justify reasoning	AI supplies final reasoning	Critical thinking/reasoning
Virtual patient/simulation	Learner makes decisions and communicates	AI directs decisions	Applied competence
Feedback/debriefing	Learner compares, reflects and revises	Feedback accepted uncritically	Metacognition
Information support	Learner verifies sources and plausibility	Generated information treated as authoritative	Information literacy
Coding/data analysis	Learner interprets outputs and checks assumptions	AI performs analysis without conceptual understanding	Analytical competence
Assessment support	AI enables authentic iterative assessment	AI completes assessed product	Authenticity
Scenario generation	AI expands exposure to complex cases	Learner becomes passive consumer	Problem solving
Writing support	AI supports organisation/revision	AI performs synthesis and argumentation	Synthesis/judgement

Note: Amplification and substitution are interpretive mechanisms derived from the synthesis; they are not mutually exclusive properties of an AI tool. The educational effect depends on task design and the cognitive responsibility retained by the learner.

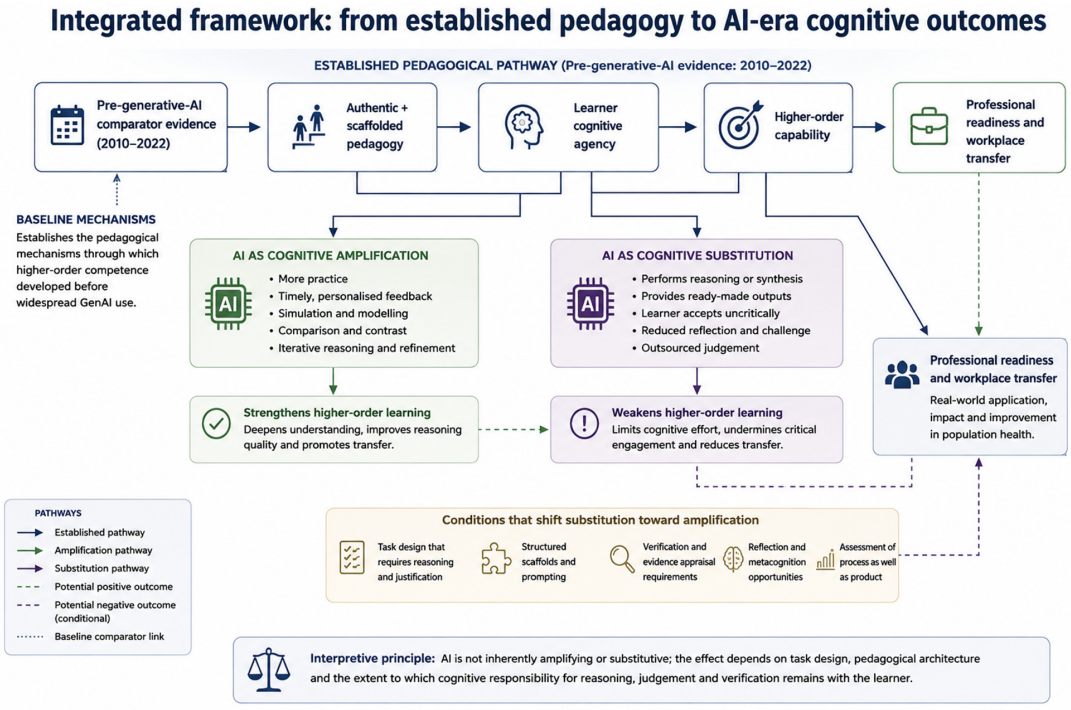


Figure 2. Integrated framework linking the pre-genAI pedagogical comparator, learner cognitive agency, cognitive amplification/substitution, and professional readiness.

