



Original Research Article

Evaluating the Efficacy of Formative MCQs on Student Learning Outcomes in Cardiovascular System Biochemistry

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Abstract

Medical students often have problems with the application of abstract biochemical concepts to clinical practice, and this problem is especially evident in complex modules such as cardiovascular system biochemistry. Formative multiple-choice questions (MCQs) have shown promise in bridging this gap; however, limited research exists on their integration into cardiovascular biochemistry curricula. This study aimed to evaluate the efficacy of weekly formative MCQs on student engagement, self-assessment, critical thinking, and exam preparedness in a cardiovascular biochemistry module. A prospective, single-cohort educational study was conducted during a 7-week cardiovascular biochemistry module at University Geomedi, Tbilisi, Georgia. Participants were 120 second-year medical students who completed weekly formative MCQs designed to emphasise clinical application across seven topics. After the module and final examination, students completed an anonymous 12-item questionnaire comprising 10 quantitative Likert-scale items and two open-ended questions. The response rate was 100%. Mean scores were high across all domains: engagement (4.77/5), learning and self-assessment (4.66/5), critical thinking (4.58/5), exam preparedness (4.43/5), and overall satisfaction (4.52/5). The highest "Strongly Agree" ratings were obtained for engagement (Question 1, 85.8%), knowledge gap identification (Question 3, 81.7%), and motivation to attend seminars (Question 2, 71.7%). Disagreement rates were minimal (0–2.5% across items). Qualitative thematic analysis revealed four dominant advantages: self-assessment and knowledge gap identification, readiness for exams, clinical reasoning and application, and engagement with active participation. Minor challenges included requests for more clinically complex questions, occasional time constraints, and public participation anxiety for a small number of students. This study demonstrates that weekly formative MCQs in cardiovascular biochemistry are highly accepted by medical students and perceived to enhance engagement, self-directed learning, clinical reasoning, and exam preparedness while reducing exam anxiety. Future research should correlate MCQ performance with final exam scores and assess long-term knowledge retention.

Keywords: formative assessment, multiple-choice questions, MCQs, medical education, cardiovascular biochemistry, student engagement, self-assessment, clinical reasoning, exam preparedness



Introduction

The transition from foundational science to clinical reasoning represents a persistent challenge in medical education, and the popularity of the integrated curriculum has continuously grown in medical education over the last two decades [1]. Medical students have difficulties applying knowledge about biomedical mechanisms to patient care activities [2], due to the existence of the gap between abstract biochemical and molecular mechanisms and practical bedside medicine. Traditionally, medical curricula have historically separated basic sciences from clinical training, and this is quite often the reason that students perceive basic sciences as subjects with low value, and their capacity to use this knowledge in clinical reasoning is substantially diminished. This problem is particularly acute in disciplines such as biochemistry, which requires students to master complex molecular and metabolic concepts before they can appreciate their clinical relevance. Among various approaches for the prevention of such undesired learning strategies, assessment plays a powerful role. As multiple authors have noted, "assessment drives learning", since the nature, form, and frequency of assessments significantly influence student study strategies and knowledge retention [3]. Traditional summative assessments, typically introduced at the end of a module, quite often encourage memorisation rather than sustained, deep engagement with material [4]. Therefore, medical education is shifting more and more towards frequent formative assessments designed to provide feedback and guide

learning rather than simply assigning final grades [5]. Formative assessment, as a key component of assessment for learning (AFL, formative with feedback), has been shown to enhance self-regulated learning, identify knowledge gaps, and promote deeper engagement with course material [6].

Multiple-choice questions (MCQs) have emerged as a particularly effective format for formative assessment in medical education [7]. MCQs offer several advantages: they can test a wide range of knowledge efficiently, provide immediate feedback, and, if MCQs are designed appropriately, they can assess higher-order cognitive skills, including clinical reasoning and application [8]. Recent evidence suggests that well-constructed, clinically integrated MCQs can promote critical thinking and help students bridge the gap between basic science knowledge and clinical practice [9]. Multiple studies have demonstrated the efficacy of formative MCQs in biochemistry education specifically. Thus, Panchbudhe et al. investigated the use of Google Form-based MCQ tests as formative assessment tools following a biochemistry lecture series for 150 Phase I MBBS students [10]. Their study demonstrated significant improvement in student scores between first and second internal assessments, and 99.3% of students reported that the formative MCQs were highly beneficial and motivated their engagement with biochemistry studies [10]. Similarly, Schwartzman et al. developed a student-faculty partnership workflow (Professor-Reviewed Exam Practice, PREP) to create single-best-response formative MCQs aligned with preclinical curriculum,



reporting high usage rates and strong student demand for such resources [11].

