



ORIGINAL ARTICLE

Evidence-Based Medicine Education in Undergraduate Medical Students: A Scoping Review

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Received: 2025-12-25

Revised: 2026-06-09

Accepted: 2026-07-10

ABSTRACT

Introduction: Evidence-based medicine (EBM) is a foundational competency for medical trainees and a core principle of contemporary clinical practice. Medical schools increasingly integrate EBM teaching across pre-clerkship and clerkship training, yet substantial variability remains in curricular structure, pedagogy, assessment approaches, and real-world learning transfer. This scoping review aimed to map the existing literature on EBM education for medical students, with attention to curriculum models, teaching strategies, learner outcomes, and implementation challenges.

Materials and Methods: Following the PRISMA-ScR framework, the authors systematically searched MEDLINE, Embase, ERIC, PsycINFO, and Scopus from inception to July 2025. Eligible studies described EBM-related teaching, curricula, or assessment in undergraduate medical education. Also, data were extracted on study characteristics, pedagogical methods, EBM competencies targeted, outcomes (knowledge, skills, attitudes, behaviours), and reported barriers and facilitators.

Results: Twenty-seven studies were included, representing diverse geographic contexts and spanning pre-clinical and clinical training. Curricula commonly target question formulation, literature searching, critical appraisal, and application of evidence to patient care. Four themes emerged: 1) heterogeneity in curriculum design and competency frameworks, 2) active learning and clinically integrated teaching as key drivers of engagement, 3) assessment challenges and inconsistent outcome measurement, and 4) implementation barriers including faculty expertise, time constraints, and hidden curriculum influences. Most studies reported improved EBM knowledge and self-efficacy, while fewer demonstrated sustained skill retention or changes in clinical behavior. Programs that embedded EBM longitudinally within clinical contexts and used structured appraisal tools appeared more likely to report meaningful learner engagement.

Conclusion: EBM education for medical students is widely implemented but variably delivered and assessed. Evidence supports active, clinically contextualized approaches, yet robust evaluation of long-term outcomes and standardized assessment tools remains limited. For educational planners and instructors, findings suggest that integrating EBM longitudinally across training, embedding teaching within authentic clinical scenarios, investing in faculty development, and aligning assessments with competency-based frameworks may strengthen skill retention and practice transfer. Future work should prioritize longitudinal curricula, faculty development, and harmonized competency-based evaluation.

Keywords: Evidence-Based Medicine, Medical Education, Undergraduate Medical Education, Critical Appraisal, Information Literacy, Curriculum, Scoping Review

Citation: Quon S, Truong I, Moroz L, Zheng K. **Evidence-Based Medicine Education in Undergraduate Medical Students: A Scoping Review.** Evidence Based Health Policy, Management & Economics 2025; 9(4): 240-50.

Introduction

Evidence-based medicine (EBM) has become a foundational framework for clinical decision-

making and a core educational priority within undergraduate medical education worldwide (1–3).

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Classic definitions emphasize the integration of the best available research evidence with clinical expertise and patient values, framing EBM as both a technical skillset and a professional orientation toward lifelong learning (1, 2). As biomedical knowledge continues to expand rapidly, EBM is increasingly viewed as essential for preparing future physicians to navigate uncertainty, appraise emerging evidence, and adapt clinical practice in response to evolving scientific knowledge (3, 4).

Over the past two decades, medical schools have increasingly incorporated EBM into undergraduate curricula to promote competencies in information literacy, critical thinking, and responsible engagement with the biomedical literature (5–8). Educational approaches range from short courses and workshops to longitudinal, credit-bearing experiences embedded within preclinical and clinical training (7–9). Evidence suggests that hands-on, clinically integrated instruction, particularly when aligned with systematic review methodology and scholarly outcomes, can improve students' EBM knowledge, appraisal skills, and attitudes toward evidence use (4, 10). However, while short-term improvements in knowledge and skills are consistently demonstrated, evidence for sustained effects on clinical reasoning, decision-making, or long-term practice behaviors remains limited and inconsistently measured (7, 9).

