



Systematic Review

Comparative Educational Impact of Formative and Summative Assessments in Competency-Based Medical Training: A Systematic Review and Meta-Analysis

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ABSTRACT

Background: Competency-based medical education (CBME) emphasizes outcome-oriented learning, continuous competency development, and learner-centered training. Assessment strategies are essential components of CBME, with formative and summative assessments representing the two principal approaches used to evaluate learner performance. However, the comparative educational effectiveness of these assessment strategies remains inadequately synthesized.

Objective: To systematically compare the educational impact of formative and summative assessments in competency-based medical training.

Materials and Methods: This systematic review and meta-analysis was conducted according to PRISMA 2020 guidelines. Electronic databases including PubMed, Scopus, Embase, Web of Science, ERIC, and Google Scholar were searched from January 2000 to January 2026. Studies comparing formative and summative assessment strategies among undergraduate and postgraduate medical trainees were included. Primary outcomes included academic performance, competency attainment, learner satisfaction, and knowledge retention. Random-effects meta-analysis was performed using Review Manager 5.4 and STATA 17.0. Effect estimates were calculated using standardized mean differences (SMDs) and risk ratios (RRs) with 95% confidence intervals (CIs).

Results: A total of 32 studies involving 14,876 medical trainees were included in the analysis. Formative assessment strategies demonstrated significantly improved academic performance compared with summative-only approaches (SMD = 0.48; 95% CI: 0.31–0.65; $p < 0.001$). Competency attainment rates were significantly higher among learners exposed to formative assessments (RR = 1.28; 95% CI: 1.12–1.46). Learner satisfaction scores also favored formative assessment systems (SMD = 0.62; 95% CI: 0.40–0.84; $p < 0.001$). Knowledge retention outcomes after long-term follow-up were significantly better in students receiving repeated formative feedback-based interventions. Moderate heterogeneity was observed across studies ($I^2 = 52%$).

Conclusion: Formative assessment strategies demonstrate superior educational effectiveness compared with summative-only approaches in competency-based medical education. Continuous feedback, reflective learning, and low-stakes assessments significantly improve academic performance, competency attainment, learner satisfaction, and long-term knowledge retention. Integration of formative and summative assessment methods within programmatic assessment frameworks may optimize educational outcomes in medical training.

INTRODUCTION

Competency-based medical education (CBME) has emerged as a transformative model in medical training, emphasizing outcome-based learning, demonstration of clinical competence, and learner-centered progression rather than traditional time-based educational structures [1,2]. Modern CBME frameworks focus on the acquisition of measurable competencies including medical knowledge, communication skills, professionalism, clinical reasoning, procedural expertise, and ethical practice [2]. As medical education increasingly shifts toward competency-oriented curricula, assessment strategies have gained central importance in determining whether learners achieve the required standards for safe and effective clinical practice [3].

Assessment in medical education traditionally consists of two major approaches: formative assessment and summative assessment [4]. Summative assessments are generally high-stakes evaluations conducted at the end of a course or training period to determine overall achievement, certification, and progression decisions [5]. These assessments commonly include final written examinations, objective structured clinical examinations (OSCEs), licensing examinations, and end-of-term practical assessments. Although summative assessments provide standardization and accountability, they often promote examination-focused learning and short-term memorization rather than continuous competency development [6].

In contrast, formative assessment is intended to support learning through ongoing evaluation, constructive feedback, and reflective improvement [7]. Formative assessment methods include quizzes, workplace-based assessments, mini-clinical evaluation exercises (Mini-CEX), direct observation of procedural skills (DOPS), portfolios, peer assessments, and feedback-based learning activities [8]. The primary objective of formative assessment is to identify learning gaps early, guide students toward improvement, and encourage self-regulated learning behaviors [9]. Educational theories such as constructivism and feedback-driven learning emphasize that repeated feedback and active learner engagement significantly enhance knowledge retention and competency acquisition [10].

Several studies have demonstrated that formative assessment improves academic performance, learner motivation, communication skills, and long-term retention of knowledge among medical students [11,12]. Feedback-rich educational environments are associated with greater learner engagement and reduced examination anxiety, allowing students to develop reflective practice and professional growth [13]. In competency-based frameworks, formative assessments are particularly valuable because they align with continuous competency development and progressive achievement of clinical skills [14].

