EMPIRICAL RESEARCH

Large-scale application of case-based learning for teaching medical biochemistry: a challenging experience with positive impacts

Sanaa Eissa[*] , Reem M. Sallam, Amr S. Moustafa and Abdelrahman M. A. Hammouda

Abstract

With the introduction of integrated approach in the medical curriculum, there is a need to teach basic sciences in a way relevant to real clinical scenarios. The aim of this study is to investigate the feasibility of case-based learning (CBL) for teaching of medical biochemistry to a large number of medical students. It also evaluates both the students' and faculty members' perception of this approach. CBL was introduced in teaching medical biochemistry in the Neuroscience block for the second-year medical students. This study's students were from two consecutive academic years ($n = 721$ and 769). Four clinical cases were prepared. Students were divided into subgroups, each having one CBL session every 2 weeks. Students were encouraged to work together to understand the given clinical scenario by building on past knowledge obtained through other teaching modalities and new knowledge acquired during the session. A pretest was administered at the beginning of the session, and an identical posttest administered at the end of the session. Perception of both the students and facilitators of the CBL-teaching approach was evaluated using end-of-block questionnaires. In both studied academic years, students got higher scores in posttest compared to pretest scores with a statistically significant difference of the paired scores ($P < 0.001$). Analysis of the students' questionnaire demonstrated that most students positively perceived the CBL approach, with a feeling that CBL has helped them learning the biochemistry concepts. Likewise, analyzing staff questionnaire revealed staff's positive attitude toward the impact of CBL in teaching biochemistry on the students and on themselves. The current work suggests that CBL is both feasible and efficient to be applied for teaching medical biochemistry on a large scale. It is positively perceived by both students and teaching staff. Future work is still needed to solve certain challenges such as increasing work load on the faculty members and to test the impact of this teaching modality on long-term retention of knowledge.

Keywords: Case-based learning, CBL, Medical biochemistry, Medical education

Introduction

In order for schools of medicine to be globally accredited, international standards for quality in medical education should be considered and introduced at both the teaching faculty's level and the medical students' level (Harden 2002; Leinster 2002; Prideaux 2003). In the last few years, several changes have been introduced to the medical curriculum at the Faculty of Medicine, Ain

Shams University (ASU), in Cairo, Egypt. Basic sciences are of special importance, since they are the first courses taught to medical students during the preclinical years. Until recently, medical biochemistry has been taught at ASU in the traditional, didactic teacher-centered system. Moreover, the curriculum was overloaded with facts and basic knowledge with few examples of clinical applications. Medical students usually demonstrate aversion to the pure biochemistry knowledge as it seems too remote from the real-world medicine. For them, biochemistry is a dry subject requiring extensive memorization of multi-step pathways, complex jargon, chemical names, and

*Correspondence: drsanaa_mohamed@med.asu.edu.eg
Department of Medical Biochemistry and Molecular Biology, Faculty of Medicine, Ain Shams University, Cairo, Egypt

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many inter-woven regulation and mechanistic events (Wood 1990). Almost all medical graduates from a traditional curriculum agree that biochemistry is one of the most difficult disciplines they have studied (Watmough et al. 2009). Biochemistry for many students is like lyrics in a foreign language, to be memorized but with no feeling. Students aim mainly at the examination marks and are almost unaware of the relevance of biochemistry to the practice of medicine. They may not realize the importance of biochemistry until they have graduated and gone to practice. By that time, they have already forgotten what they learnt, which compromises their professional efficiency (D'Eon 2006; Ling et al. 2008; Wilhelmsson et al. 2013). Therefore, new learning modalities are required to achieve better linkage of biochemistry as a basic medical science to the clinical practice (Boyer 2000; Hermes-Lima et al. 2002; Se et al. 2008; Ramasamy et al. 2013; Surapaneni and Tekian 2013; Jabaut et al. 2016). A curriculum reform should avoid giving too many details pertaining to the organic chemistry of biomolecules and concentrate on what is relevant to medicine (Wood 1990).

Medical students need to learn medically relevant biochemistry, and we must minimize rote memorization of materials and make information stick (Afshar and Han 2014). Recently, our faculty has approved a reform in the medical education system changing it from the traditional way to a more interactive, student-centered, and self-directed education. In the reformed system, an integrated approach is undertaken, in which medical biochemistry and molecular biology are integrated with other basic sciences in a body systems-oriented approach as opposed to the previous subject-oriented approach. Simultaneously, undergraduate medical biochemistry curriculum was revised to adapt to the new system. Unnecessary theoretical knowledge was filtered out while trying to bridge the gap between theory and practice through students' exposure to clinical scenarios in the setting of small-group discussions.

Early clinical exposure is recommended by many studies (Dornan and Bundy 2004; Dornan et al. 2006; Dyrbye et al. 2007; Michalec 2012; Sathishkumar et al. 2007). It contributes to students' satisfaction with medical education and avoids the abrupt transition from academic textbooks to patients and diseases. It helps medical students socialize to their chosen profession and makes their learning more real and relevant. Since actual on-patient experience is not possible for our students in preclinical academic years, other possible ways of clinical exposure ought to be sought (Abraham et al. 2008). Case-based learning (CBL) is a form of small-group learning that uses a guided inquiry method. The method was proven to assist in the development and improvement in problem-solving skills and critical thinking in

medical students (McLean 2016). It helps retention of knowledge and proper perception of basic sciences in the medical curriculum (Malau-Aduli et al. 2013). In comparison with problem-based learning (PBL), CBL was demonstrated to offer more efficient use of students and faculty's time in a goal-directed manner (Srinivasan et al. 2007). Each case in CBL has learning objectives that are shown to the students after discussing the clinical data and patient's investigation. During the CBL session, students are presented with the clinical case, provided with the resources—textbooks and Internet access—and instructed about the time needed for actively working together to solve this case. Case solving in CBL requires integration of prior and newly acquired knowledge and is guided by the facilitator's questions to keep the group on the right track toward solving the problem and fulfilling the case's intended learning objectives (ILOs). CBL has already been highly recommended for teaching medical biochemistry (Hartfield 2010; Joshi et al. 2014; McRae 2012; Nair et al. 2013; Rybarczyk et al. 2007). This teaching method is capable of providing the medical students with the necessary training skills that will be required in their future clinical practice, i.e., collecting relevant information and the clever use of basic knowledge for solving medical problems.

Faculty members need to be well trained to properly facilitate the CBL session. It takes lots of faculty training to avoid acting as lecturer and abide by their expected role of group's guidance and correction if needed, keeping the self-learning, scientific curiosity, and self-confidence merits of the students intact, and allowing each student to be a "content expert" at the end of the session. In addition, facilitator's guidance aims at achieving the ILOs set ahead at the beginning of each CBL session (Costa and Magalhaes 2009).

