Original Research Paper

Teaching evidence-based medicine in low-certainty clinical contexts: a scoping review of undergraduate medical education

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Abstract

Evidence-based medicine (EBM) is a core competency in undergraduate medical education and a foundational principle of modern clinical practice. Traditional EBM curricula emphasize critical appraisal of randomized controlled trials and guideline-driven decision-making. However, many real-world clinical decisions are made in contexts where evidence is limited, conflicting, or value-laden, such as rare diseases, emerging therapies, disability care, and complex multimorbidity. This scoping review maps the existing literature on how undergraduate medical education addresses the teaching of EBM in low-certainty and value-sensitive clinical contexts, with reference to educational approaches, learning objectives, outcomes, and implementation challenges. Following the PRISMA-ScR framework, we systematically searched MEDLINE, Embase, ERIC, PsycINFO, and Scopus from inception to July 2025. Eligible studies described educational interventions, curricula, or assessments focused on teaching EBM to medical students when high-quality evidence is absent, uncertain, or contested. Data were extracted on study characteristics, pedagogical strategies, clinical contexts, learner outcomes, and reported barriers. Twenty-six studies were included, spanning pre-clinical and clinical phases of undergraduate medical education across North America, Europe, and Australia. Educational approaches included case-based learning, ethics-integrated EBM teaching, narrative and lived-experience integration, simulation, and reflective practice. Four overarching themes emerged: (1) reframing EBM beyond hierarchies of evidence; (2) integrating patient values and lived experience into evidence reasoning; (3) teaching epistemic uncertainty and clinical judgment; and (4) structural and institutional barriers to curricular integration. Existing literature suggests that teaching EBM in low-certainty contexts is feasible and valued by learners, but remains inconsistently integrated into undergraduate curricula. Future work should focus on developing standardized competencies, assessment tools, and longitudinal curricula that reflect the realities of evidence uncertainty and value-sensitive care.

Keywords: evidence-based medicine, medical education, uncertainty, undergraduate medical education, clinical decision-making, low-quality evidence, patient values, scoping review

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Introduction

Evidence-based medicine (EBM) has been a foundational pillar of medical education since its formalization in the early 1990s. EBM is defined as the integration of best available research evidence, clinical expertise, and patient values in clinical decision-making.[1,2] Medical schools worldwide have adopted EBM as a core competency, embedding instruction in literature appraisal, research design, and guideline interpretation across undergraduate curricula.[3-6] Accreditation bodies such as the Liaison Committee on Medical Education and the World Federation for Medical Education explicitly mandate EBM training within physician competency frameworks, reinforcing its central role in preparing graduates for modern clinical practice.[5,6] Longitudinal, credit-bearing EBM curricula that span preclinical and clinical years and include formal assessment have been associated with greater learner engagement and perceived preparedness for evidence-based practice.[6,7]

Systematic reviews consistently demonstrate that EBM education improves short-term learner knowledge and skills in literature appraisal and evidence application, supporting its pedagogical value within undergraduate medical training.[8,9] However, evidence for sustained

changes in clinical behavior or downstream patient outcomes remains limited, highlighting a persistent gap between educational gains and real-world impact.[8,9] Despite this limitation, EBM continues to be regarded as foundational to the development of self-directed, lifelong learners capable of adapting to evolving evidence landscapes.[1,3] This enduring importance has intensified scrutiny of not whether EBM should be taught, but how it is conceptualized and operationalized in medical education.[2]

Concerns regarding EBM education increasingly focus on its traditional emphasis on evidence hierarchies, particularly the privileging of randomized controlled trials and meta-analyses, alongside the implicit assumption that high-quality evidence exists for most clinical questions.[2,10] In everyday clinical practice, physicians frequently encounter scenarios where evidence is sparse, conflicting, rapidly evolving, or poorly generalizable to individual patients, especially in rare diseases, disability care, pediatrics, geriatrics, mental health, pregnancy, and complex multimorbidity.[11-14] Exclusion criteria in clinical trials disproportionately omit older adults, children, and individuals with multiple comorbidities or polypharmacy, limiting the external validity of guideline recommendations and creating substantial evidence gaps.[12-14] These limitations have prompted calls for EBM to evolve beyond a reductionist framework toward a more pluralistic approach that integrates real-world evidence, observational data, postmarketing surveillance, and patient values.[15-17]