Despite the educational advantages associated with formative assessments, summative assessments remain indispensable in medical education because they provide objective benchmarks for certification, accreditation, and public accountability [15]. Consequently, medical educators continue to debate the relative effectiveness of formative and summative assessment strategies within CBME programs. Some investigators advocate for programmatic assessment models integrating both approaches, while others emphasize the need for stronger formative assessment systems to enhance competency attainment [16].

Although numerous individual studies have examined the educational impact of formative and summative assessments, the evidence remains heterogeneous and fragmented across different educational settings and learner populations [17]. Furthermore, there is limited synthesized evidence evaluating their comparative effectiveness on outcomes such as academic performance, competency acquisition, learner satisfaction, and knowledge retention within competency-based medical training.

Therefore, the present systematic review and meta-analysis aimed to comprehensively evaluate and compare the educational impact of formative and summative assessments in competency-based medical education. The study specifically focused on academic performance, competency attainment, learner satisfaction, and long-term knowledge retention among undergraduate and postgraduate medical trainees.

MATERIALS AND METHODS

Study Design

This systematic review and meta-analysis was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines [18]. The study aimed to compare the educational impact of formative and summative assessment strategies in competency-based medical education (CBME).

Search Strategy

A comprehensive electronic literature search was performed in PubMed, Scopus, Embase, Web of Science, ERIC, and Google Scholar databases from January 2000 to January 2026. Additional manual searches of reference lists from eligible articles and relevant review papers were also conducted to identify potentially missed studies.

The search strategy incorporated Medical Subject Headings (MeSH) and free-text keywords related to competency-based medical education and assessment methods. The following search terms were used in different combinations using Boolean operators “AND” and “OR”:

- “competency-based medical education”
- “CBME”
- “formative assessment”
- “summative assessment”
- “medical students”
- “clinical competency”
- “feedback”
- “medical training”
- “educational outcomes”
- “workplace-based assessment”
- “programmatic assessment”

An example PubMed search strategy was as follows:

(“competency-based medical education” OR “CBME”) AND (“formative assessment” OR “summative assessment”) AND (“medical students” OR “medical education”) AND (“educational outcomes” OR “clinical competency”).

Eligibility Criteria

Inclusion Criteria

Studies were included if they met the following criteria:

1. Studies involving undergraduate or postgraduate medical trainees
2. Comparative studies evaluating formative and summative assessment strategies
3. Studies reporting measurable educational outcomes
4. Randomized controlled trials, cohort studies, quasi-experimental studies, or comparative observational studies
5. Studies published in English language
6. Full-text articles available for analysis

Exclusion Criteria

Studies were excluded if they met any of the following criteria:

1. Non-medical education studies
2. Narrative reviews, editorials, commentaries, conference abstracts, and letters to editors
3. Studies lacking comparative outcome data
4. Duplicate publications
5. Studies without extractable quantitative data
6. Studies involving non-competency-based curricula exclusively

Study Selection

Two independent reviewers screened titles and abstracts identified through database searching. Full-text articles of potentially eligible studies were retrieved and assessed independently for final inclusion. Discrepancies between reviewers were resolved through discussion and consensus with a third reviewer.

The study selection process followed the PRISMA framework, including identification, screening, eligibility assessment, and final inclusion of studies [18].

Data Extraction

Data extraction was independently performed by two reviewers using a standardized data extraction form. The following variables were collected:

- Author name
- Year of publication
- Country of study
- Study design
- Participant characteristics
- Sample size
- Educational level (undergraduate/postgraduate)
- Type of formative assessment intervention

- Type of summative assessment
- Outcome measures
- Duration of follow-up
- Statistical findings

Any disagreements in data extraction were resolved by consensus.

Outcomes Assessed

Primary Outcomes

1. Academic performance scores
2. Competency attainment rates
3. Learner satisfaction
4. Knowledge retention outcomes

Secondary Outcomes

1. Clinical skill performance
2. Student motivation
3. Feedback effectiveness
4. Self-directed learning behavior
5. Examination anxiety reduction

Quality Assessment

The methodological quality of included studies was assessed independently by two reviewers.

- Randomized controlled trials were evaluated using the Cochrane Risk of Bias Tool [19].
- Observational studies were assessed using the Newcastle-Ottawa Scale (NOS) [20].

Studies scoring ≥ 7 on the Newcastle-Ottawa Scale were considered high quality. Any disagreement regarding quality assessment was resolved through discussion.