We previously investigated the introduction of CBL approach for teaching of medical biochemistry on a relatively small number of second-year medical students who were involved in a special undergraduate medical program, Extended Modular Program (EMP), at Faculty of Medicine, ASU (Eissa and Sabbour 2016). The results were both encouraging and promising.

Motivated by our previous results and the recent introduction of the system-based curriculum for the main stream students at the ASU Faculty of Medicine, we proposed a large-scale application of CBL for teaching medical biochemistry. Certain logistic issues are needed to be considered to allow the introduction of CBL on a large scale at ASU. These issues include the large number of students, the limited space and educational tools, and the limited number of trained instructors. Therefore, the primary objective of the current study is to investigate the feasibility and efficiency of adopting CBL in the medical biochemistry

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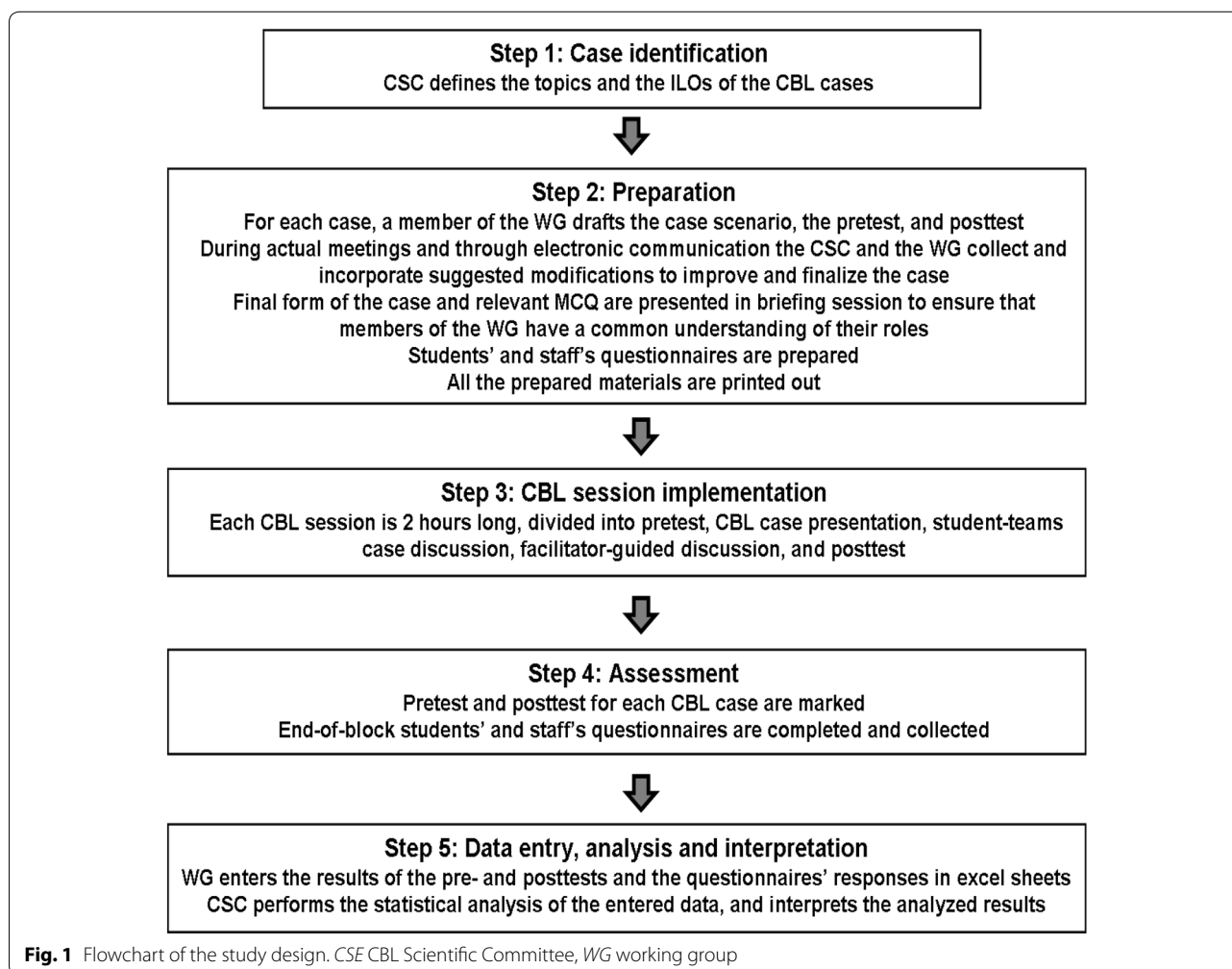
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curriculum at ASU on a relatively large number of students. Specific aims include designing proper cases to fit in the ILOs of the course being taught, preparing the faculty members to play the role of expert facilitator, preparing the environment for proper conduction of CBL sessions, and finally assessing the impact of CBL on the students' performance, by pre- and posttests, and perception of the new teaching approach using questionnaire-based method.

Methods

The current work was conducted in the Department of Medical Biochemistry and Molecular Biology at the Faculty of Medicine, ASU, Cairo, Egypt. CBL approach was approved by the department's undergraduate medical education committee, by the Faculty of Medicine Vice-deanship for Students Affairs, and by the ASU Faculty of Medicine Ethical Committee (document # 2016-88). Informed, written consent was obtained from all participants of the study. A flowchart of the study design is illustrated in Fig. 1.

This CBL approach was conducted during the first block for the second-year medical students, the Neuroscience block. Target students were from two consecutive academic years, 2016–2017 ($n1 = 721$ students) and 2017–2018 ($n2 = 769$ students). Prepared materials included 4 clinical cases, identical pretests and posttest, and students' and staff members' questionnaires.

A CBL scientific committee (CSC), including the authors of this work, was nominated by the chairperson of the Medical Biochemistry Department. Tasks of this committee included: defining the topics of the CBL's cases, preparing the clinical cases, training of CBL staff, supervising the arrangement for conducting CBL sessions, preparing the assessment tools (pre- and posttest and end-of-block questionnaires), and statistical analysis and interpretation of the data obtained by these tools. A working group (WG) including senior and junior staff members prepared the draft of the cases and helped in conducting the session.