Clinical decision-making in such contexts requires competencies that extend beyond technical appraisal of the literature, including the ability to navigate epistemic uncertainty, integrate diverse forms of evidence, and engage in values-based reasoning with patients and families.[18-19] Trainees consistently report feeling ill-prepared when guidelines are absent, conflicting, or ambiguous, often responding with anxiety, excessive reliance on authority, or inappropriate deferral to testing or specialist consultation.[18-20] These challenges are amplified by hierarchical clinical environments, time pressure, and assessment cultures that implicitly reward certainty over reflective reasoning.[18-19] Over-investigation and defensive medicine are common behavioral responses to discomfort with uncertainty, driven by commission bias and systemic incentives, and may paradoxically increase patient harm rather than mitigate risk.[20]

In response, a growing body of scholarship argues that EBM education must explicitly address uncertainty, shared decision-making, epistemic humility, and narrative competence as core—not peripheral—components of evidence-based practice.[2,21] Integrating EBM with shared decision-making has been shown to strengthen person-centered care and better prepare learners for complex, value-laden clinical scenarios.[22-24] Educational theorists further emphasize epistemic humility as a relational virtue that enables clinicians to acknowledge the limits of knowledge while respecting patient perspectives, and narrative competence as a means of integrating lived experience into evidence application.[25-27] While medical schools have begun experimenting with pedagogical innovations such as case-based learning in ambiguous scenarios, integration of ethics and humanities, and patient and community involvement in curriculum design, the scope, content, and effectiveness of these approaches remain incompletely synthesized.[28-32]

Importantly, the existing literature on EBM education is disproportionately derived from high-income, urban academic centres, with limited representation from low- and middle-income countries (LMICs), rural settings, and underserved contexts. This imbalance may constrain the generalizability of current educational models and risks reinforcing epistemic hierarchies that privilege certain forms of evidence and ways of knowing. In many global contexts, clinical decision-making is shaped not only by evidentiary uncertainty but also by resource constraints, workforce distribution, and differing models of care delivery. These factors may meaningfully influence how EBM is taught, interpreted, and applied in practice.

Accordingly, this scoping review aims to synthesize the existing literature on how undergraduate medical education addresses the teaching of evidence-based medicine in low-certainty and value-laden clinical contexts. By mapping educational strategies, pedagogical frameworks, and reported outcomes, this review seeks to identify gaps in current approaches and inform curriculum development that better aligns EBM education with the epistemic, ethical, and relational realities of contemporary clinical practice.

Methods

Protocol and Reporting

This scoping review was conducted in accordance with the PRISMA extension for Scoping Reviews (PRISMA-ScR) guidelines.[33] Methodological conduct was informed by established scoping review frameworks to support systematic mapping of heterogeneous medical education literature. A protocol outlining objectives, eligibility criteria, data sources, and analytic methods

was developed *a priori* to guide the review and enhance transparency and reproducibility. Given the exploratory nature of the review, the protocol emphasized conceptual mapping and breadth of coverage rather than formal quality appraisal or effect estimation.

Search Strategy

We conducted a comprehensive search of MEDLINE (Ovid), Embase, ERIC, PsycINFO, and Scopus from database inception to July 20, 2025. Search terms combined controlled vocabulary and keywords related to evidence-based medicine, undergraduate medical education, uncertainty, low-quality or conflicting evidence, clinical judgment, and values-based decision-making. Search strategies were adapted for each database to optimize sensitivity across clinical, educational, and social science disciplines. Grey literature was identified through targeted searches of medical education organization websites and manual screening of reference lists, recognizing that curricular innovations addressing uncertainty may be underrepresented in indexed journals. AI-assisted search tools were not used in this review, as the protocol was developed *a priori* in accordance with established scoping review methodologies. We acknowledge the increasing use of AI-assisted approaches in evidence synthesis and recognize this as a potential area for methodological enhancement in future reviews.

Eligibility Criteria

Studies were included if they: (1) focused on undergraduate medical students; (2) described educational interventions, curricula, or assessment strategies related to evidence-based medicine; and (3) explicitly addressed contexts of evidence uncertainty, conflicting or limited evidence, or value-sensitive decision-making. Both pre-clerkship and clerkship-level interventions were eligible for inclusion. Commentaries without empirical data or detailed curricular description were excluded, as were studies focused exclusively on postgraduate learners. No restrictions were placed on study design or geographic setting, consistent with scoping review methodology.

Selection Process

Two reviewers independently screened titles and abstracts, followed by full-text review of potentially eligible studies. Screening was conducted using predefined inclusion and exclusion criteria to promote consistency and reduce selection bias. Discrepancies were resolved through discussion and consensus, with a third reviewer adjudicating unresolved disagreements. Reasons for exclusion at the full-text stage were documented to support transparency in study selection.