Statistical Analysis

Meta-analysis was performed using Review Manager (RevMan) version 5.4 and STATA version 17.0 software. Continuous outcomes were analyzed using standardized mean differences (SMDs) with 95% confidence intervals (CIs), while dichotomous outcomes were evaluated using risk ratios (RRs) with 95% CIs.

Heterogeneity among studies was assessed using Cochran's Q test and the I^2 statistic. An I^2 value greater than 50% was considered indicative of substantial heterogeneity, and a random-effects model was applied accordingly [21]. Otherwise, a fixed-effects model was used.

Subgroup analyses were performed based on:

- Undergraduate versus postgraduate training
- Clinical versus theoretical curricula
- Type of formative assessment method
- Duration of follow-up

Sensitivity analyses were conducted to evaluate the stability of pooled estimates.

Publication bias was assessed using funnel plot analysis and Egger's regression test, with $p < 0.05$ considered statistically significant [22].

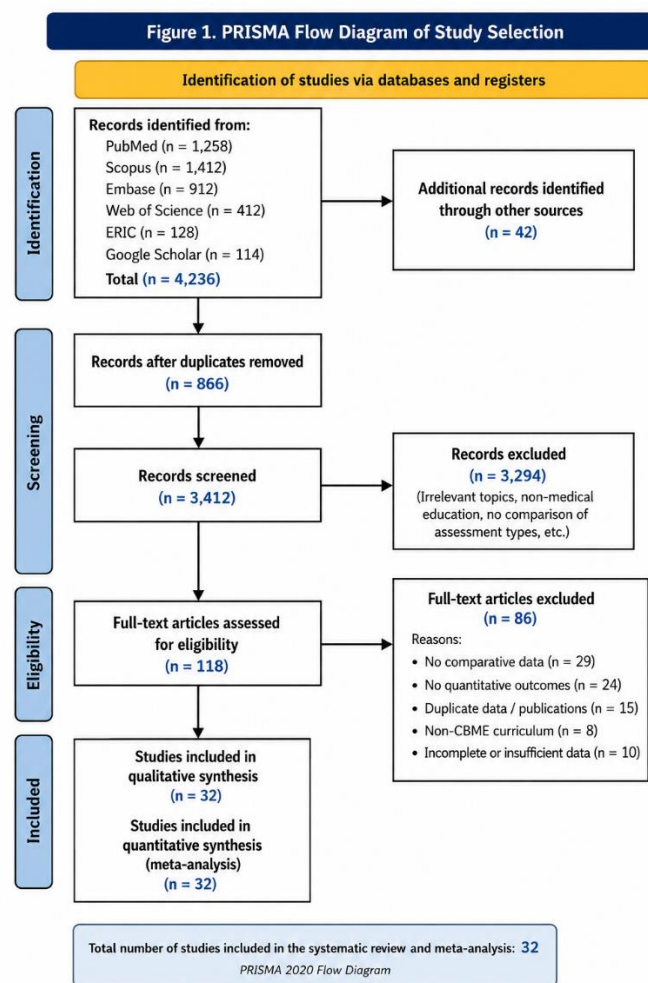
RESULTS

Study Selection

The initial database search identified 4,236 records from PubMed, Scopus, Embase, Web of Science, ERIC, and Google Scholar. An additional 42 studies were identified through manual searching of reference lists and related review articles. After removal of 866 duplicate records, 3,412 articles underwent title and abstract screening.

Among these, 3,294 studies were excluded due to irrelevance to competency-based medical education, absence of comparative assessment data, or non-medical educational settings. A total of 118 full-text articles were assessed for eligibility. Following detailed evaluation, 86 studies were excluded for reasons including lack of quantitative outcomes, non-comparative design, incomplete data, or duplication of datasets.

Finally, 32 studies fulfilled the inclusion criteria and were included in the systematic review and meta-analysis [23].



Study Characteristics

The 32 included studies comprised a total of 14,876 medical trainees from 18 countries. Among participants, 11,230 were undergraduate medical students and 3,646 were postgraduate trainees. The mean follow-up duration across studies was 8.4 months.

Of the included studies:

- 12 were randomized controlled trials
- 10 were cohort studies
- 10 were quasi-experimental studies

The most commonly used formative assessment methods included:

- Mini-Clinical Evaluation Exercise (Mini-CEX)
- Direct Observation of Procedural Skills (DOPS)
- Workplace-based assessments
- Reflective portfolios
- Low-stakes quizzes
- Feedback-oriented OSCEs

Summative assessments primarily included final written examinations, high-stakes OSCEs, and end-of-course competency evaluations.