Fig. 1 Flowchart of the study design. *CSE* CBL Scientific Committee, *WG* working group

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Defining the topics and designing of the clinical cases

The selection of topics of CBL session aimed at achieving the objectives of the Neuroscience block, re-enforcing the basic biochemical and molecular core concepts, and highlighting the biochemical pathways of relevance. Most of the cases were first prepared by junior staff, then revised, modified, and finalized as needed by the CSC. The CSC first defined the clinical cases that best reflect core biochemical concepts that are discussed in the Neuroscience block. A faculty orientation training workshop on how to formulate cases for CBL was conducted in the department. Topics of the clinical cases were allocated to the working group consisting of senior and junior faculty staff members. The prepared cases were then revised by the CSC to ensure that the proposed ILOs for each case were adequately illustrated. Four cases were designed. An example is "My girl has pallor and jaundice" (Appendix 1), a carefully designed case on a patient with pyruvate kinase deficiency hemolytic anemia that can gracefully address the most important glycolytic pathway and its connection to the patient's anemia. In addition, the complex pathway of heme degradation and bilirubin production was also perfectly addressed in relation to the patient's jaundice. Briefly, a CBL case began by introducing the personal information, clinical presentation, relevant history, and results of physical examination and requested investigations. This was followed by defining the case's learning objectives and guiding questions as well as illustration of the relevant biochemical concept, pathway, or process involved in the case discussion.

Training and skill development of CBL's Staff

All CBL staff members attended a hands-on workshop conducted by a medical education-qualified member of the CSC. The main topics of the training included but not limited to skills and tips for preparing CBL cases, conducting the CBL sessions, presenting the case, encouraging and guiding the students for active learning, answering the students' questions if needed, and connecting all threads of thoughts to each case's ILOs.

Students at the CBL session

All the second-year medical students at the Faculty of Medicine, ASU, for two consecutive academic years: 2016–2017 and 2017–2018, totaling 721 and 769 students, respectively, were exposed to the CBL approach. Each group of approximately 75 students was divided into smaller subgroups (~25 students/subgroup). The sessions were conducted every 2 weeks for each group. The CBL session was conducted in lecture rooms equipped with audiovisual tools and Internet access. Students were encouraged to work actively in a team and to interact with each other and with the facilitator during the CBL

sessions. Medical biochemistry textbooks were available to the students during the case discussion. Each session lasted for approximately 2 h, divided as follows: 5 min for the pretest (5 MCQs or equivalent items), 20 min for the CBL case presentation, 45 min for the case discussion by students as a teamwork, 30 min for facilitator-guided whole subgroup discussion, 10 min for conclusion and case closure, and 5 min for the posttest (which was identical to pretest).

Students came to the CBL sessions prepared or partially prepared for the topic of the case by lectures and practical sessions conducted prior to the CBL session. However, the previously gained information was not sufficient for the students to master all of the learning objectives of the CBL case, and the students were required to solve the problem through interactive discussion of critical points that were presented in the case scenario. In addition, the biochemical and/or molecular basis of the disease and the diagnostic and therapeutic approaches were included in the discussion. During the session, the students were allowed to refer to the available textbooks and to conduct online searches in order to integrate prior and acquired knowledge. The facilitator guided the group discussion by correcting inaccurate information and explaining difficult concepts. The ongoing discussion was student-centered as the facilitator avoided lecturing or dominating the discussion.

Questionnaires

The end-of-block questionnaires were prepared following a standard previously published procedure (Williams 2003).

Student's questionnaire At the end of the Neuroscience block of each academic year 2016–2017 and 2017–2018, the students were requested to reply to a 10-item, 5-point Likert scale questionnaire (Appendix 2) concerning their perception of the utility of CBL in learning medical biochemistry. The scale was from 0 to 4 (strongly disagree to strongly agree). The first section of the questionnaire included items related to the CBL session organization and preparation (item 1), as well as the ability of the method and the presented cases to challenge the students to think and interact (item 2), students' understanding of the metabolic pathways (items 3 and 7 and 8), and the students' interest in the field of medical biochemistry (item 4). In addition, the relevance of the cases presented to the biochemistry content of the block (item 5), and the clarity and logical framework nature of presenting biochemical information in the context of real-world cases (item 6) were evaluated. As an overall feedback, the students commented on whether they would recommend applying CBL to all medical biochemistry topics (topic 9) as well as to other basic science courses (item 10). The

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questionnaire also contained open-ended questions giving the students the chance to comment on what they liked/disliked about CBL approach (items 1.4 and 1.5). The second section of the questionnaire contained four personal questions pertaining to the student's gender, nationality, and pre-university education.

Staff's questionnaire The participating staff members were given a 16-item, 5-point Likert scale questionnaire (Appendix 3) at the end of the block and were requested to give their perception of the utility of CBL method. The questionnaire items aimed at assessing the staff opinion on 3 different, yet complementary, points: the impact of CBL on the students, CBL's impact on themselves, and lastly, the process of conducting the CBL sessions. The questionnaire also contained four open-ended questions that gave the participating staff members the chance to comment on what they liked/disliked about CBL and give their recommendations. The questionnaire first asked for information about the staff's gender, professional title, and the duration of practicing in the clinical field including laboratory medicine. This last question was critical as it was indirectly helpful to assess the expected level of clinical knowledge of participating staff members.

In both student's and staff's questionnaires, writing the name and phone number of the participating student or staff member was an optional entry to ensure obtaining unbiased, yet complete information.

Statistical analysis

Data analysis and graph preparation were conducted using Microsoft Excel and SPSS Statistical Package (IBM Corp. IBM SPSS Statistics for Windows, version 22.0. Armonk, NY: IBM Corp). A *p* value < 0.05 was considered statistically significant. Nonparametric tests (Mann–Whitney, Kruskal–Wallis) were used because the data did not show normal distribution as proved by Kolmogorov–Smirnov test.

Results

The pre- and posttest

Two consecutive academic years, 2016–2017 (721 students) and 2017–2018 (769 students), were included in the study. All students attended the CBL sessions and took the pre- and posttests. Analysis of the paired results showed a statistically significant rise in the posttest scores ($p < 0.001$). Table 1 shows a summary of the pre- and posttest scores of all students for the CBL1 session.

Student's questionnaire

Student's questionnaire was distributed to students of both academic years. Response rate was almost identical in both years: 405 out of 721 students of the year 2016–2017 (56%) and 439 out of 769 students of the year

Table 1 Summary of pre- and posttest scores of all students ($n = 1490$) for one session

	Mean	SD	Minimum[a]	Maximum[a]
Pretest	2.24	1.69	0	5
Posttest	4.10	1.18	0	5
Difference[b]	1.86	1.53	− 2	5

[a] A score of 5 in pretest = 210 students, a score of 0 in posttest = 22 students

[b] Paired Wilcoxon signed ranks test: negative ranks = 13, positive ranks = 1112, ties = 365, $P < 0.001$. A nonparametric test was used because the data did not show normal distribution as proved by Kolmogorov–Smirnov test

2017–2018 (57%). None of the students have missed all the items of the questionnaire. The first section of the questionnaire comprised 10 items assessing the students' perception of the impact of the CBL approach, their level of agreement/disagreement to it, and their overall recommendation. Ten students did not respond to this section of the questionnaire. Students who completed all the 10 items were 780 students. The reliability coefficient (Cronbach's alpha) of this part of the students' questionnaire was 0.89. Table 2 shows a numerical summary of the student responses to the 10 questions. Figure 2 illustrates the responses of all students to individual items on the Likert scale. Figure 3 summarizes all the student responses. Overall, the majority of students gave a positive opinion regarding the implementation of this CBL method.