4. Discussion

This scoping review identified three linked findings. First, online or blended delivery could support higher-order public health learning when embedded in authentic, active, and practice-oriented pedagogy [1–3,5–8,10–13,34,35]. Second, AI was not a pedagogy in itself; favourable AI-supported outcomes were most apparent when technology was embedded within established approaches such as problem-based learning, simulation, structured feedback, Socratic questioning, and metacognitive scaffolding [14–16,18,19]. Third, the synthesis indicated that the educational contribution of AI was shaped by whether learner cognitive responsibility was preserved, distinguishing cognitive amplification from cognitive substitution (Table 3; Figure 2). Across the four review questions, these findings converged on a common principle: higher-order learning and professional readiness were associated primarily with pedagogical designs that required learners to apply, integrate, justify, and transfer knowledge in authentic contexts, rather than with delivery modality or AI adoption alone. Direct public health evidence particularly emphasised authentic application and workplace or professional transfer, whereas transferable evidence substantially expanded the evidence concerning AI-supported learning.

First, the direct PG public health literature indicates that delivery modality alone is not the principal determinant of educational effectiveness. Online and blended programmes could support competence development, critical thinking, systems thinking, interdisciplinary learning and application to professional practice when learning was deliberately structured around authentic problems, cases, projects, practicums, community engagement, collaboration and reflection. The central distinction was therefore not between online and face-to-face education, but between learning environments that required active cognitive engagement and those dominated by knowledge transmission [1–3,5–8,10–13,34,35].

Second, the evidence suggests that AI should not be conceptualised as a pedagogy in itself. The transferable literature showed considerable growth in AI-supported education, yet favourable findings were most apparent when AI was embedded within an established pedagogical architecture, such as problem-based learning, simulation, virtual patients, structured feedback, Socratic questioning or metacognitive scaffolding. The educational contribution of AI therefore depended on the cognitive activity surrounding its use [14–16,18,19].

Third, the synthesis identified an important distinction between cognitive amplification and cognitive substitution. AI appeared educationally advantageous when it increased opportunities for learners to practice, receive feedback, encounter complex scenarios, test alternatives and refine reasoning while retaining responsibility for interpretation, verification and judgement. Conversely, when AI assumed the cognitive processes that constituted the intended learning outcome, apparent improvements in task completion or product quality could occur without equivalent evidence of higher-order learning [15,17–19]. These findings suggest that the central challenge for AI-era online MPH education is not whether AI should be permitted or incorporated, but how curricula can preserve the cognitive work through which professional competence develops.

4.1. From Online Delivery to Authentic PG Public Health Learning

The direct evidence also provides an important historical comparator. Studies conducted before widespread genAI adoption already demonstrated that cases, practicums, capstones, community engagement, interprofessional learning, and systems-oriented curricula could develop application, synthesis, and professional transfer [1–13,29,34,35]. This matters conceptually: the review does not attribute higher-order learning to AI. Instead, the pre-genAI literature establishes the pedagogical baseline, while the AI-era literature sug-

gests how AI can either strengthen those established mechanisms or displace the cognitive work on which they depend.

This finding is particularly relevant to public health because professional competence requires more than disciplinary knowledge. Public health practitioners must interpret incomplete evidence, integrate epidemiological and contextual information, negotiate competing stakeholder priorities, recognise system interactions, communicate uncertainty and formulate defensible actions under real-world constraints. These capabilities are poorly represented by assessments that primarily reward recall or reproduction of established knowledge.

The direct studies demonstrated several mechanisms through which PG programmes can move beyond this limitation. Case- and problem-based learning required students to apply knowledge to contextualised problems. Practicums and community-engaged learning exposed students to the organisational and social complexity of public health practice. Capstones and projects required synthesis across disciplinary domains. Interprofessional activities introduced negotiation and collaborative decision-making. Systems-oriented curricula required learners to consider relationships extending beyond individual risk factors or interventions.

The prominence of workplace and professional transfer in the direct evidence is especially important. Practice or workplace transfer was represented in 18 of 27 direct studies, substantially more frequently than in the transferable evidence. This suggests that the MPH literature offers an important dimension that much of the rapidly expanding AI-education literature currently lacks: evidence concerning whether learning can be applied beyond the immediate educational task [1,2,10–13,34,35].