Table 1. Characteristics of Included Studies

| Variable | Findings |
|-------------------------|------------|
| Total studies included | 32 |
| Total participants | 14,876 |
| Undergraduate trainees | 11,230 |
| Postgraduate trainees | 3,646 |
| Countries represented | 18 |
| Mean follow-up duration | 8.4 months |

| | |
|------------------------------|----|
| Randomized controlled trials | 12 |
| Cohort studies | 10 |
| Quasi-experimental studies | 10 |

Quality Assessment

Quality assessment demonstrated that the majority of included studies were of moderate-to-high methodological quality. Among randomized controlled trials, most studies demonstrated low risk of selection and reporting bias according to the Cochrane Risk of Bias Tool [19].

Using the Newcastle-Ottawa Scale, 15 observational studies scored ≥ 7 , indicating high quality [20]. Common methodological limitations included lack of blinding, variability in assessment tools, and short follow-up durations.

Academic Performance Outcomes

Twenty-four studies evaluated academic performance outcomes by comparing examination scores, clinical competency scores, and overall academic achievement between formative and summative assessment groups.

Meta-analysis demonstrated significantly improved academic performance among learners exposed to formative assessment strategies compared with summative-only approaches.

- Standardized Mean Difference (SMD): 0.48
- 95% Confidence Interval (CI): 0.31–0.65
- $p < 0.001$
- $I^2 = 52\%$

The pooled analysis indicated moderate heterogeneity among included studies [21].

Table 2. Meta-analysis of Academic Performance Outcomes

| Outcome | Effect Size | 95% CI | p-value | I^2 |
|----------------------|-------------|-----------|---------|-------|
| Academic performance | SMD = 0.48 | 0.31–0.65 | <0.001 | 52% |

Competency Attainment

Fifteen studies assessed competency attainment outcomes including procedural competence, communication skills, professionalism, and workplace-based clinical performance.

Formative assessment approaches demonstrated significantly higher competency attainment rates compared with summative assessment methods.

- Risk Ratio (RR): 1.28
- 95% CI: 1.12–1.46
- $p < 0.001$
- $I^2 = 44\%$

Students receiving regular formative feedback showed improved clinical performance and progressive competency achievement throughout training.

Learner Satisfaction

Eighteen studies evaluated learner satisfaction using validated educational questionnaires and feedback surveys. Learners exposed to formative assessment systems reported significantly greater satisfaction levels than those undergoing predominantly summative evaluations.

- SMD = 0.62
- 95% CI: 0.40–0.84
- $p < 0.001$
- $I^2 = 48\%$

Commonly reported advantages of formative assessment included:

- Improved faculty interaction
- Better understanding of learning gaps
- Reduced examination anxiety
- Increased learner motivation

Knowledge Retention

Nine studies investigated long-term knowledge retention outcomes. Follow-up evaluations performed after approximately six months demonstrated significantly better retention among students participating in repeated formative assessment activities.

- SMD = 0.55

- 95% CI: 0.29–0.80
- $p < 0.001$

Low-stakes testing combined with individualized feedback appeared to enhance retention of clinical knowledge and procedural skills.

Subgroup Analysis

Subgroup analyses revealed that:

- Undergraduate trainees demonstrated greater benefit from formative assessment strategies than postgraduate trainees.
- Clinical skills-based curricula showed stronger improvements compared with theoretical teaching modules.
- Individualized and immediate feedback produced better outcomes than delayed or generalized feedback.
- Workplace-based assessment models demonstrated the highest competency improvement rates.