Only 782 of 844 students of the 2 years (92.7%) responded to the gender question. Of those, 287 students (36.7%) were males and 495 students (63.3%) were females. There was no significant difference between the average score of the ten items in the two groups (Table 3).

As to the student nationality, 782 students (92.7%) responded to this question. Of those, 665 students (85%) were Egyptian. There was no significant difference regarding the average score of the ten items between Egyptian and non-Egyptian students (Table 4).

Only 771 students (91.4%) answered the question about the location of their high school. Their distribution is shown in Table 5. There was no significant difference regarding the average score of the ten items between students from Cairo, other governorates, or other countries high schools (Table 6).

As to the type of high school, 762 students (90.3%) answered this question. Their distribution is shown in Table 7. There was no significant difference regarding the average score of the ten items between students from different types of high schools (Table 8).

Respondents to the open-ended questions commented in a generally positive manner. Comments as: "great job," "better way of learning," "we need summer CBL," and

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Table 2 Student responses to section 1 of the questionnaire on a scale of 0–4

	Year 2016–2017			Year 2017–2018			All		
	n	Mean	SD	*n*	Mean	SD	*n*	Mean	SD
Item 1	394	3.21	0.78	438	3.18	0.82	832	3.19	0.80
Item 2	393	3.17	0.81	437	3.20	0.83	830	3.19	0.82
Item 3	385	2.98	0.85	436	2.92	0.93	821	2.95	0.90
Item 4	394	2.83	0.96	435	2.77	1.07	829	2.80	1.00
Item 5	391	3.15	0.74	436	3.24	0.85	827	3.20	0.80
Item 6	384	3.09	0.78	437	3.07	0.84	821	3.08	0.81
Item 7	390	3.05	0.81	437	3.02	0.91	827	3.03	0.87
Item 8	385	3.04	0.90	436	3.07	0.90	821	3.06	0.90
Item 9	388	2.99	1.05	433	2.93	1.16	821	2.96	1.11
Item 10	390	2.98	1.13	431	2.86	1.24	821	2.92	1.19
Average[a]	395	3.05	0.62	439	3.02	0.68	834[b]	3.03	0.65

Nonparametric tests were used because the data did not show normal distribution as proved by Kolmogorov–Smirnov test

[a] Kruskal–Wallis test: There are significant differences between the responses to different items

[b] Mann–Whitney test: no significant difference between the two academic years in all except item 5

Fig. 2 Responses to individual items in questionnaire by all students
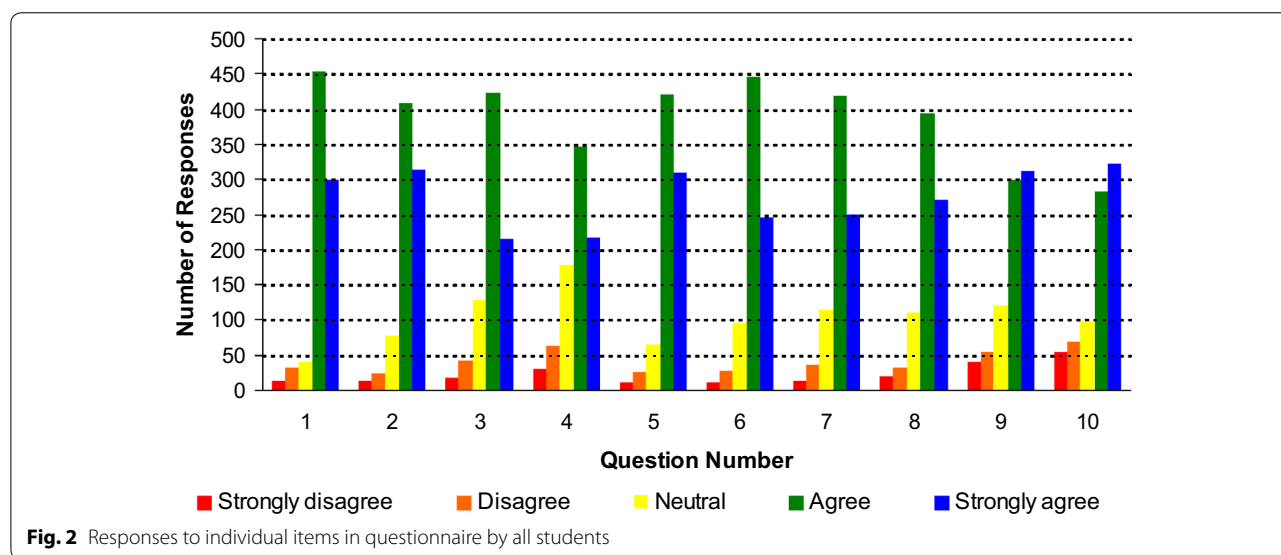
"hope to be applied in other departments as well" were obtained from 10% of students. Students' suggestions included adding videos and animations to the case presentation, providing the CBL material prior to attending the session, conducting lectures' revisions prior to CBL to improve their performance in case discussion, and increasing the number of cases.

Staff's questionnaire

The staff's responses to the questionnaire were collected from 9 staff members. The reliability coefficient (Cronbach's alpha) for the 5-point Likert scale items was 0.88. Total number of responses ($n = 144$) had a mean ± SD of 3.64 ± 0.56 (on a scale of 0–4). Figure 4 illustrates the number of responses given for each of the categories of the used scale.