4.2. Public Health-Specific AI Evidence Gap

A striking finding was the disparity in AI integration between the two evidence layers. AI was incorporated in only 3 of 27 direct PG public health studies, compared with 57 of 65 transferable studies [14,22–24]. This does not imply that AI is absent from public health education in practice. Rather, it indicates that the published empirical evidence evaluating AI-supported higher-order learning within PG public health education has not kept pace with the wider health professions literature. This marked imbalance represents an important evidence gap and supports the need for direct evaluation of AI-supported pedagogies within MPH and related PG public health programmes.

This gap matters because findings from medicine, nursing and other health professions programmes cannot simply be assumed to transfer unchanged to public health. Clinical education frequently centres on individual patients, diagnostic reasoning, procedural competence and clinician–patient communication. Public health education must additionally develop population-level reasoning, systems thinking, policy analysis, epidemiological interpretation, programme planning, stakeholder engagement, equity-oriented decision-making and the capacity to act within complex organisational and political systems [12,19].

The transferable literature is therefore valuable for identifying mechanisms, but the direct public health evidence remains necessary for determining how those mechanisms operate within population health problems. The absence of simulation among the 27 direct core studies is particularly notable given its prominence in the transferable evidence. AI-enabled simulations could potentially expose MPH learners to complex situations that are difficult to reproduce through conventional coursework: outbreak response, environmental health emergencies, risk communication, resource allocation, policy negotiation, stakeholder conflict, or rapidly evolving evidence. This represents a clear area for empirical development.

4.3. AI as Cognitive Amplification

The synthesis supports a conceptualisation of AI as potentially valuable when it functions as a cognitive amplifier. As such, AI does not remove the intellectual challenge from the learning task. Instead, it increases the learner's opportunity to engage with that challenge. An AI-supported simulation may generate multiple stakeholder responses; a virtual public health scenario may evolve according to learner decisions; an AI tutor may challenge assumptions through Socratic questioning; a feedback system may identify inconsistencies that require reconsideration; or a generative system may produce alternative explanations that learners must compare and critique. The defining characteristic is therefore not the technology but the retention of epistemic responsibility by the learner. Learners must still determine whether information is credible, whether an interpretation is defensible, whether assumptions are appropriate and whether proposed actions are justified. AI increases the volume, responsiveness, or complexity of the learning environment without assuming final responsibility for reasoning.

This interpretation is consistent with the predominance of favourable findings where AI was embedded in structured cases, simulation, iterative feedback, and metacognitive scaffolding. It also provides a plausible explanation for why AI-supported interventions may improve practical or applied outcomes without consistently producing superior knowledge test performance. AI's greatest educational value may lie not in increasing the quantity of information learners acquire, but in expanding the opportunities through which knowledge is used [15,16,18,19]. This pattern supports guarded or staged scaffolding rather than unrestricted assistance: AI access can be timed after an initial period of independent analysis or productive struggle, used to challenge or extend a learner's reasoning, and progressively reduced where independent judgement is the intended outcome. AI-companion designs should therefore preserve learner agency and require active verification rather than simply supplying completed answers. Explicit hallucination–detection and source–verification tasks can make epistemic vigilance an observable component of AI literacy.

4.4. Cognitive Substitution and the Performance Competence Problem

The converse mechanism emerging from the synthesis is cognitive substitution. Generative AI creates an unusual educational problem because it can produce outputs resembling the products traditionally used as evidence of learning. Essays, analyses, code, policy briefs, statistical interpretations, and recommendations may appear sophisticated even when substantial components of the underlying reasoning have been delegated to the system. Consequently, the observable product quality is not the same as demonstrated learner competence. This distinction has major implications for PG assessment. Several studies in the core evidence showed that positive outcomes such as engagement, confidence, efficiency, or overall task performance did not necessarily coincide with improvements in reasoning or knowledge. Other findings identified weaknesses in individualisation, problem-to-plan connections, verification, or independent cognitive processing despite apparently successful AI-supported task completion [15,17–19]. These findings suggest that educational institutions should distinguish performance support from competence development. AI may legitimately support professional performance; indeed, future public health practitioners are likely to work with AI-enabled tools. However, a learner's ability to produce a strong AI-assisted output does not establish that the learner independently possesses the analytical capability represented by that output. The educational objective should therefore not necessarily be AI-independent performance. Rather, programmes need mechanisms for determining which cognitive capabilities learners must demonstrate independently and which can appropriately be augmented by technology.