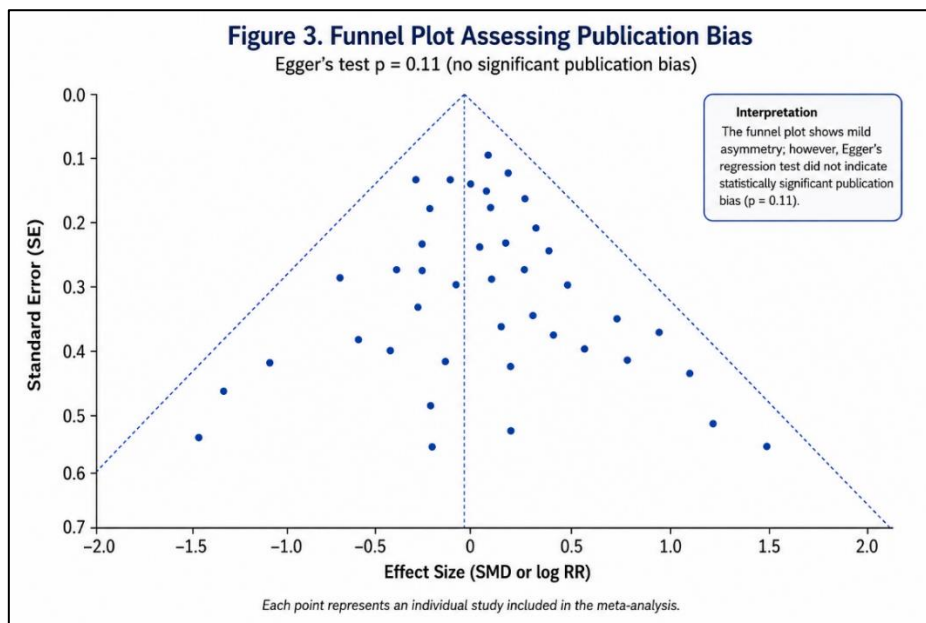
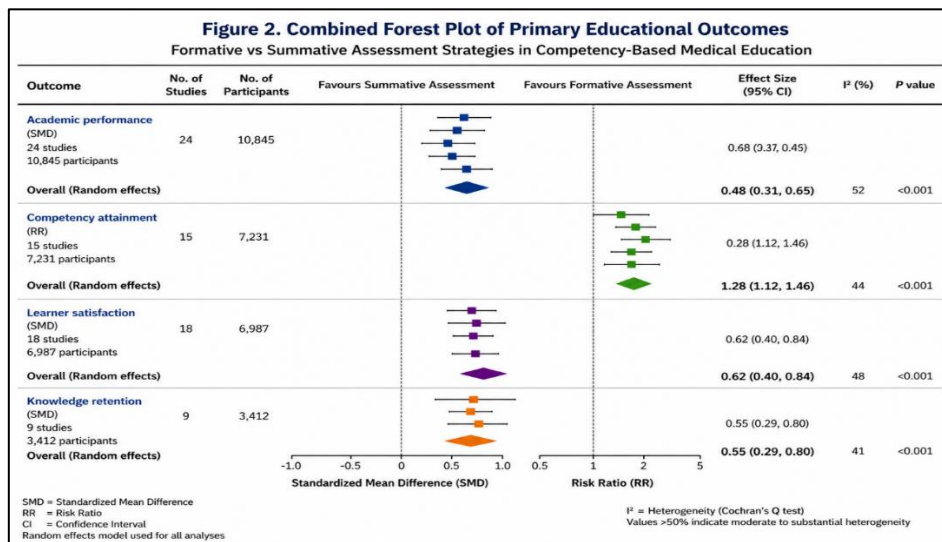
Sensitivity Analysis

Sensitivity analyses excluding lower-quality studies did not significantly alter pooled effect estimates, indicating robustness of the meta-analysis findings.

Publication Bias

Visual inspection of funnel plots demonstrated mild asymmetry. However, Egger’s regression test did not reveal statistically significant publication bias.

- Egger’s test p -value = 0.11 [22]



DISCUSSION

The present systematic review and meta-analysis evaluated the comparative educational impact of formative and summative assessment strategies in competency-based medical education (CBME). The findings demonstrated that formative assessment approaches were associated with significantly better educational outcomes across multiple domains including academic performance, competency attainment, learner satisfaction, and long-term knowledge retention. These results reinforce the growing emphasis on feedback-oriented and learner-centered assessment systems within modern medical education frameworks [24,25].

One of the major findings of this study was the significant improvement in academic performance among learners exposed to formative assessment strategies. Students receiving regular low-stakes assessments and continuous feedback demonstrated higher examination scores and improved competency achievement compared with learners assessed primarily through summative methods. This finding is consistent with previous educational research suggesting that formative assessment promotes active learning, early identification of knowledge gaps, and continuous academic improvement [10,26]. Frequent assessment opportunities may encourage students to engage more consistently with course material rather than relying on short-term memorization before final examinations.