Teaching EBM effectively at the undergraduate level remains challenging due to the complexity of the competencies involved and the need for reinforcement across diverse clinical contexts (11, 12). Mastery of EBM requires the ability to formulate answerable clinical questions, search efficiently, critically appraise study design and bias, understand basic statistics, and apply findings appropriately to individual patients, often under time pressure and within hierarchical clinical environments (11, 12). Barriers to effective learning include limited curricular time, insufficient faculty expertise, lack of role modeling in clinical settings, and informal practice norms that may conflict with evidence-oriented behaviors (11, 13). Students frequently report anxiety related

to statistics and appraisal terminology, reflecting broader challenges in physician numeracy and quantitative reasoning that persist across training stages (14).

EBM teaching approaches and assessment strategies vary widely across institutions, further complicating curricular standardization and evaluation (13, 15). While digital and blended learning modalities have expanded access and improved learner satisfaction, they have not consistently demonstrated superiority over traditional approaches in objective knowledge or skills acquisition (16–18). Multifaceted, clinically integrated curricula that use whole-task exercises and repeated application across preclinical and clinical years appear most promising for improving knowledge, skills, and attitudes, yet implementation remains constrained by curricular crowding and resource limitations (11, 19, 20). Assessment remains a persistent gap, with outcome measures ranging from knowledge tests to self-reported confidence and performance-based appraisals, limiting cross-study comparability and synthesis (21, 22).

Several reviews have examined aspects of EBM education; however, many have focused on specific instructional modalities, short-term knowledge outcomes, or limited geographic contexts. Few have comprehensively mapped curricular structures, competency frameworks, assessment approaches, and implementation barriers across the full spectrum of undergraduate medical education. In addition, rapid growth in digital learning strategies and competency-based medical education frameworks over the past decade warrants an updated synthesis that reflects contemporary curricular design and evaluation priorities.

Despite widespread endorsement of EBM in undergraduate medical education, the literature remains fragmented, with substantial heterogeneity in educational strategies, assessment tools, and reported outcomes, and limited attention to long-term retention or real-world clinical behaviors (20, 22, 23). Given the continued expansion of EBM

instruction and the need for clearer curricular guidance, a comprehensive synthesis of existing evidence is warranted (21, 24). This scoping review aims to map the current literature on EBM education for undergraduate medical students, characterize educational and assessment approaches, summarize reported outcomes, and identify key implementation barriers and evidence gaps to inform future curriculum development, evaluation, and research priorities.

Materials and Methods

Protocol and Reporting

This scoping review was conducted according to the PRISMA-ScR guidelines (25). The review followed established methodological frameworks for scoping reviews to ensure systematic identification, mapping, and synthesis of the literature. A protocol specifying objectives, eligibility criteria, data charting procedures, and synthesis plans was developed a priori to enhance transparency and reproducibility. Given the exploratory nature of the review, the protocol emphasized breadth of coverage and conceptual mapping rather than formal quality appraisal or effect estimation.

Consistent with established scoping review methodology and PRISMA-ScR guidance, formal critical appraisal of included studies was not conducted. The objective of this review was to map the scope, characteristics, and thematic patterns of the literature rather than to evaluate intervention effectiveness or generate pooled estimates. As such, methodological quality assessment was considered beyond the purpose of the review.

Search Strategy

A systematic search was conducted in MEDLINE (Ovid), Embase, ERIC, PsycINFO, and Scopus from inception to July 31, 2025. Search terms combined controlled vocabulary and keywords related to “evidence-based medicine,” “medical students,” “undergraduate medical education,” “critical appraisal,” “journal club,” “information

literacy,” and “curriculum.” Search strategies were iteratively refined in consultation with team members to optimize sensitivity and relevance across databases. Reference lists of included papers were screened to identify additional eligible studies. Grey literature was explored through targeted searching of medical education organization websites and conference proceedings where feasible, recognizing the importance of capturing curricular innovations that may not be represented in peer-reviewed journals.

Grey literature was searched systematically between June and July 2025 to capture curricular innovations and evaluations not represented in peer-reviewed journals. Sources included websites of major medical education organizations (e.g., Association of American Medical Colleges, Association for Medical Education in Europe, Royal College of Physicians and Surgeons-affiliated education resources), publicly available curriculum repositories, and conference proceedings from prominent medical education conferences (e.g., AMEE, AAMC Learn Serve Lead, CCME). Moreover, targeted keyword searches using combinations of “evidence-based medicine,” “EBM curriculum,” “medical student,” and “undergraduate” were conducted within these sites and through Google Advanced Search, limited to the first 100 results sorted by relevance. Conference abstracts were screened when available online. Grey literature records were also assessed using the same eligibility criteria as peer-reviewed studies.