4.5. Implications for Assessment in the AI Era

This distinction requires reconsideration of assessment design. Attempts to preserve conventional assessment simply by prohibiting AI are unlikely to provide a durable solution. Equally, unrestricted AI use risks making some traditional assessment products increasingly weak proxies for competence. Assessment should instead shift towards making learner reasoning more observable. For online MPH programmes, this may include staged case analyses in which students explain evolving decisions; oral defence of AI-assisted work; critique and correction of deliberately flawed AI outputs; comparison of alternative recommendations; reflective documentation of prompts, verification and revisions; simulation-based decision tasks; authentic datasets requiring interpretation; stakeholder role exercises; and assessments in which students must justify actions under uncertainty.

The key assessment question becomes "What cognitive work must the learner demonstrate, regardless of the tools available?" This approach also changes the meaning of AI literacy. AI literacy should extend beyond prompt construction or knowledge of AI capabilities. Within PG public health, it should include epistemic vigilance, source verification, recognition of uncertainty and bias, appropriate delegation of cognitive tasks, ethical judgement and the ability to detect when generated outputs conflict with epidemiological evidence or contextual knowledge. Operationally, assessment policy should begin with the construct being assessed and specify which AI functions are permitted at each stage. Where AI is permitted, programmes can require auditable prompts or interaction records, source verification and documented revision, while retaining observable learner reasoning through explanation, justification, oral or interactive defence, and explicit assessment of uncertainty and verification. This provides a practical way to distinguish AI-supported cognitive amplification from substitution of the reasoning or judgement the assessment is intended to measure.

4.6. Implications for Online MPH Curriculum Design

The evidence supports four interacting curriculum principles: authenticity, scaffolding, cognitive agency and transfer. Learning tasks should reproduce the uncertainty and competing priorities of public health practice; scaffolding should progress towards independent judgement; learners should retain responsibility for interpretation, verification, synthesis and decision-making; and competence should be demonstrated in unfamiliar or professionally relevant contexts. Practicums, capstones, simulations, projects and community-engaged activities are therefore central rather than peripheral to online MPH preparation. These principles are more informative than a simple AI-enabled/non-AI-enabled distinction.

4.7. Implications for Public Health Educators and Institutions

Institutions should distinguish AI-supported learning from AI use that invalidates the intended assessment construct. Educator development should therefore focus on designing tasks and rubrics that make reasoning, verification and justification visible, supported where appropriate by oral, interactive and formative components. At programme level, curriculum mapping should show where critical thinking, systems thinking, analytical reasoning, communication, ethical judgement and applied decision-making are progressively developed and demonstrated; AI literacy should be integrated across the MPH rather than isolated in a single technology module.

4.8. Equity-Conscious AI Scaffolding

Subgroup reporting across the included evidence was too sparse and inconsistent to support quantitative conclusions by prior knowledge, self-efficacy, language background,

or access conditions. These are therefore evidence gaps rather than demonstrated subgroup effects. This limitation is consistent with emerging literature indicating that equity-related dimensions of GenAI use in higher education remain insufficiently examined, despite the potential importance of socioeconomic position, digital access, disability and language background in shaping learners' opportunities to engage with AI-supported education [36]. Equity-conscious AI design should therefore prioritise transparent and equitable access arrangements, accessible alternatives where technological, financial or connectivity barriers exist, explicit AI-literacy and verification training, and approaches that preserve learner agency and opportunities to demonstrate competence without dependence on a particular commercial AI platform [37,38]. Support may also need to be staged and responsive to learners' prior experience and capability, as emerging empirical evidence indicates that AI self-efficacy can influence how learners engage with GenAI-supported feedback, including their self-monitoring, critical-thinking awareness and strategic use of feedback [39]. Future studies should report subgroup outcomes, including prior knowledge, self-efficacy, language background, disability, digital access and socioeconomic position, to determine whether AI-supported educational designs narrow, reproduce or widen educational inequities [36,37].