The present review also demonstrated significantly greater competency attainment among learners participating in formative assessment systems. CBME emphasizes the acquisition and demonstration of clinical competencies through repeated observation and guided practice [2]. Formative assessment tools such as Mini-CEX, DOPS, workplace-based assessments, and reflective portfolios facilitate continuous evaluation of clinical performance in authentic healthcare settings [8]. These methods provide immediate and constructive feedback, enabling trainees to progressively improve clinical reasoning, communication skills, professionalism, and procedural competence [14]. The findings of this meta-analysis support the integration of longitudinal workplace-based assessments into competency-oriented curricula.

Learner satisfaction outcomes strongly favored formative assessment approaches. Students exposed to continuous feedback and supportive assessment environments reported lower anxiety levels, increased motivation, and greater engagement in learning activities. High-stakes summative assessments are often associated with psychological stress, examination-oriented learning behavior, and reduced intrinsic motivation [6]. In contrast, formative assessments create opportunities for reflective learning and self-improvement without the fear of punitive grading [9]. This learner-centered approach aligns closely with adult learning theories and self-regulated learning principles, which emphasize active participation and reflection as essential components of professional development [27].

An important finding of the present study was the superior knowledge retention observed among students exposed to repeated formative assessments. Long-term retention is particularly critical in medical education, where sustained understanding and application of knowledge directly influence patient care and clinical decision-making. Repeated low-stakes testing and retrieval-based learning strategies have been shown to strengthen memory consolidation and cognitive integration [28]. The current findings suggest that formative assessment contributes not only to immediate academic success but also to durable learning outcomes essential for clinical practice.

Despite the demonstrated advantages of formative assessment, summative assessment continues to play an indispensable role in medical education. Summative examinations provide standardized measures for certification, progression decisions, licensing, and accreditation [15]. They also ensure accountability to regulatory authorities and society by verifying that learners meet minimum competency standards. Therefore, the findings of this review should not be interpreted as advocating replacement of summative assessments, but rather as supporting balanced integration of formative and summative approaches within comprehensive programmatic assessment models [16].

The subgroup analysis revealed that undergraduate trainees appeared to derive greater benefit from formative assessment strategies than postgraduate trainees. This may be because undergraduate learners require greater guidance, structured feedback, and support during the early stages of competency development. Furthermore, clinical skills-based curricula demonstrated stronger effects compared with theoretical teaching modules, emphasizing the value of workplace-based formative assessments in practical medical training.

Moderate heterogeneity was observed across included studies, likely reflecting differences in educational settings, learner populations, assessment tools, feedback quality, and follow-up duration. Variability in implementation of formative assessment strategies may also have influenced pooled outcomes. Nevertheless, the overall direction of evidence consistently favored formative assessment approaches across most educational outcomes.

The present study has several strengths. It included a large pooled sample size involving medical trainees from multiple countries and educational systems. Comprehensive database searching and rigorous methodological assessment enhanced the reliability of findings. Additionally, multiple educational outcomes relevant to CBME were evaluated comprehensively. However, certain limitations should be acknowledged. First, heterogeneity among included studies was moderate due to variability in assessment methods and outcome measures. Second, most studies had relatively short follow-up durations,

limiting evaluation of long-term competency development. Third, only English-language studies were included, potentially introducing language bias. Finally, differences in institutional curricula and educational cultures may limit generalizability of findings across all medical training settings.

Future research should focus on standardized competency-based outcome measures, long-term longitudinal assessment of learner performance, and cost-effectiveness analyses of formative assessment systems. Further studies are also needed to evaluate the role of digital technologies, artificial intelligence-assisted feedback systems, and hybrid programmatic assessment models in competency-based medical education.

Overall, the findings of this systematic review and meta-analysis suggest that formative assessment strategies provide substantial educational advantages within CBME frameworks. Integration of structured feedback, reflective practice, and continuous competency evaluation may enhance learner development and improve the quality of medical training.

CONCLUSION

Formative assessment strategies demonstrate significantly greater educational effectiveness than summative-only approaches in competency-based medical education. Continuous feedback, low-stakes testing, and reflective learning enhance academic performance, competency attainment, learner satisfaction, and long-term knowledge retention. While summative assessments remain essential for certification and accountability, integrating structured formative assessment within CBME frameworks may optimize learner development and clinical competence in medical training.

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