The striking example of the module where there is a great gap between abstract biochemical mechanisms and practical bedside medicine is the biochemistry of the cardiovascular system. In this module, students must understand cardiac energy metabolism (including creatine kinase and ATP generation pathways), lipid metabolism, operation of ion channels and receptors, and biochemical markers of cardiovascular disease, and all these topics require integration of basic biochemical principles with clinical scenarios such as myocardial infarction, dyslipidemia, and heart failure [12]. The complexity and volume of this material, combined with the abstract nature of many biochemical concepts, can overwhelm students and lead to undesirable learning strategies focused on memorisation rather than deep conceptual understanding. Despite growing evidence supporting formative MCQs in medical education generally and in biochemistry specifically, limited research has examined their application in cardiovascular system biochemistry modules [13]. Therefore, the cardiovascular system module at University Geomedi provides an ideal context for examining formative MCQs in this domain. Second-year medical students face the transition from basic science instruction to clinically integrated learning, and the cardiovascular module represents one of their first exposures to system-based, clinically oriented biochemistry.

Considering the documented challenges of teaching clinically integrated

biochemistry, the demonstrated benefits of formative MCQs in medical education, and the specific gap in cardiovascular biochemistry literature, this study aimed to evaluate the efficiency and benefits and/or disadvantages of integration of weekly formative MCQs into the cardiovascular biochemistry curriculum at University Geomedi.

Materials and Methods

Study Design and Participants

A prospective, single-cohort educational study was conducted during a 7-week cardiovascular biochemistry module. Participants were second-year medical students (n=120) at University Geomedi, Tbilisi, Georgia. No exclusion criteria were applied; all enrolled students participated.

Formative MCQ Intervention

Formative MCQs, specifically designed to emphasise clinical application, were administered weekly during a 7-week cardiovascular biochemistry module for second-year medical students (n=120). The MCQs were categorised according to the following topics: (1) ion channels and contraction of myocardium; (2) adrenergic and cholinergic receptors in cardiac tissue; (3) heart as a secretory organ; (4) vasoactive peptides; (5) cardiac energy metabolism (including creatine kinase and ATP generation); (6) lipid metabolism and biochemistry of atherosclerosis; (7) biochemical markers of cardiovascular disease.

Data Collection

After the completion of the module and final examination, students completed an



anonymous questionnaire developed by us consisting of 12 questions (Table 1):

10 quantitative items on a 5-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree). The following aspects were covered by these 10 questions: engagement (Questions 1–2), learning/self-assessment (Questions 3–5), critical thinking (Questions 6–7), exam preparedness (Questions 8–9), and overall satisfaction (Question 10).

Two open questions on the advantages and challenges of the MCQ method (Questions 11 and 12, Table 1).

Data Analysis: Quantitative data were analysed using descriptive statistics. Response frequencies (counts and percentages) for each rating (5, 4, 3, 2, 1) were calculated directly from the Excel file (calc sheet). Qualitative open-ended responses were analysed using thematic analysis and are reported.

Ethical Considerations

The study was conducted as part of the routine curriculum evaluation. All responses were anonymous, and participation in the questionnaire did not affect course grades.

Table 1. Questionnaire used in the study.

Quantitative Items (questions 1-10, 1-5 Scale)

(Scale: 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree)

Question number	Section	Question Text	Rating (1-5)
1	Engagement	The use of MCQs made the biochemistry seminars more engaging.	
2	Engagement	I was more motivated to attend seminars knowing that MCQs would be discussed.	
3	Learning	Solving MCQs helped me identify gaps in my knowledge (self-assessment) better than just reading notes.	
4	Learning	The immediate feedback provided after MCQs helped clarify complex metabolic pathways.	



Question number	Section	Question Text	Rating (1-5)
5	Learning	Regular MCQ practice improved my long-term retention of biochemical concepts.	
6	Critical Thinking	The MCQs encouraged me to apply concepts to clinical scenarios rather than memorise facts.	
7	Critical Thinking	Discussing MCQs in class helped me understand the "why" behind the correct answer.	
8	Assessment Prep	I feel less anxious about the final exams because of regular MCQ practice.	
9	Assessment Prep	The formative MCQs were representative of the difficulty level expected in the exams.	
10	Satisfaction	I believe formative MCQs should be integrated into other pre-clinical subjects.	

Qualitative Items (Open-Ended)

Question number	Section	Question Text
11	Qualitative	What is the biggest advantage of using MCQs in biochemistry teaching?