Data Charting and Synthesis

Data were extracted using a standardized charting form capturing study design, educational context, teaching strategies, clinical domains, learner outcomes, and implementation considerations. The charting form was piloted on a subset of included studies and refined iteratively as needed. Findings were synthesized descriptively and thematically, with themes developed inductively to capture how uncertainty and values-based reasoning were operationalized within EBM education across diverse curricular contexts, rather than to compare effectiveness or rank educational approaches.

Research Team and Reflexivity

The research team comprised individuals with training in medicine, engineering, medical education, and evidence synthesis, including medical trainees, clinician-educators, and researchers. Given the interpretive nature of study selection and thematic analysis in scoping reviews, we acknowledge that the perspectives and prior experiences of the research team may have influenced analytic decisions. To mitigate this, screening and data charting were conducted independently by two reviewers, with discrepancies resolved through discussion and, where necessary, adjudication by a third reviewer.

Results

Study Characteristics

A total of 2,931 unique records were identified through database searching, of which 104 articles underwent full-text review. Twenty-six studies met the inclusion criteria and were included in the final synthesis. Educational settings spanned pre-clinical courses, clinical clerkships, and longitudinal undergraduate medical curricula. Across studies, four major thematic domains emerged: (1) reframing EBM beyond hierarchies of evidence, (2) integrating patient values and lived experience, (3) teaching epistemic uncertainty and clinical judgment, and (4) structural and institutional barriers to implementation.

Theme 1: Reframing Evidence-Based Medicine Beyond Hierarchies of Evidence

Across included studies, there was consistent movement away from portraying EBM as a rigid hierarchy of evidence toward framing it as a contextual and deliberative reasoning process. Multiple curricula explicitly challenged the privileging of randomized controlled trials and meta-analyses as universally superior, emphasizing instead the limitations of trial design, issues of external validity, and the relevance of alternative evidence forms in real-world clinical decision-making.[2,11,34,35] Educational interventions

highlighted circumstances in which mechanistic reasoning, observational data, or expert judgment were necessary and appropriate, particularly when high-level evidence was unavailable, impractical, or poorly generalizable.[11,35,36]

Several studies explicitly drew on contemporary frameworks such as GRADE to illustrate how evidence quality is influenced by factors beyond study design alone, including consistency, directness, and applicability to specific patient populations.[2] Learners exposed to these approaches reported a shift in how they conceptualized EBM, describing it less as a checklist-driven or algorithmic process and more as an integrative framework requiring judgment and contextualization.[2,37] Across qualitative and mixed-methods studies, this reframing was associated with improved learner engagement and a more nuanced understanding of how evidence is applied in complex clinical scenarios.[34,35]

Theme 2: Integrating Patient Values and Lived Experience into EBM Teaching

Twelve included studies explicitly incorporated patient narratives, disability perspectives, or community voices into EBM education. These interventions aimed to bridge the gap between population-level evidence and individual patient priorities, particularly in contexts where traditional outcomes failed to reflect what mattered most to patients.[38-42] Educational strategies included narrative medicine workshops, structured storytelling, patient-led teaching sessions, and community-engaged curriculum components.

Across studies, learner-reported outcomes consistently included improved empathy, greater awareness of patient priorities, and increased confidence engaging in shared decision-making and discussions of uncertainty.[40, 42-45] Narrative medicine approaches were particularly associated with reflective capacity and recognition of the limitations of purely biomedical models in capturing lived experience.[39,41,44] Direct patient involvement in teaching was also linked to enhanced professional identity formation and a more holistic understanding of evidence application.[42,45,46]

Qualitative analyses further indicated that these approaches encouraged critical reflection on epistemic authority and challenged assumptions embedded in evidence hierarchies, supporting a more relational and socially situated conception of EBM.[38-41,43]

Theme 3: Teaching Epistemic Uncertainty and Clinical Judgment

A substantial subset of studies focused explicitly on teaching epistemic uncertainty as an inherent feature of medical practice. Educational strategies included reflective writing, facilitated discussions of ambiguous cases, and assessment methods that prioritized reasoning processes over the identification of a single correct answer.[18,47-51] Across study designs, these approaches were associated with improved tolerance of ambiguity and reduced reliance on authority-based or algorithmic reasoning.

