Introducing TBL in Clinical Biochemistry: Perceptions of Students and Faculty

Aliaa Alamoudi[1], Mohammed Hassanien[2], Lana Al Shawwa[3], Abdulhadi Bima[4], Hoda Gad[5], Ara Tekian[6]

Corresponding author: Dr Mohammed Hassanien mohammedhassanien700@yahoo.com

Institution: 1. Department of Clinical Biochemistry, Faculty of Medicine, King Abdulaziz University, 2. Assessment Centre and Medical Education Department, Fakeeh College for Medical Sciences and Department of Medical Biochemistry, College of Medicine, Tanta University, 3. Department of Medical Education, Faculty of Medicine, King Abdulaziz University, 4. Department of Clinical Biochemistry, Faculty of Medicine, King Abdulaziz University, 5. Department of Clinical Biochemistry, Faculty of Medicine, King Abdulaziz University and Department of Medical Biochemistry, Faculty of Medicine, Alexandria University, 6. University of Illinois College of Medicine, Chicago

Categories: Educational Strategies, Teaching and Learning

Received: 09/12/2017
Published: 25/01/2018

Abstract

Clinical biochemistry is one of the foundational sciences essential for preparing medical students to achieve the optimal benefit of their clinical experience. In the Faculty of Medicine of King Abdulaziz University (FOM-KAU), clinical biochemistry is taught as a core course and system-based modules in 2nd, 3rd and 4th year. The teaching strategy is mainly teacher-centered, with lecture comprising the highest percentage among teaching methods, while self-directed learning (SDL) receiving the lowest percentage.

The aim of this study was to evaluate the current teaching methods of clinical biochemistry at the FOM-KAU, while concurrently assessing the need for introducing a new student-centred teaching method. This was done through evaluating the level of knowledge, interest, and attitude of medical students and teaching faculty in Team Based Learning (TBL) in clinical biochemistry courses.

The results of this study revealed that almost half of the second year medical students did not enjoy attending clinical biochemistry lectures. In addition, approximately half of them recall only 30% of the information they have learned one year after the exam. On the other hand, more than 50% of them enjoyed solving problems /cases, and doing activities during the session. At the same time students and academic staff members had some concerns regarding introducing TBL as a new teaching method.

In conclusion, the current teaching methods of clinical biochemistry at the FOM-KAU needs to be modified, with introducing more student-centered teaching methods, like TBL. However, students’ concerns such as team work, and
faculty concerns regarding student preparation need to be addressed carefully with the participation of all stakeholders. Workshops to teach both students and faculty the elements of TBL would be of great benefit to address any concerns.

**Keywords:** Team Based Learning (TBL), Teaching Clinical biochemistry, Medical students.

**Introduction**

The clinical biochemistry course at the FOM-KAU is regarded as biochemistry that is applied to humans in health and diseases. It covers the methodology and interpretation of biochemical tests to support diagnosis, treatment, and disease monitoring. It is therefore one of the foundational sciences which is essential to prepare medical students to get the optimal benefit of the clinical experience available in their medical curriculum. Teaching foundational sciences, including clinical biochemistry would provide a high-quality learning experience whenever they relate to clinical problems or cases. Similarly, clinical teaching becomes a highly effective learning experience when it is well promoted through the foundational sciences. Teaching clinical biochemistry in such a way will help students to apply scientific reasoning in clinical decision-making. In addition, it provides a strong foundation for solving medical problems, which need a molecular and/or biochemical understanding. (Finnerty et al., 2010; Seifert, 2011)

At KAU, teaching of clinical biochemistry generally starts early during the medical curriculum with other basic medical foundational sciences such as Anatomy, Physiology, Histology, Pathology, and others. At the FOM-KAU, clinical biochemistry is introduced during the second year, which follows the preparatory year, in the form of a core course which extends over the first semester. In the third year, clinical biochemistry is taught as a part of system-based modules in an integrated manner with other basic medical sciences and a few clinical sciences. In the fourth year, clinical biochemistry is taught as a part of a laboratory module that also includes Pathology and Hematology.

Teaching methods for clinical biochemistry at the FOM-KAU are mainly in the form of didactic lectures, tutorials, and practical sessions. Teaching is therefore mainly in the form of large group teaching either in large classrooms for lectures and tutorials or in biochemistry laboratory for practical sessions.

At KAU, given the educational culture in Saudi Arabia, most students were not taught how to be interactive learners, how to deal with the material on their own, how to self-assess their own work and have a student-based learning experience within the classroom. In addition, tutors themselves have not practiced taking on the role of a facilitator more than a lecturer.