Question number	Section	Question Text
12	Qualitative	What challenges or disadvantages have you faced with this method? (e.g., time constraints, quality of questions, etc.)

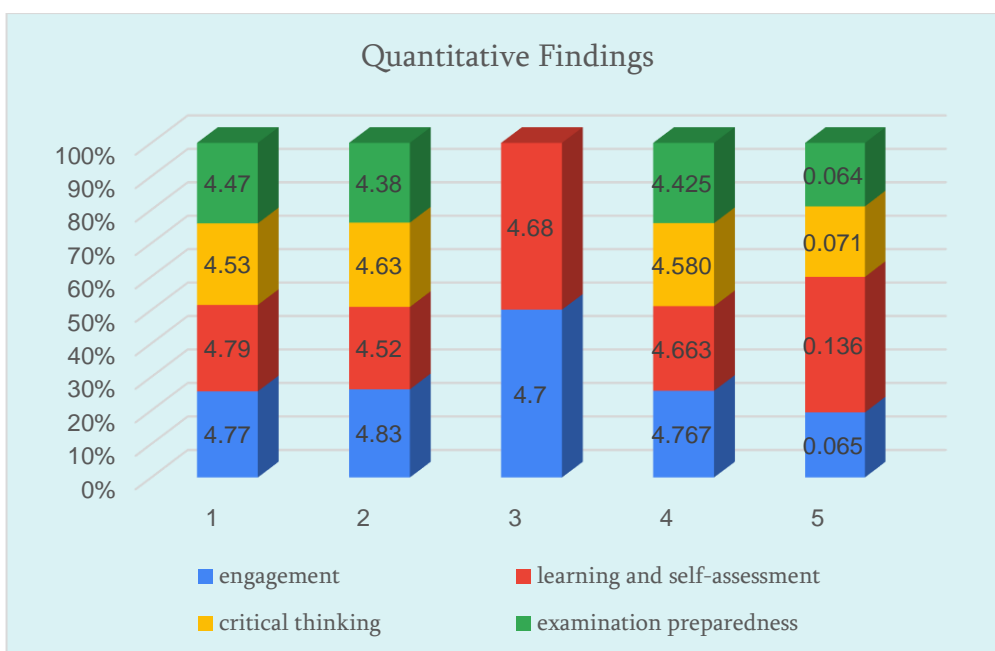


Fig. 1. Quantitative findings of the study.

Table 2. Student’s response distribution (%)

Question	5 (%)	4 (%)	3 (%)	2 (%)	1 (%)
1	85.8	11.7	2.5	0.0	0.0
2	71.7	26.7	1.7	0.0	0.0
3	81.7	15.8	2.5	0.0	0.0
4	65.0	24.2	8.3	1.7	0.8
5	70.8	26.7	2.5	0.0	0.0
6	65.8	23.3	7.5	2.5	0.8
7	70.0	23.3	6.7	0.0	0.0



Question	5 (%)	4 (%)	3 (%)	2 (%)	1 (%)
8	60.0	27.5	10.8	0.8	0.8
9	53.3	31.7	14.2	0.8	0.0
10	65.8	22.5	10.0	1.7	0.0

Results

Quantitative Findings

All 120 students completed the questionnaire (100% response rate). The distribution of responses is shown in Table 2. Mean scores were as follows:

Engagement: 4.77/5 (Question 1: 4.83; Question 2: 4.70)

Learning and self-assessment: 4.66/5 (Question 3: 4.79; Question 4: 4.52; Question 5: 4.68)

Critical thinking: 4.58/5 (Question 6: 4.53; Question 7: 4.63)

Exam preparedness: 4.43/5 (Question 8: 4.47; Question 9: 4.38)

Satisfaction: 4.52/5 (Question 10) (Fig. 1)

Based on the analysis of the obtained results, the following observations were made:

The highest “Strongly Agree” (5) ratings were revealed for Question 1 (85.8%), Question 3 (81.7%), and Question 2 (71.7%). Neutral responses (3) were highest for Questions 9 (14.2% – exam difficulty representation) and 8 (10.8% – exam anxiety). The percentage of answers reflecting disagreement (2 or 1) was very rare (0–2.5% across items).

Qualitative Findings

Thematic analysis of open-ended responses (n=120, with many students providing multiple comments) revealed four dominant domains:

Domain 1: Self-assessment and knowledge gap identification

The most frequently reported advantage. Students valued the ability to “identify gaps in knowledge.”