As regards the staff opinion on the impact of CBL on the students, none of the points of inquiry received a negative response of "strongly disagree" or "disagree." Eight participants gave positive responses of either "agree" or "strongly agree" to all ten points of this part. One participant gave positive responses to 5 points and a neutral response of "neither agree nor disagree" for the other 5 points. As regards the staff opinion on the impact of CBL on themselves, all the three points received a positive response of either "agree" or "strongly agree"
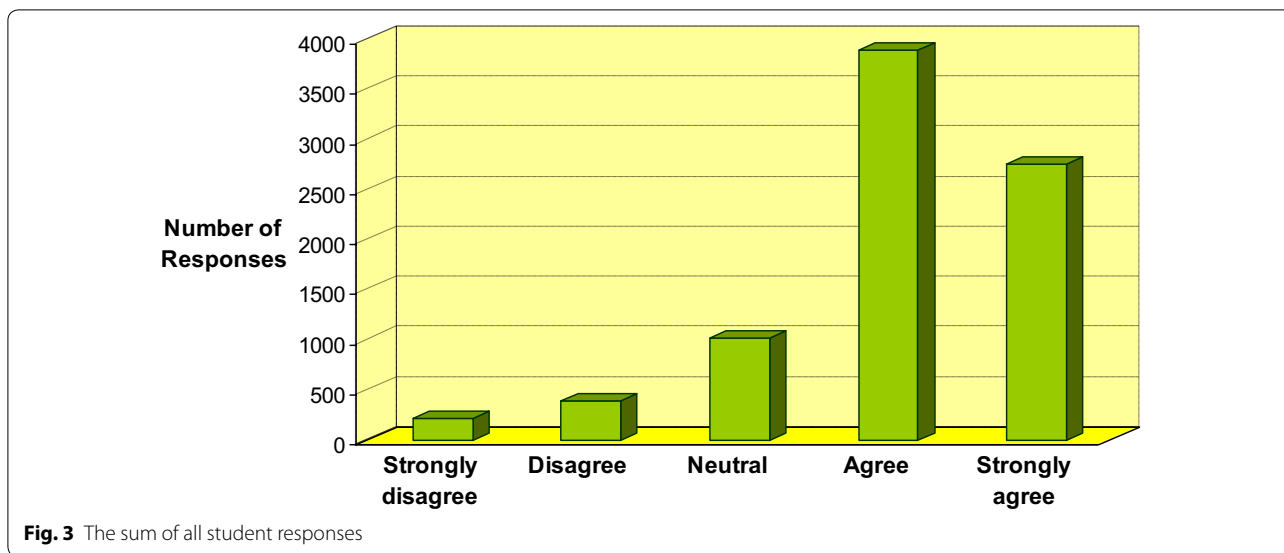
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Fig. 3 The sum of all student responses

Table 3 Comparing the average of 10-item responses according to gender

Gender[a]	*n*[b]	Mean	SD
Male	285	3.06	0.60
Female	487	3.05	0.67

[a] Mann–Whitney test: no significant difference

[b] Ten students did not respond to any of the ten items

Table 4 Comparing the average of 10-item responses in Egyptian versus non-Egyptian students

Nationality[a]	*n*[b]	Mean	SD
Egyptian	657	3.05	0.64
Non-Egyptian	115	3.06	0.67

[a] Mann–Whitney test: no significant difference

[b] Ten students did not respond to any of the ten items

Table 5 The location of the high school of the study students

Location	Frequency	%
Cairo	436	56.5
Other governorates	151	19.6
Other countries	184	23.9
Total	771	100.0

Table 6 Comparing the average of 10-item responses in students from high schools from different locations

Location[a]	*n*[b]	Mean	SD
Cairo	429	3.03	0.68
Other governorates	150	3.07	0.55
Other countries	183	3.10	0.63

[a] Kruskal–Wallis test: no significant difference

[b] Nine students did not respond to any of the ten items

Table 7 The type of the high school of the study students

School type	Frequency	%
Public	334	43.8
Pubic experimental Arabic	80	10.5
Pubic experimental English	76	10.0
Private Arabic	91	11.9
Private English	120	15.7
Other private	43	5.6
Other	18	2.4
Total	762	100.0

by all participating staff. As regards the staff opinion on the process of conducting the CBL, the respondents strongly agreed or agreed that the sessions were organized and well prepared, that instructors were essentially monitoring the students' performance, and that they were keeping control of the learning session. Only one staff member gave a neutral response to the point of the sessions' organization and good preparation. This respondent disliked the time- and effort-consuming nature of the sessions' preparation and organizations. This particular staff member added an important comment that involvement of clinicians, in his/her view, will improve the organization and preparation of the sessions.

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Table 8 Comparing the average of 10-item responses in students from different types of high schools

School type[a]	n[b]	Mean	SD
Public	327	3.09	0.61
Pubic experimental Arabic	80	3.08	0.67
Pubic experimental English	74	2.98	0.80
Private Arabic	90	2.97	0.68
Private English	120	3.03	0.59
Other private	43	3.04	0.70
Other	18	3.41	0.44

[a] Kruskal–Wallis test: no significant difference

[b] Ten students did not respond to any of the ten items

In response to the open-ended questions, the staff members generally gave positive comments. Examples of positive comments from the facilitators included the following: "CBL sessions have helped the students to understand biochemical metabolic pathways," "CBL sessions have increased students' interest in studying biochemistry," "CBL sessions have helped students to revise the biochemical information," "I recommend applying this method to all biochemistry topics," and "I recommend applying this method to other basic medical courses." All participating staff members liked the fact that CBL bridged the gap between basic and clinical sciences; one staff member described this as "breaking the ice" between both fields of science. Exposing the students to "real-life" clinical situations has helped the medical students, as per the staff view, to better learn the biochemistry content and to "think strategies" as well. The staff believed that the students became more interested to attend the practical sessions and to learn biochemistry. One staff member commented on the benefit of applying CBL as: "it is an active and student-centered approach as opposed to the traditional passive and tutor-centered learning". More detailed description for the active learning process included the students' searching for, and applying information obtained from other disciplines to discuss the cases. One staff member liked the in-depth discussion of cases as it emphasized on "apparently subtle knowledge" that could be otherwise missed. The staff acknowledged the teamwork nature of preparing and conducting the sessions and mentioned that both teacher–student and student–student interactions were improved by applying CBL. Because of the small student's number per group and interactive nature of CBL sessions, instructors reported a closer follow-up and monitoring of the students' performance.