4.9. Implications for Research

Research priorities are clear [14–19]. More empirical studies are needed specifically in PG public health education, using demonstrable higher-order outcomes rather than satisfaction or perceived usefulness alone. The marked imbalance between AI-related evidence in transferable settings (57/65 studies) and direct PG public health settings (3/27 studies) reinforces this priority. Comparative and longitudinal studies should test reasoning, systems thinking, evidence appraisal, communication, decision-making, and transfer to unfamiliar or workplace problems. Research should also define the threshold between productive scaffolding and cognitive offloading: which cognitive tasks can be delegated, for which learners and at what stage of competence, without compromising learning. Studies should distinguish short-term improvements in AI-assisted task performance from durable learner competence and should examine whether AI-supported learning transfers to authentic professional contexts. Public health-specific AI simulations of outbreaks, environmental or occupational health emergencies, policy negotiation and risk communication are particularly important opportunities. Future AI-era evaluations should also use novel cases or unseen datasets, blinded scoring of reasoning, delayed retention testing, oral defence or think-aloud explanation, error/hallucination detection tasks, confidence calibration, practicum or workplace performance, supervisor ratings and longitudinal follow-up. Where feasible, studies should compare AI-assisted performance with later independent or differently supported performance and report subgroup effects to determine whether learning transfers beyond the immediate AI-supported task.

4.10. Strengths and Limitations

This review has three principal strengths: it separates direct PG public health from transferable evidence; distinguishes primary learner outcome studies from syntheses, programme evidence and contextual literature; and evaluates higher-order learning, competence and real-world readiness rather than treating satisfaction or AI acceptance as educational effectiveness. A further strength is the deliberate inclusion of pre-genAI evidence, which provides a historical comparator for determining which pedagogical mechanisms pre-dated AI and therefore should not be attributed to it.

Several limitations should be recognised. First, the review searched PubMed and Scopus. ERIC, PsycINFO, CINAHL, ACM Digital Library and IEEE Xplore were not searched,

so education- and technology-specific transferable studies may have been missed. Reference list checking of key syntheses and eligible sources provided supplementary discovery but does not make the search comprehensive. No language filter was applied during database searching, but eligibility was restricted to English-language publications at full-paper review, so relevant non-English evidence may have been excluded. Second, title and abstract screening, detailed eligibility assessment, and data charting were undertaken by a single reviewer. Predefined PCC criteria, a structured coding rubric, repeated source-level checking and reconciliation of analytic role assignments supported internal consistency, but no independent duplicate screening, duplicate charting, verification subset, or inter-rater reliability statistic was available. Third, formal methodological quality or risk-of-bias appraisal of individual sources was not performed, consistent with the evidence mapping purpose of the scoping review. Study design was used descriptively to contextualise credibility, but the synthesis should not be interpreted as a quality-weighted or causal estimate of intervention effectiveness. Fourth, report-level retrieval status was not independently tracked for all 401 records entering detailed eligibility assessment; separate counts for reports sought for retrieval and reports not retrieved therefore could not be reconstructed reliably and were not retrospectively imputed. Fifth, Scopus AI was used as an interactive supplementary discovery aid. The sequential selection/input history and unique candidate yield were not prospectively logged and cannot be reconstructed reliably. Finally, the raw historical Scopus query-history export and family- or database-specific retrieval counts were not retained; Supplementary Material S1 therefore presents corrected executable Scopus reconstructions preserving the recorded terms and intended concept block logic, without retrospectively inventing unrecorded counts. The absence of an independent verification subset remains an unresolved limitation and may have increased the risk of selection, extraction, and classification error despite the internal consistency procedures used. The restriction to PubMed and Scopus is a substantive limitation, particularly for the transferable evidence layer, because relevant education, learning-science, and human–computer-interaction studies indexed primarily in ERIC, PsycINFO, CINAHL, ACM Digital Library, or IEEE Xplore may have been under-retrieved. Furthermore, the missing report-retrieval counts constitute a deviation from complete PRISMA-ScR flow reporting. The Scopus AI discovery pathway should likewise be regarded as non-reproducible because neither its complete interaction history nor its unique yield can be reconstructed.