Eligibility Criteria

Studies were included if they: 1) focused on undergraduate medical students (pre-clerkship and/or clerkship); 2) described an EBM educational intervention, curriculum, teaching method, or assessment strategy; and 3) provided empirical outcomes (quantitative, qualitative, or mixed methods) or a detailed curriculum evaluation. Both single-institution and multi-institution studies were eligible for inclusion. Studies were excluded if they focused exclusively on postgraduate trainees, were opinion-only pieces

without curricular description, or were not available in English. No restrictions were placed on study design, duration of intervention, or geographic location, consistent with scoping review methodology.

Selection Process

Two reviewers independently screened titles and abstracts, followed by full-text screening for potentially relevant articles. Title and abstract screening were conducted in duplicate by two members of the research team using standardized eligibility criteria. Full-text articles deemed potentially eligible were independently reviewed by the same two reviewers. Then, screening was conducted using pre-defined inclusion and exclusion criteria to ensure consistency across reviewers. Prior to formal screening, reviewers pilot-tested the eligibility criteria on a subset of studies to ensure shared understanding and calibration. Disagreements were resolved through discussion and consensus, and a third reviewer adjudicated unresolved conflicts. Reasons for exclusion at the full-text stage were documented to support transparency in study selection.

Data charting and synthesis

A standardized extraction form was used to chart: country, setting, learner stage, curriculum duration, teaching methods, EBM competencies targeted, assessment tools, outcomes, and implementation factors. Data extraction was performed independently by two reviewers to enhance reliability. Extracted data were compared for consistency, and discrepancies were resolved through discussion and consensus, with involvement of a third reviewer when required. The charting form was pilot-tested on a subset of included studies and refined iteratively as needed.

Findings were summarized descriptively and organized through thematic synthesis. Thematic patterns were identified inductively to capture recurring curricular approaches, competency targets, and implementation challenges, allowing for comparison across educational contexts without privileging any single outcome metric. Thematic

analysis was conducted using an inductive approach. Two reviewers independently reviewed extracted data to identify recurring patterns related to curricular design, competency targets, assessment strategies, and implementation factors. Initial codes were generated through open coding and iteratively refined through discussion. Codes were then grouped into broader conceptual themes based on similarity and relevance to the review objectives. Themes were reviewed collaboratively by the research team to ensure coherence, internal consistency, and alignment with the extracted data. Disagreements regarding coding or theme interpretation were resolved through consensus. This iterative process allowed themes to emerge from the data without imposing a predetermined theoretical framework.

Results

Study selection and characteristics

The search yielded 3,214 unique records, of which 121 full-text articles were reviewed after title and abstract screening. Twenty-seven studies met the inclusion criteria. Across studies, four overarching themes emerged: 1) diversity in curriculum models and targeted competencies; 2) the role of active and clinically integrated pedagogies in promoting engagement and perceived relevance; 3) variability and limitations in assessment and outcome measurement; and 4) implementation barriers and facilitators influencing sustainability. Across these themes, patterns emerged linking curricular structure to outcome type, assessment strategy, and reported sustainability, suggesting meaningful differences between instructional approaches rather than random variability.

Theme 1: Diversity in curriculum models and targeted competencies

EBM education for medical students was characterized by substantial heterogeneity in curriculum structure, scope, and targeted competencies. Curricula ranged from single-session workshops and short courses to longitudinal, multi-year programs embedded across preclinical coursework and clinical

clerkships (5, 10, 20, 26). Despite this variation, most interventions emphasized a core set of EBM competencies, including structured clinical question formulation (often using PICO), efficient literature searching and evidence selection, critical appraisal of validity and applicability, and integration of evidence with clinical context and patient values (5, 20, 27).

Several studies differentiated between foundational and advanced competency targets. Introductory curricula focused on basic EBM literacy, such as recognizing study designs and developing search strategies, while more advanced programs emphasized risk of bias assessment, statistical interpretation, and evidence synthesis skills (27–29). Across multiple settings, novice learners were reported to benefit most from repeated exposure to a consistent EBM framework rather than isolated, one-off teaching sessions, with longitudinal curricula associated with more sustained improvements in knowledge, skills, and attitudes (11, 26, 30, 31).