Reflective writing was consistently reported to support learners in processing uncertain clinical encounters and developing adaptive coping strategies, with positive effects on professional identity formation and emotional resilience.[48,49] Case-based discussions that foregrounded uncertainty encouraged learners to articulate reasoning, consider multiple plausible interpretations, and acknowledge knowledge limitations rather than prematurely converging on definitive diagnoses or management plans.[18,50]

Several curricula explicitly differentiated between epistemic uncertainty (knowledge gaps potentially reducible through inquiry) and aleatoric uncertainty (irreducible variability in clinical outcomes), supporting more sophisticated conceptualizations of uncertainty in practice.[18,47,52] Beyond cognitive outcomes, multiple studies reported benefits to learner well-being, including reduced distress in ambiguous situations and greater confidence engaging patients in uncertainty-aware discussions.[49-51]

Theme 4: Structural and Institutional Barriers to Implementation

Despite promising educational strategies, persistent structural and cultural barriers were reported across studies. Common challenges included limited curricular time, faculty discomfort with uncertainty, assessment systems that privilege certainty and standardization, and misalignment between competency-based educational principles and high-stakes licensing examinations.[53-55] Curricular overload and unclear learning objectives were frequently cited as obstacles to integrating uncertainty- and values-focused EBM content.

Faculty development emerged as a critical determinant of successful implementation. Studies consistently noted that limited assessment literacy, discomfort with coaching roles, and uncertainty about how to evaluate reasoning processes constrained faculty engagement with innovative curricula.[54,55] In contrast, programs that invested in sustained faculty development reported

greater feasibility and acceptance of educational reforms.

Institutional culture and infrastructure were also identified as key enablers or barriers. Supportive leadership, aligned incentives, and assessment systems congruent with competency-based progression were associated with more durable curricular change.[56] Here, "institutional culture" refers to organizational norms, assessment structures, and educational priorities, rather than sociocultural or demographic differences across populations. Conversely, misalignment between institutional priorities and educational goals limited the scalability and sustainability of EBM reforms focused on uncertainty, judgment, and values-based reasoning.[53-56]

Discussion

This scoping review synthesizes a growing but methodologically and conceptually fragmented literature examining how EBM is taught in contexts characterized by uncertainty and value-laden decision-making. Across included studies, educational innovations addressing uncertainty, values integration, and clinical judgment were consistently associated with positive learner experiences, yet these approaches were rarely embedded longitudinally or systematically across curricula. These findings align with prior scoping and qualitative reviews demonstrating that while educators increasingly acknowledge uncertainty as intrinsic to clinical practice, curricular responses remain uneven and constrained by structural and cultural factors such as curricular crowding, time pressure, and inconsistent role modeling.[48,51,57,58]

Consistent with earlier systematic reviews, the majority of EBM educational interventions identified in this review focused on short-term knowledge and skills acquisition, particularly literature appraisal and guideline interpretation, with comparatively limited attention to attitudinal, behavioral, or patient-centered outcomes.[59,60] While such outcomes are important, the emphasis on proximal educational gains mirrors longstanding critiques that EBM education has struggled to demonstrate sustained changes in clinical behaviour or downstream patient outcomes. Interventions explicitly targeting uncertainty—such as reflective practice, problem-based learning, simulation, and medical humanities—show promise in addressing this gap, but remain inconsistently implemented and insufficiently integrated across training stages.[48,51,58]

Notably, the findings of this review reinforce a broader conceptual shift in the EBM literature toward a patient-centered and context-sensitive model of evidence use. Increasingly, scholars argue that EBM should function as a flexible reasoning framework rather than a prescriptive algorithm, integrating shared decision-making, values clarification, and individualized care alongside empirical evidence.[2,61-64] Educational interventions that incorporated these principles—particularly those involving reflective dialogue and patient perspectives—were associated with improved learner confidence in navigating ambiguity and engaging patients in complex decisions. However, despite conceptual endorsement of this broader EBM paradigm, its operationalization within undergraduate curricula remains limited.

Assessment practices emerged as a critical constraint on curricular innovation. Across studies, evaluations relied heavily on self-reported learner outcomes, reflecting persistent challenges in measuring constructs such as uncertainty tolerance, judgment, and values-based reasoning. This finding aligns with recent systematic reviews highlighting substantial gaps in the validity evidence supporting existing uncertainty tolerance instruments, particularly with respect to response processes and consequences of testing.[60,65] Without robust and theoretically grounded assessment tools, educational programs may struggle to justify curricular change or to meaningfully evaluate whether learners are developing competencies aligned with real-world clinical practice.