Domain 2: Readiness for the exam

Many students noted that formative MCQs reduced anxiety and familiarised them with question formats like the final exam. One student wrote: “I was much less nervous because I had already practised 60+ clinical MCQs.”

Domain 3: Clinical reasoning and application

Students appreciated that questions required applying biochemistry to patient cases rather than pure recall. Example quote: “It made me think like a doctor, not just memorise pathways.”

Domain 4: Engagement and active participation

Seminars were described as “more interactive” and “less passive.”



Reported minor challenges:

A small percentage of students requested more difficult, clinically complex questions. The common drawback mentioned by students also included occasional time constraints during seminars, and a few comments were made regarding public participation anxiety when MCQs were discussed.

Discussion

This study demonstrates that weekly formative MCQs in a cardiovascular biochemistry module are highly accepted by medical students and perceived to enhance engagement, self-directed learning, and clinical reasoning.

Interpretation of Key Findings

The high mean scores for engagement questions (mean 4.77) and learning/self-assessment (mean 4.66) align with the principle that frequent, low-stakes testing encourages continuous study habits. The strong endorsement of Question 3 (“MCQs helped me identify gaps in my knowledge better than just reading notes”) supports the self-assessment function of formative assessment. Critical thinking scores (mean 4.58) should be mentioned separately since they reflect perceived application of biochemistry to clinical scenarios, which is eventually a core goal of medical education. The open-ended comments confirmed that students valued clinical integration. Exam preparedness scores were slightly lower (mean 4.43), with the highest percentage of neutral responses (14.2% for Question 9). This finding may indicate that some students found the formative MCQs easier than the final examination, or that they desired even

more challenging questions. Nevertheless, most students still agreed/strongly agreed that MCQs helped with exam preparedness.

Our findings align with existing evidence from medical education. For instance, a recent study on formative assessment in biochemistry reported that 99.3% of students found regular MCQ tests highly beneficial for their learning and motivation [10]. Additionally, research has shown that disclosing and reusing MCQ items for low-stakes formative purposes can decrease student anxiety while improving feedback and transparency in the learning process [14]. Furthermore, the use of a formative online assessment platform helped 72% of medical students feel more supported in their learning, and 75% identify their own knowledge gaps, both of which are key contributors to building confidence and reducing summative exam stress [15]. However, our study adds domain-specific evidence for cardiovascular biochemistry, a traditionally difficult area due to the integration of metabolism, enzymology, and clinical markers.

Practical Implications and Future Directions

The results of our study indicate the necessity for curriculum integration and clearly demonstrate that formative MCQs should be embedded weekly, not as isolated events. Also, open-ended questions indicated that a small proportion of students requested higher-difficulty questions, indicating that future iterations should include a tiered difficulty system (basic recall versus complex clinical reasoning). The results of our study also allowed us to identify a few students with



public participation anxiety, indicating that anonymous digital response systems (clickers or polling apps) should be introduced as a possible choice for this group. We believe that the approach used in this study could be applied to other system-based modules, such as biochemistry of musculoskeletal, gastrointestinal, respiratory, endocrine, reproductive, urinary, and nervous systems.

Limitations of the Study

This study has several limitations, including its single-university, single-cohort design and the absence of a control group. Perceptions were measured post-course immediately, and therefore, the long-term retention was not assessed, and the use of self-report data may overestimate positive effects. Additionally, the study did not directly correlate MCQ performance with

final exam scores, which is planned as the next phase.

Thus, as was demonstrated by this study, formative MCQs in cardiovascular biochemistry significantly enhanced student engagement, self-assessment, and clinical reasoning. Students strongly endorse this method and report few challenges. These findings strongly support the broader adoption of active, formative assessment strategies in pre-clinical medical curricula, particularly in system-based disciplines where clinical integration is essential.

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სასწავლო (განმავითარებელი) მრავალჯერადი არჩევნის კითხვების (MCQs) ეფექტურობის შეფასება სტუდენტთა სწავლის შედეგებზე გულ-სისხლძარღვთა სისტემის ბიოქიმიაში