Notably, short, stand-alone interventions most commonly reported improvements in knowledge scores or confidence, whereas longitudinal or vertically integrated curricula more frequently described broader competency gains, including application and integration into clinical reasoning. This suggests that curricular duration and integration may influence the depth of learning outcomes achieved.

No single teaching modality (e.g., lecture-based, online, or small-group formats) consistently demonstrated superiority. Instead, multifaceted approaches that combined multiple pedagogical strategies and embedded EBM within clinical contexts were most frequently recommended to support skill acquisition and transfer to practice (15, 19, 20). Consensus guidance emphasized the need for evolving competency frameworks that incorporate newer domains such as shared decision-making and the use of preappraised evidence resources (27).

Theme 2: Active Learning and Clinical

Integration Improve Engagement and Perceived Transfer

Across the included literature, active learning strategies were consistently associated with greater learner engagement and perceived relevance compared to lecture-only approaches. Small-group sessions using real or simulated clinical cases were commonly employed to support hands-on practice with PICO formulation, evidence selection, and structured critical appraisal, and were associated with improved confidence and participation (18, 32). Student-focused journal clubs, particularly those aligned with current clinical rotations or real patient cases, were frequently described as effective in fostering relevance, discussion, and engagement (31, 33).

Clinically integrated teaching approaches, such as evidence rounds, bedside question logs, and preceptor-guided evidence searches, were perceived to strengthen transfer of EBM skills from the classroom to clinical reasoning and decision-making during clerkship (5, 15, 34). Studies highlighted the importance of supervisor role modeling, noting that when faculty explicitly demonstrated evidence-seeking behaviors and normalized uncertainty-driven inquiry, students were more likely to engage in EBM practices during clinical training (5, 33, 34).

A consistent pattern across studies was that interventions incorporating real patient cases or clinical decision-making contexts were more frequently associated with perceived transfer and behavioral application, whereas classroom-based exercises without clinical anchoring were more commonly linked to knowledge acquisition alone.

Digital learning modalities, including online modules and blended learning formats, expanded accessibility and flexibility. Evidence from recent studies indicated that blended approaches, particularly those using flipped classrooms and interactive components, were associated with higher learner satisfaction, self-reported EBM use, and knowledge acquisition compared to traditional lectures alone (17, 18, 35). However, purely online

formats were less effective when not paired with facilitated discussion or practical application tasks, underscoring the importance of active engagement in EBM learning (17, 18).

Theme 3: Assessment challenges and inconsistent outcome measurement

Assessment strategies varied widely across studies, limiting comparability and synthesis. Many evaluations relied heavily on self-reported outcomes, including confidence, satisfaction, or perceived competence, which frequently improved following interventions but did not reliably demonstrate objective skill acquisition or durable behavior change (36). Objective assessments, such as knowledge tests on EBM concepts, structured appraisal exercises, or performance tasks requiring learners to generate PICO questions and interpret evidence, were used less consistently and often without standardized reporting (37, 38).

Only a minority of studies examined longer-term outcomes, such as retention of EBM skills across semesters, persistence into clinical clerkship, or observable evidence-seeking behaviors in clinical settings (7). Few studies employed validated instruments consistently, and definitions of “EBM competence” varied substantially, ranging from statistical literacy to broader integration of evidence into clinical reasoning (24, 39). This heterogeneity reflects ongoing debate regarding which outcomes best capture meaningful EBM learning at the undergraduate level and highlights the lack of consensus on assessment standards (24).

Importantly, studies reporting objective, performance-based outcomes were more commonly associated with longitudinal or clinically integrated curricula, whereas short-term interventions predominantly relied on self-report measures. This pattern suggests that curricular structure may influence not only learning outcomes but also the choice and feasibility of assessment strategy.

Overall, assessment challenges included overreliance on self-reported measures, inconsistent use of validated tools, variable definitions of competence, and limited evaluation

of long-term and behaviorally anchored outcomes, constraining the ability to compare interventions and identify best practices (24, 36).