Other suggestions by respondents included increasing the manpower participating in CBL activity to increase its efficiency. Most of the staff members suggested specific topics to be the subject for further cases. Examples of these topics included vitamins, minerals, obesity, hyperuricemia, and hemoglobinopathies. One staff member suggested providing background knowledge about each case's topic, via other learning tools, prior
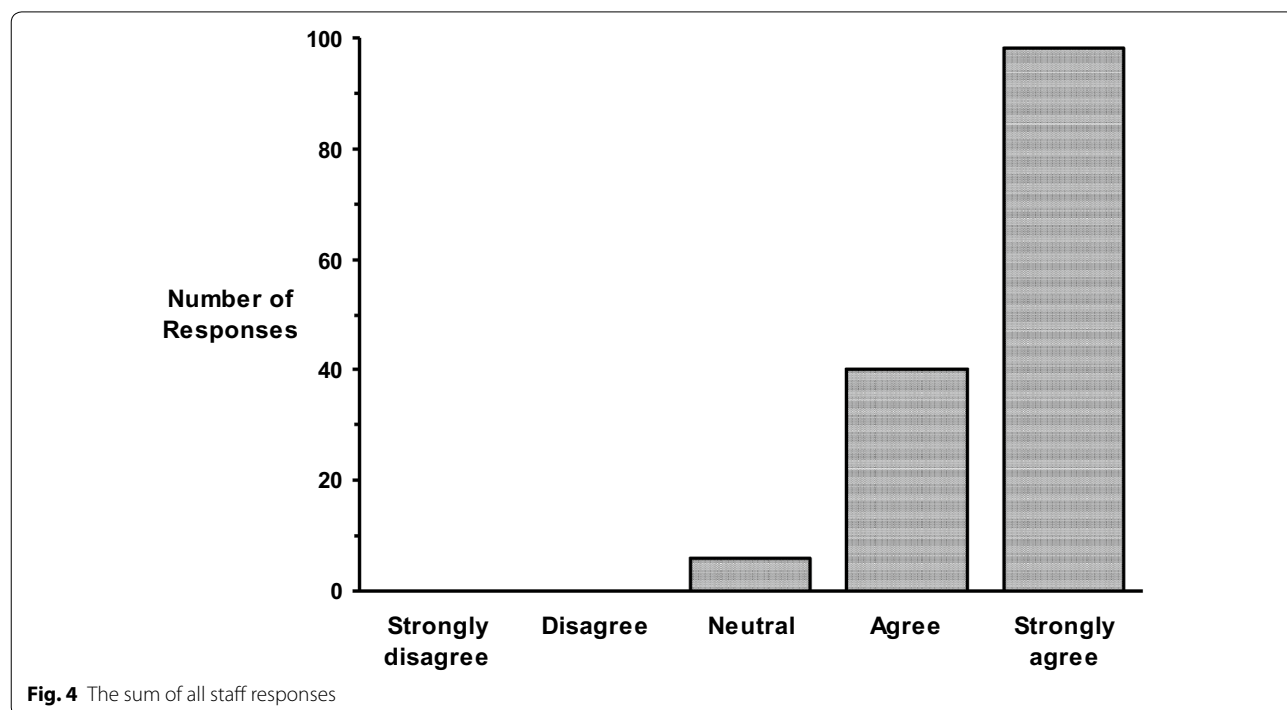

Fig. 4 The sum of all staff responses

to conducting the CBL session. Encouraging comments from facilitators included the suggestion to use the CBL approach for "all possible topics in biochemistry" and for teaching biochemistry for "postgraduate students of clinical specialties." A staff member commented that "Teaching through CBL is a new experience; however, some of the teaching habits of the staff need to be adjusted."

Discussion

Curriculum planning and full implementation of an integrated approach in medical education is not an easy job (Bandiera et al. 2013; Davis and Harden 2003; Harden 2000). The current work describes the impact of applying a new well-recommended approach in teaching medical biochemistry on a relatively large number of undergraduate medical students. Major challenges were faced in order to implement CBL, for instance, the large students' number and a limited number of well-trained staff members capable of playing the role of expert facilitators. The large number of students and lesser number of teaching hours is already acknowledged as an obstacle that strongly pushes toward the teacher-centered education (Lee et al. 2010; Varghese et al. 2012). By careful subgrouping and schedule adjustment to allow a session every 2 weeks for each subgroup, we could have 25 students per session, just a slightly higher number than that proposed for efficient small-group teaching (Thistlethwaite et al. 2012).

Designing proper cases to fit in the ILOs of the biochemistry topics of the Neuroscience block was a multistep task. The CSC first defined required clinical cases. A faculty orientation training workshop on how to formulate cases for CBL was conducted. Topics of the clinical cases were allocated to the working group (WG) consisting of senior and junior staff members. The prepared cases were then revised by the CSC. These cases served as scaffolds upon which facts and concepts could be reorganized and reinforced. Our designed cases were not much different from those described by other workers (McRae 2012). Our approach for designing the cases served not only to provide the teaching material, but also to prepare the faculty members to play the role of expert facilitators, which is another specific objective of this study.

Teaching and learning of biochemistry can be improved, by understanding the students' perceptions (D'Souza et al. 2013). Evaluating the students' perception of the CBL approach is a major specific aim of the present study. Our students' questionnaire was formulated to explore the respondents' opinions about CBL sessions. Internal consistency of the questionnaire is evident by the high value (0.89) of Cronbach's alpha (Tavakol and Dennick 2011). Although most medical students

enrolled in Ain Shams Faculty of Medicine are Egyptians, there are an increasing number of students coming from different countries. In addition, Egypt is a relatively big country with different cultural and socioeconomic nature of its various regions. Therefore, in an attempt to explore these potential factors that might have an influence on the study's results, comparisons were made between students from different countries, different high schools, and different genders. Most of the students either agreed or strongly agreed that the CBL approach was well prepared and has helped them academically in various ways. This perception was not gender-dependent, neither was it dependent on the type of pre-university education or cultural differences arising from difference in nationality or area of residence. The majority of students agreed that this approach has been effective in advancing their meaningful learning in biochemistry. This agrees with previous studies (Harden 2000; Williams et al. 2018), which showed the value of CBL for the students' perception and gaining the required knowledge both immediate and on relatively long-term basis.

Our students were given the chance to work in a team during the sessions. Team learning has already been proved in different medical sciences to be beneficial for better learning and memorization (Chung et al. 2009; Mcinerney and Fink 2003; Rigby et al. 2012; Sisk 2011; Vasan et al. 2011; Zgheib et al. 2011). The discussion in our sessions ran in an interactive way, with the textbooks and Internet access available for the students to get the answers themselves. This active learning engages students in the topic and allows them to develop their critical thinking skills. The positive responses to the first eight items of section 1 in the student's questionnaire demonstrate clearly these beneficial aspects of CBL (Figs. 2 and 3). In addition, the positive responses to the staff questionnaire (Fig. 4) emphasize on the successful use of CBL for better students' understanding, retention, and application of biochemical concepts. Moreover, favorable perception of CBL method by both students and staff has led them to strongly recommend its application to all biochemistry topics and also to other courses. In agreement with our results, several reports showed that active/interactive learning is one of the most common educational approaches promoting student-centered learning with a focus on critical thinking and problem solving (Michael 2006; Popil 2010; Shanley 2007; Zgheib et al. 2011).

The participating staff members strongly agree that CBL is a better method of teaching/learning than the didactic one. In accordance with our results, it has been shown that CBL is superior to the traditional lecture approach (Eissa and Sabbour 2016). Based on the significant improvement in the students' scores in the posttest as compared to the pretest in our study, CBL seems to

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be an effective method of learning for the students. This implies that the students grasped the knowledge and were inspired to concentrate on biochemical concepts.