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აბსტრაქტი

მედიცინის სტუდენტებს ხშირად უჭირთ აბსტრაქტული ბიოქიმიური კონცეფციების გამოყენება კლინიკურ პრაქტიკაში. ეს პრობლემა განსაკუთრებით თვალსაჩინოა ისეთ კომპლექსურ მოდულებში, როგორც გულ-სისხლძარღვთა სისტემის ბიოქიმია. სასწავლო (განმავითარებელი) მრავალჯერადი არჩევნის კითხვებმა (MCQs) კარგი შედეგები აჩვენა ამ ხარვეზის აღმოფხვრის კუთხით, თუმცა, გულ-სისხლძარღვთა ბიოქიმიის კურიკულუმში, მათ ინტეგრაციაზე მწირი კვლევებია. წინამდებარე კვლევის მიზანი იყო ყოველკვირეული განმავითარებელი ტესტების ეფექტურობის შეფასება სტუდენტების ჩართულობაზე, თვითშეფასებაზე, კრიტიკულ აზროვნებასა და გამოცდისთვის მზადყოფნაზე გულ-სისხლძარღვთა ბიოქიმიის მოდულში. პროსპექტული, ერთკოჰორტული (დაკვირვებითი ჯგუფი) საგანმანათლებლო კვლევა ჩატარდა 7 კვირიანი გულ-სისხლძარღვთა ბიოქიმიის მოდულის ფარგლებში, უნივერსიტეტ გეომედში (თბილისი, საქართველო). კვლევაში მონაწილეობდა მედიცინის ფაკულტეტის მე-2 კურსის 120 სტუდენტი, რომლებიც, ყოველკვირეულად, განმავითარებელ ტესტებს გადიოდნენ (MCQs). ეს კითხვები შეიქმნა 7 სხვადასხვა თემაში კლინიკური პრაქტიკის მნიშვნელობის ხაზგასმის მიზნით. მოდულისა და დასკვნითი გამოცდის დასრულების შემდეგ, სტუდენტებმა შეავსეს 12 კითხვიანი ანონიმური კითხვარი, რომელიც მოიცავდა 10 რაოდენობრივ (ლიკერტის სკალა) და 2 ღია კითხვას. გამოხმაურების მაჩვენებელი 100% იყო. საშუალო ქულები, ყველა კრიტიკული მიმართულებით, მაღალი იყო: ჩართულობა (4,77/5), სწავლა და თვითშეფასება (4,66/5), კრიტიკული აზროვნება (4,58/5), გამოცდისთვის მზადყოფნა (4,43/5) და საერთო კმაყოფილება (4,52/5). ყველაზე მაღალი შეფასება, „სრულიად ვეთანხმები“, დაფიქსირდა ჩართულობის (კითხვა 1, 85,8%), ცოდნაში არსებული ხარვეზების იდენტიფიცირების (კითხვა 3, 81,7%) და სემინარებზე დასწრების მოტივაციის (კითხვა 2, 71,7%) კატეგორიებში. უარყოფითი პასუხების მაჩვენებელი მინიმალური იყო (0-2,5% სხვადასხვა პუნქტში). თვისებრივმა თემატურმა ანალიზმა 4 ძირითადი უპირატესობა გამოავლინა: თვითშეფასება და ცოდნის ხარვეზების იდენტიფიცირება, გამოცდებისთვის მზადყოფნა,



კლინიკური მსჯელობა და მიდგომების გამოყენება. ასევე, აქტიური მონაწილეობა და ჩართულობა. მცირე გამოწვევებს შორის დასახელდა უფრო რთულ კლინიკურ კითხვებზე მოთხოვნა, დროის სიმცირე და, სტუდენტების მცირე ნაწილისთვის, საჯარო მონაწილეობით გამოწვეული შფოთვა. ეს კვლევა აჩვენებს, რომ გულ-სისხლძარღვთა ბიოქიმიაში, ყოველკვირეული განმავითარებელი ტესტები დადებითადაა მიღებული მედიცინის ფაკულტეტის სტუდენტების მიერ. მათ მიაჩნიათ, რომ ეს მეთოდი ზრდის ჩართულობას, თვითორიენტირებულ სწავლებას, კლინიკურ მსჯელობასა და გამოცდისთვის მზადყოფნას. ამასთანავე, იგი ამცირებს საგამოცდო შფოთვას. სამომავლო კვლევებმა უნდა დაადგინოს ტესტების (MCQs) შედეგებსა და ფინალური გამოცდის ქულებს შორის კორელაცია. ასევე, შეაფასოს ცოდნის გრძელვადიანი შენარჩუნება.

საკვანძო სიტყვები: განმავითარებელი შეფასება, მრავალჯერადი არჩევნის მქონე კითხვები/ტესტური კითხვები, მრავალჯერადი არჩევნის კითხვები (MCQs), სამედიცინო განათლება, გულ-სისხლძარღვთა სისტემის ბიოქიმია, სტუდენტთა ჩართულობა, თვითშეფასება, კლინიკური მსჯელობა/კლინიკური აზროვნება, გამოცდისთვის მზადყოფნა.

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