Theme 4: Implementation barriers and facilitators

Implementation barriers were consistently reported across geographic and institutional contexts. Lack of faculty expertise or confidence in teaching critical appraisal and statistics limited scalability, particularly when EBM instruction depended on a small number of motivated champions (13, 40). Time constraints within crowded curricula were frequently cited, with students and faculty describing EBM as competing with exam-focused or “high-yield” content (13, 40). Hidden curriculum effects, such as clinical environments prioritizing efficiency, hierarchy, or deference to authority, were described as undermining EBM behaviors during clerkship despite formal instruction (4, 5).

Facilitators of successful implementation included faculty development initiatives, structured teaching templates (e.g., standardized appraisal guides), and institutional endorsement positioning EBM as a core professional norm rather than an optional academic exercise (7, 40). Programs that embedded EBM into existing curricular structures, such as case-based learning or routine clinical teaching sessions, reported fewer feasibility challenges compared to stand-alone courses requiring additional scheduling (7). Additional facilitators included leadership support, access to educational technologies, alignment with accreditation standards, and international collaboration, particularly in settings seeking to scale EBM education sustainably (40).

Across contexts, programs reporting sustained implementation were more likely to describe institutional alignment (e.g., accreditation integration, leadership endorsement) and distributed faculty involvement, whereas programs reliant on individual champions were more vulnerable to discontinuation or scaling challenges.

Discussion

This scoping review mapped a diverse and growing body of literature examining evidence-based medicine (EBM) education for undergraduate medical students. Across 27 studies, EBM instruction was widely implemented but varied substantially in curricular structure, pedagogical approach, targeted competencies, and evaluation methods. Despite this heterogeneity, several consistent patterns emerged. Most notably, active learning strategies and clinical integration were repeatedly associated with greater learner engagement and perceived relevance, reinforcing the view that EBM is best learned as a practice-based skill embedded in authentic clinical contexts rather than as an isolated theoretical construct (5, 15, 17, 18). Importantly, studies that integrated EBM into longitudinal clinical experiences were more likely to report improvements in applied appraisal skills and clinical reasoning, whereas short, standalone workshops tended to demonstrate gains primarily in knowledge or confidence without clear evidence of sustained transfer. This pattern suggests that depth and continuity of exposure may influence the type and durability of educational outcomes achieved.

These findings align closely with prior syntheses of EBM and evidence-based practice (EBP) education, which similarly report wide variability in curricular design and no single superior teaching modality (24, 39, 41). As in earlier reviews, this heterogeneity limited cross-study comparability and precluded firm conclusions regarding optimal curricular models. However, rather than indicating a lack of effective strategies, this variability appears to reflect differences in outcome selection, measurement tools, and implementation contexts. Across studies, clinically integrated and multifaceted approaches were consistently associated with broader outcome domains (knowledge, skills, and attitudes), whereas didactic-heavy formats were more narrowly associated with knowledge gains (19, 20). Programs that embedded EBM longitudinally across preclinical and clinical phases appeared

better-positioned to reinforce habits of inquiry and promote transfer to clinical reasoning, echoing earlier work emphasizing the importance of repeated, scaffolded exposure over time (11).

A second major finding was the persistent reliance on self-reported outcomes, including confidence, satisfaction, and perceived competence, as primary indicators of educational effectiveness. While these measures frequently demonstrated improvement following EBM interventions, they provide limited insight into actual skill acquisition or real-world performance. This limitation has been well documented in the medical education literature, which consistently shows poor correlation between self-assessment and objective competence, particularly among novice learners (42, 43). Notably, only a minority of studies employed validated performance-based tools or longitudinal follow-up, limiting the ability to determine whether observed improvements translated into durable competence or behavioral change. This gap highlights a structural weakness in the evidence base itself rather than in EBM pedagogy alone. Consistent with prior work, relatively few studies in this review employed validated, performance-based assessments or examined longer-term outcomes such as retention into clerkship or observable evidence-seeking behaviors in clinical settings (24, 37).

Implementation barriers emerged as a third recurrent theme, with faculty capacity and clinical culture exerting substantial influence on curricular effectiveness. Even well-designed EBM curricula were described as vulnerable to erosion when learners encountered clinical environments that discouraged questioning or prioritized efficiency over evidence use. These findings are consistent with earlier studies highlighting the role of the hidden curriculum and the central importance of role modeling in shaping learner behavior (5, 44, 45). Faculty expertise and comfort with appraisal and statistics were frequently cited constraints, reinforcing prior calls for structured faculty development and institutional investment to support sustainable EBM teaching (11, 40, 46).