Preparing the faculty members to play the role of expert facilitators, as a specific aim of this study, was achieved by the departmental workshops and by engaging them in designing the cases. The success of CBL approach measured by the students' performance and opinion in this study implies a success of the facilitators. This can be nicely illustrated by the presence of a significant difference between the 2 years regarding item 5 of the students' questionnaire. The students' response is better in the second academic year (2017–2018) than the first one (2016–2017). This would imply that the staff members have gained more experience in conducting CBL classes in the second academic year. In addition, the students of the second batch could have obtained some sort of positive feedback from their peers of the first batch. Overall, the participating staff provided positive and encouraging responses, whether to the closed or open-ended questions as stated above. This reflects the staff members' common belief that the new approach has improved teacher–student relationship and has benefited them scientifically and professionally, increasing their "teaching competence." Moreover, they found that CBL method for teaching biochemistry was an enjoyable experience. A critical issue about the staff of basic sciences is that they may not be currently involved in patient-related clinical services; they may be shifted more toward the basic science research. We inquired about the staff's clinical experience in the questionnaire. However, we could not make conclusions about this issue due to the small number of staff participating in this study.

Encouraging results were also reported by adopting CBL approach in teaching of other basic science courses: pharmacology (Kamat et al. 2012; Gupta et al. 2014), physiology (Gade and Chari 2013), microbiology (Ciraj et al., 2010; Singhal 2017), and pathology (Dubey and Dubey 2017). Although the facilitators of CBL sessions in pathology in the latter report felt positively, they recommended using this CBL method for selected topics because of its inherent extra time and effort for preparation and conduction. This opinion certainly applies to students who come at a large number like ours. Some of our staff already shared this opinion and suggested to use the help of clinicians in preparing the cases to cut down the time and effort. Nonetheless, a lot of published reports emphasize the usefulness of this teaching modality for the preclinical education (Ghosh 2007; Malau-Aduli et al. 2013; McLean 2016).

The current work has several strength points and certain limitations. Strength points include the application of CBL to a large number of students on two consecutive academic years. Our number of students per an academic year may be the highest to be reported till now. Another strength point is the engagement of different levels of academic/professional staff members in preparing the clinical cases and conducting the CBL sessions. The assessment of CBL experiment by both students and facilitators is another point of strength, since it will allow for applying more effective future modification to improve the outcomes. In addition, the use of pre- and posttest serves as an internal control and an objective method to assess the short-term retention of knowledge and the ability of the facilitators to reinforce the core concepts of biochemistry.

Limitations of this study that should be considered include the small number of participating staff members. Not all biochemistry staff would accept this new process of teaching either due to lack of clinical experience, lack of proper training, or both. Conduction of CBL orientation seminars and more hands-on CBL training workshops throughout the academic year would be helpful to overcome limitation of trained staff. The number of students included in each subgroup (~ 25 students) is a relative limitation, since small-group discussions are preferably managed with a lower number, up to 15 students for best outcomes (Thistlethwaite et al. 2012). Increasing the number of well-trained staff members will allow for dividing the students in the future into smaller subgroups. Furthermore, while the current work assessed the short-term retention of knowledge (same session pre- and posttest scores), it did not test the long-term retention. Future study is needed where the impact of CBL on the students' performance at the end-of-block examination would be assessed. Another limitation of the current work is the absence of a control group for whom traditional teaching methods for the same topics are used with no CBL implementation. However, such design would be hard to implement. One way to partially overcome this limitation is to design a future study where we assess the students' performance in topics that are taught using both didactic and CBL and compare it to their performance in topics taught without CBL sessions in the same block.

The system-based integrated medical curriculum has just started in our medical school. More studies are warranted to find out the best approach for teaching the concepts of medical biochemistry and other basic sciences into the context of this new curriculum.

Conclusion

In conclusion, by filtering out unneeded theoretical details and concentrating on what is relevant to medicine, the introduction of CBL in the current work had positive outcomes. Example of such outcomes includes

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strengthening critical skills of medical students, such as problem solving, critical thinking, teamwork, time management, and best use of resources. Such outcomes have increased the medical students' awareness of the relevance of biochemistry to the practice of medicine and are expected to ease the abrupt transition from academic textbooks to real-life practice of medicine.

Last but not least, the answer is "yes" to the question of feasibility of adopting CBL in medical biochemistry with a large number of students. It is not only feasible, but also efficient as evidenced by the students' performance. It is positively perceived by both students and teaching staff. This could not have been achieved without the good preparation of the learning environment, the topic cases, and the session facilitators. However, future work is needed to solve certain challenges such as increasing work load on the faculty members and the time-consuming nature of preparing CBL sessions, and to test the impact of this teaching modality on long-term retention of knowledge.

Abbreviations
ASU: Ain Shams University; CBL: Case-based learning; CSC: CBL scientific committee; EMP: Extended Modular Program; ILOs: Intended learning objectives (outcomes); MCQ: Multiple-choice question; PBL: Problem-based learning; WG: Working group.

Availability of data and materials
The datasets used during the current study are available upon request from the corresponding author.

Ethics approval and consent to participate
This CBL approach was approved by the department's undergraduate medical education committee, by the Faculty of Medicine Vice-deanship for Students Affairs, and by the ASU Faculty of Medicine Ethical Committee, proposal 2016/88.

Consent for publication
All authors have read the manuscript and agreed to all its contents. All authors gave their consent for publication.

Competing interests
The authors declare that they have no competing interests.

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Appendix 1: CBL case

Neuroscience Block: CBL1
My Girl Has Pallor and Jaundice

A 7-day-old female was admitted to hospital suffering from pallor, lethargy and jaundice. History taking showed that she was jaundiced at day 1 of life but discharged without diagnosis and didn't receive any treatment. Mother and father were cousins from a small village in Sohag. Physical examination revealed hypotonia and mild splenomegaly.