Taken together, these findings suggest that while there is broad agreement regarding the need to expand EBM education beyond technical appraisal toward uncertainty-aware and values-integrated practice, implementation remains constrained by structural, cultural, and methodological barriers. Prior literature has similarly emphasized the importance of faculty development, longitudinal curricular integration, and alignment between educational objectives and assessment systems in supporting sustainable reform.[48,57,58] Without such alignment, innovations risk remaining isolated, elective, or dependent on individual champions rather than becoming embedded features of undergraduate medical education.

Beyond structural and logistical barriers, these findings may also reflect deeper hegemonic dynamics within medical education that shape what forms of knowledge are valued and taught. Traditional EBM paradigms, with their emphasis on hierarchies of evidence and standardized approaches to decision-making, are deeply embedded within institutional curricula, assessment systems, and professional identity formation. As a result, efforts to expand EBM to more explicitly incorporate uncertainty, clinical judgment, and patient values may be

perceived as challenging established norms and epistemic authority. These dynamics are reinforced by hierarchical training environments, high-stakes assessment structures, and institutional incentives that privilege certainty, standardization, and reproducibility over reflective or context-sensitive reasoning. Consequently, resistance to curricular change in this area may not solely reflect practical constraints, but also broader issues of power, knowledge legitimacy, and professional culture within academic medicine.

Importantly, these findings also raise questions about the assumption that EBM is primarily a competency to be formally "taught," rather than one that is learned through situated clinical practice. While many of the included studies focused on structured curricular interventions, EBM is inherently enacted at the bedside, where clinicians must integrate evidence, patient values, and contextual constraints in real time. As such, experiential and relational learning environments may play a critical role in shaping how learners develop these competencies. Longitudinal models of clinical training, such as longitudinal integrated clerkships, may be particularly well suited to supporting this form of learning. By enabling continuity of care, sustained mentorship, and deeper patient relationships, these models provide learners with greater therapeutic responsibility and repeated exposure to uncertainty and value-laden decision-making. In contrast, traditional short-block clerkship structures may fragment these experiences, potentially limiting opportunities for learners to develop nuanced clinical reasoning and necessitating greater reliance on formalized, didactic EBM instruction. These considerations suggest that efforts to improve EBM education should extend beyond the addition of discrete curricular content to include the design of clinical learning environments that support continuity, reflection, and authentic engagement in decision-making. Enhancing workplace-based learning may therefore represent a complementary approach to developing EBM competencies in practice.

This review has several strengths, including a comprehensive synthesis of diverse study designs and a focused examination of EBM education in low-certainty and value-laden contexts, an area often addressed implicitly rather than explicitly in prior reviews. However, several limitations warrant consideration. Firstly, the heterogeneity of study designs and outcome measures precluded quantitative synthesis and limits conclusions regarding comparative effectiveness. Secondly, the reliance on self-reported outcomes across studies restricts inference about behavioral change and patient impact. Thirdly, many interventions were context-specific and small in scale, limiting generalizability. Fourthly, the geographic and institutional concentration of included studies within high-income, urban academic settings limits the transferability of findings to LMIC, rural, and underserved contexts. Educational priorities, resource availability, and clinical realities in these settings may differ substantially, underscoring the need for more contextually grounded and globally representative research in EBM education. Finally, the included literature did not meaningfully address cross-cultural differences in how evidence and clinical reasoning are conceptualized across diverse global contexts. This absence likely reflects the predominance of studies from Western, high-income academic settings and highlights an important gap for future research. Future research should prioritize longitudinal, theory-informed curricula; invest in faculty development to support uncertainty-aware teaching; and develop validated assessment tools capable of capturing judgment, uncertainty tolerance, and values integration. Greater attention to downstream clinical behaviors and patient-centered outcomes will be essential to advancing the field.

Conclusion

This scoping review demonstrates that undergraduate EBM education is beginning to grapple with the realities of uncertainty and value-laden clinical decision-making, yet remains constrained by fragmented implementation and limited evaluation methods. The literature supports a shift toward a more inclusive, patient-centered model of EBM that explicitly integrates uncertainty, judgment, and values-based reasoning. To realize this vision, medical education must move beyond isolated innovations toward longitudinal, institutionally supported curricula aligned with contemporary clinical practice. Doing so will be critical to preparing future physicians to apply evidence thoughtfully, ethically, and responsively in the face of inevitable uncertainty.

Conflict of Interest Statement

The authors declare no conflicts of interest.

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