The evidence base itself also has limitations. Direct empirical evidence concerning AI-supported higher-order learning in PG public health education was limited, requiring cautious use of transferable health professions and higher-education evidence. Although this evidence was selected for conceptual and pedagogical relevance, differences in disciplinary context, learner populations, and professional requirements limit direct transferability to PG public health education. Heterogeneity in interventions, populations, study designs and outcome measures precluded meaningful quantitative pooling, and many studies relied partly on self-reported competence or confidence. Higher-order constructs such as critical thinking, reasoning, competence and professional readiness were also operationalised inconsistently across studies; favourable perceptions, engagement or efficiency should therefore not be assumed to represent demonstrated cognitive or professional capability. Finally, the AI-related evidence was recent, limiting conclusions about long-term retention and workplace transfer. Rapidly evolving technologies may also outpace platform-specific evidence. The findings should therefore be interpreted as a map of the evidence available up to the final search on 20 August 2026 rather than as a definitive assessment of mature AI-enabled educational practice. The amplification/substitution distinction may consequently be more durable than recommendations tied to individual tools.

5. Conclusions

Online PG public-health education can support higher-order learning and professional readiness when learners engage in authentic, scaffolded, and cognitively demanding work. The pre-genAI literature demonstrates that these mechanisms pre-date widespread AI adoption; AI should therefore be understood as a modifier of established pedagogy rather than its source. AI may amplify cognition when it expands practice, feedback, simulation, and iterative reasoning while preserving learner responsibility for verification and judgement, but may create a risk of cognitive substitution when it performs the cognitive processes learners are expected to develop. The amplification/substitution distinction should be interpreted as a synthesis-derived conceptual framework rather than a prospectively validated causal model and requires direct prospective testing in PG public-health settings. These conclusions are constrained by the limited direct AI evidence in PG public health and by the review's database coverage; omission of education- and computing-focused databases may have shaped the transferable evidence base and limits claims of comprehensiveness.

The central curriculum question is therefore which cognitive work must remain visible, assessable and attributable to the learner. Online MPH programmes should combine authentic cases, simulations, projects, community/workplace application and assessments that expose reasoning rather than merely evaluating final products. The implication is not simply to increase or restrict AI use, but to design learning and assessment so that AI augments rather than obscures the development of higher-order capability. Future research should directly evaluate these principles within PG public health populations using longitudinal, authentic, and practice-oriented outcomes capable of distinguishing AI-assisted performance from durable competence and professional readiness. The goal is not simply an AI-enabled MPH but graduates able to use AI without surrendering the critical thinking, systems reasoning, professional judgement and epistemic responsibility required for public health practice.

Supplementary Materials: The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/ime5040101/s1: Supplementary Material S1: PubMed search strategy and corrected reproducible Scopus queries, with search parameters, language stage clarification and reproducibility note; Supplementary Material S2: Completed PRISMA abstract checklist; Supplementary Material S3: Completed PRISMA-ScR checklist; Supplementary Material S4: Evidence-charting matrix and coding rubric for the 92 core studies, including AI-function stratification of the 57 AI-integrated transferable studies.

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Data Availability Statement: The data supporting this scoping review are derived from the published sources cited in the manuscript. The source-level evidence charting matrix and coding rubric for the 92 core studies are provided in Supplementary Material S4.

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the author. Grammarly 1.2 (Grammarly Inc., San Francisco, CA, USA) and ChatGPT GPT-5.6 Sol (OpenAI, San Francisco, CA, USA) were used to support language refinement, organisation and structuring of text, grammar correction and editorial revision. All outputs generated or assisted by AI tools were critically reviewed and verified by the author. The author retained responsibility for study selection, data extraction, evidence interpretation, synthesis, and the final manuscript and takes full responsibility for its content.

Conflicts of Interest: The author declares no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

AI	Artificial intelligence
GenAI	Generative artificial intelligence
MPH	Master of Public Health
PCC	Population–concept–context
PG	Postgraduate

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