Laboratory investigations:

- **CBC**

    - **Hb: 6 g/dL (N:12.7-18.3).**

    - **Reticulocyte count: increased.**

    - **Normocytic normochromic anemia.**

    - **Blood smear: RBCs with thorny projections.**

- **S.total bilirubin: 19 mg/dL (5–30 days: 0.0–1.8)**

- **S.direct (conjugated) bilirubin: 1 mg/dL (N:0.0–0.4)**

- **S.indirect (unconjugated) bilirubin: 18 mg/dl (N: 0-1.4)**

- **Increased serum 2,3-BPG.**

- **RBC's enzyme assay: Decreased pyruvate kinase activity (=15% of normal).**
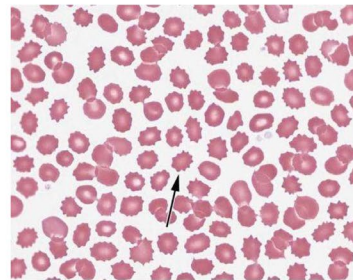
Treatment Plan:
- **Treatment of anemia:**

    - Blood transfusion

    - Folic acid and other vitamin B supplement

    - Splenectomy

- **Treatment of hyperbilirubinemia**

    - Phototherapy

    - Exchange transfusion

Questions
1. **What is your diagnosis?**

2. **Did family history support your diagnosis?**

3. **What is the metabolic pathway affected in this case?**

4. **Explain the cause of hyperbilirubinemia in this case.**

5. **Explain the presence of neurological symptoms in such case.**

6. **Explain why the liver has not been affected by this enzyme deficiency?**

7. **Compare this metabolic pathway in neurons & astrocytes**

8. **What are other enzyme deficiencies affecting glycolysis?**

9. **Mention other carbohydrate-related enzyme deficiencies that can cause hemolytic anemia.**

10. **Explain biochemical basis of therapy**

CBL1 Pretest (5 marks)

Student Name...

Student ID..

I. **Choose the best answer: (1 mark/mcq)**

1- *Which one of the following compounds is an allosteric effector that enhances the activity of phosphofructokinase-1 of the glycolytic pathway?*
A) Adenosine monophosphate (AMP).
B) Citric acid.
C) Acetyl CoA.
D) Glucose-6-phosphate.
E) Fructose-1,6-bisphosphate.

2- *Which one of the following diseases can be due to genetic absence of pyruvate kinase in RBCs?*
A) Glucosuria.
B) Hemolytic anemia.
C) Fatty liver
D) Lactic acidosis
E) Obstructive jaundice

II. **Complete the following table comparing metabolism in neurons and astrocytes. (1 mark/ point)**

	Neurons	Astrocytes
Rate of glycolysis		
Lactate utilization as fuel		
Lactate production		

CBL1 Post test

Student Name………

Student ID……….

I. **Choose the best answer:**

  1- Which oneof the following compoundsis an allosteric effector that enhances the activity of phosphofructokinase-1 of the glycolytic pathway?

  A) AMP.
  B) Citric acid.
  C) Acetyl CoA.
  D) Glucose-6-phosphate.
  E) Fructose-1,6-bisphosphate.

  2- Which one of the following diseases can be due to genetic absence of pyruvate kinase in RBCs?

  A) Glucosuria.
  B) Hemolytic anemia.
  C) Fatty liver
  D) Lactic acidosis
  E) Obstructive jaundice

II. **Complete the following table comparing metabolism in neurons and astrocytes.**

	Neurons	Astrocytes
Rate of glycolysis		
Lactate utilization as fuel		
Lactate production		

Appendix 2: Students' Questionnaire

Evaluation of a new instructional strategy (Case based learning) for biochemistry in 2nd year Neuroscience module

Your serious participation in this survey will be most valuable
for you and your colleagues

Your name is not required

Section 1:

Please read carefully and check one box for every question

1.x	Do you agree with the following statements about this new learning method CBL?					
		strongly disagree	disagree	neither agree nor disagree	agree	strongly agree
CBL:						
1	Was well organized and prepared	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
2	Challenges me to think and interact	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
3	Helped me understand the metabolic pathway	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
4	Has increased my interest in the field of biochemistry	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
5	Case presented was significantly relevant to biochemistry content of the module	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
6	In CBL, biochemical information presented was following a clear and logical framework highlighting its clinical significance	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
Class Discussion						
7	Helped me to revise the biochemical information	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
8	Challenges me to think and interact	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
Overall:						
9	I recommend applying this method to all biochemistry topics	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
10	I recommend applying this method to other courses	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐

Please read carefully and check one box for every question

1.4	What did you like most about this learning method? Please write

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1.5	What didn't you like about this learning method? Please write

Section 2:

2.1	What is your gender?
	1☐ Male 2☐ Female

2.2	What is your nationality?
	1☐ Egyptian 2☐ Malay 3☐ other (… … …)

2.3	Your secondary (high) school resides in?
	1 ☐ 2 ☐ 3 ☐ Cairo other governorate (… …) other country (… …)

2.4	What type of school do you come from?		
	1 ☐ public	2 ☐	public experimental Arabic
	3 ☐ public experimental English	4 ☐	private Arabic
	5 ☐ private English	6 ☐	private other language (please specify …………………..)
	7 ☐ other (please specify … … …)		

2.5	Do you have other comments?Please write

Thanks for participation

Appendix 3: Staff's Questionnaire

A Staff questionnaire for the evaluation of a new instructional strategy (Case based team learning; CBL) for Biochemistry in 2nd year medical studies

Your kind participation in this survey will be most valuable
for improving learning approaches of Medical Biochemistry

Name (optional):

Section 1: Please read carefully and check one box for every point:

1.1	**Your gender:**	☐ Male	☐ Female

1.2	**Your professional title in Biochemistry:**			
	☐ Professor	☐ Assistant Professor	☐ Lecturer	☐ Teaching assistant

1.3	**How long did you practice in clinical fields including laboratory medicine?**	
	☐	Never
	☐	Less than a year
	☐	Less than 5 years
	☐	Less than 10 years
	☐	More than 10 years

Section 2: Please read carefully and check one box for every question/statement:

		strongly disagree	disagree	neither agree nor disagree	agree	strongly agree
2.1 CBL: Was better for students?						
a	CBL is a better method of teaching/learning than the traditional one.	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
b	CBL promotes self-study and problem-solving capabilities of the students.	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
c	CBL helps in bridging basic to clinical sciences.	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
d	CBL helps in better retention of knowledge.	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
e	CBL sessions have helped the students to understand biochemical metabolic pathways.	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
f	CBL sessions have increased students' interest in studying Biochemistry.	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
g	CBL sessions have helped students to revise the biochemical information.	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
h	CBL has helped in improving the students' communication skills.	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
i	I recommend applying this method to all Biochemistry topics.	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
j	I recommend applying this method to other basic medical courses.	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
2.2 CBL: Was better for you as a staff?						
a	CBL sessions have facilitated a better teacher-student relationship.	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
b	Preparing the cases of CBL has benefited you scientifically.	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
c	Participation in CBL has improved your teaching competence.	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐

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2.3 CBL: Was properly conducted?						
a	CBL sessions were organized and well-prepared.	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
b	You were essentially monitoring the students' performance.	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
c	You were keeping control of learning session.	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐

Section 3: Please read carefully and write concisely:

3.1	What did you like most about CBL?

3.2	What did you dislike about CBL?

3.3	Suggest New topics that can be taught by CBL

3.4	Do you have other comments?

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