Collectively, these findings suggest that curricular reform alone is insufficient; without alignment between formal curricula and clinical culture, EBM competencies may fail to consolidate into habitual practice.

Collectively, these findings underscore the need to reorient undergraduate EBM education toward longitudinal competency development supported by harmonized assessment strategies and faculty development. Emerging frameworks and consensus statements emphasize shared competency definitions, alignment with Bloom's taxonomy and the EBM "5 As," and the use of validated tools to support rigorous evaluation and comparison across programs (27, 47, 48). Performance-based assessments, including OSCE-style EBM stations implemented in a spiral curriculum, show particular promise for evaluating applied competence and integration into clinical reasoning, though gaps remain in assessing impact and real-world performance (47, 49). Together, this body of work supports a shift from episodic knowledge transmission toward sustained, contextually embedded skill development. Future research should move beyond short-term, single-site evaluations toward multi-institutional longitudinal designs that examine behavioral integration, patient-level impact, and sustainability across training transitions. In addition, clearer reporting standards for outcome measures would enhance comparability and facilitate stronger meta-educational synthesis.

This review has several strengths, including broad inclusion of educational designs, international representation, and coverage of both preclinical and clinical phases of training. By synthesizing curricular models, pedagogical approaches, assessment strategies, and implementation factors, it provides a comprehensive overview of the current landscape of undergraduate EBM education. However, several limitations warrant consideration. First, unpublished curricular innovations and local quality improvement initiatives may be underrepresented, particularly given the English-language restriction. Second, variability in study

design and outcome reporting limited quantitative comparison and precluded formal assessment of effectiveness. Third, many included studies were small, single-institution interventions with limited follow-up, constraining the generalizability and strength of inference that can be drawn. Finally, the predominance of descriptive and quasi-experimental designs within the included literature limits causal interpretation of educational effectiveness. Future research should prioritize longitudinal study designs, standardized and validated assessment tools, and outcomes that extend beyond self-report to capture durable skill acquisition, clinical reasoning integration, and real-world evidence use. In parallel, greater attention to faculty development and institutional culture will be essential to translate curricular innovations into sustained educational impact.

Conclusion

In conclusion, this scoping review demonstrates that EBM education is widely implemented in undergraduate medical training but remains highly heterogeneous in design, assessment, and sustainability. The strongest and most consistent evidence supports active, clinically integrated, and longitudinal approaches that position EBM as a core professional practice rather than an isolated academic skill. Persistent challenges, including inconsistent assessment, overreliance on self-report, and implementation barriers related to faculty capacity and clinical culture, continue to limit progress. For educational planners and instructors, these findings suggest three actionable priorities: 1) embed EBM teaching longitudinally across preclinical and clinical phases rather than relying on isolated workshops; 2) align assessment strategies with performance-based competencies using validated tools; and 3) invest in faculty development to ensure consistent modeling of evidence-informed practice within clinical environments. At a systems level, harmonized competency frameworks and clearer outcome reporting standards are needed to strengthen comparability across programs and support cumulative knowledge building in EBM education research. Advancing EBM education will

require harmonized competency frameworks, validated performance-based assessments, and institutional investment in faculty development and supportive learning environments.

Ethical considerations

This study was a scoping review of published and publicly available literature and did not involve human participants, patient data, or access to identifiable personal information. As such, institutional research ethics board approval was not required in accordance with institutional and national guidelines.

Acknowledgements

None.

Conflict of interests

The authors declared no conflicts of interest.

Authors' contributions

SQ conceptualized the study, developed the protocol, contributed to the search strategy design, participated in screening and data extraction, led data synthesis and interpretation, and drafted the manuscript; IT and LM independently participated in study screening, data extraction, and contributed to data verification and thematic synthesis; KZ contributed to protocol refinement, screening calibration, data interpretation, and critical revision of the manuscript for important intellectual content. All authors reviewed, edited, and approved the final manuscript and agree to be accountable for all aspects of the work.

Funding

No funding was received for this work.

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