It is known that active learning, which aims to involve students in their learning process, can promote an atmosphere of attention and participation. Indeed, active learning techniques, such as group exercises, debates and discussions, case/problem solving and Problem-Based Learning (PBL) can enhance learning (Sawatsky, Berlacher, & Granieri, 2014). One of the interesting implemented formats for active learning is TBL. Although originally developing in business schools, TBL has gained popularity in medical education and has been implemented in several universities. In general, TBL follows the *Constructivist learning theory* in which the main elements rely on the teacher being a facilitator and that students learn actively using relevant problems and group interactions (Hrynychak & Batty, 2012). This theory is derived from the idea that the focus of learning is on the mental representation of information by the learner (Svinicki, 2004). The learner collects new knowledge from the environment and experience and then reconstructs it with his/her long-term memory representations (Svinicki, 2004). For this to happen, learners must process the new material and integrate it with existing understanding to form a new cognitive structure that is unique to them based upon their own process of learning.
TBL has been described as an active learning and small group instruction method that provides students with knowledge through structured activities, teamwork and immediate feedback (Burgess, McGregor, & Mellis, 2014). Haidet and colleague have introduced a framework to define the main elements of TBL which included team formation, assuring readiness of students in knowing the subject, allowing immediate feedback, the four S's (a significant applicable problem, same problem, specific choice, and simultaneous reporting from groups), a structured grading, and peer review (Burgess et al., 2014). TBL has been introduced in several basic sciences settings and indeed some reports have described its success in biochemistry material (Phadtare, Abali, & Brodsky, 2013).

At KAU, it has not been explored, how do medical students and teaching faculty feel towards the current teaching and learning of clinical biochemistry, and what are their perspectives towards student active learning such as TBL.

Understanding these perspectives can help us to design more effective active learning sessions that can fit the current cultural needs, and enhance students' motivation for learning. In addition it can allow us to anticipate some of the challenges, including required resources and training.

The aim of this study was to evaluate students and teaching faculty perceptions towards the current teaching methods of clinical biochemistry at the FOM-KAU. The study also aimed to assess the need for introducing new active student-centred teaching method through evaluating the level of knowledge, interest, attitude of medical students and teaching faculty towards TBL in clinical biochemistry courses.

Materials and Methods

Participants

All 483 second year medical students (males and females) and all 17 faculty members of the clinical biochemistry department received a direct link of the survey via email. Of the 483 students, 152 students responded (31.5%), while 13 out of the 17 faculty members responded (76.5%).

Survey

A 21-item survey with additional three open ended questions was developed and tested for initial validity evidence, including psychometric characteristics and item analysis. In order to ensure further validity (content and clarity of items in response process), the survey was tested by a focused group. The survey's link was distributed to all participants via email. The survey was divided into two sections designed to cover two main areas: (1) teaching and learning in clinical biochemistry, (2) beliefs towards TBL and its components.

Ethical approval was obtained from the Unit of Biomedical Ethics, Research Committee, College of Medicine, King Abdulaziz University (reference number 132-17).

Results

Participant characteristics

Among the 152 medical students who participated in the survey, 55% were male students, while 45% were female
In terms of faculty members’ participation, 46% of participants were male and 54% were female. Out of the participants, 38% were professors, 31% were associate professors, and 31 were assistant professors. Descriptive statistics of participants are summarized in Table 1.

Table 1. Descriptive statistics (%)

| Factor                      | Percent (%) |
|-----------------------------|-------------|
| **Students**                |             |
| Gender                      |             |
| Male                        | 55          |
| Female                      | 45          |
| Knowledge on TBL            |             |
| Yes                         | 23          |
| No                          | 77          |
| Participation in TBL        |             |
| Yes                         | 15          |
| No                          | 85          |
| **Faculty**                 |             |
| Gender                      |             |
| Male                        | 46          |
| Female                      | 54          |
| Academic position           |             |
| Assistant professor         | 31          |
| Associate professor         | 31          |
| Professor                   | 38          |
| Knowledge on TBL            |             |
| Yes                         | 62          |
| No                          | 38          |
| Participation in TBL        |             |
| Yes                         | 23          |
| No                          | 77          |
Four different teaching methods are currently used for teaching clinical biochemistry for second and third year medical students at the FOM-KAU. These methods include lectures, tutorials, practicals and SDL, their number and percentage respectively are as following: 101 (62%), 29 (18%), 27 (16%) and 6 (4%) (Table 2).

Table 2. Different Methods of Clinical biochemistry teaching in FOM-KAU

| Course/Year       | Lecture | Tutorial | Practical | Self-Directed Learning |
|-------------------|---------|----------|-----------|------------------------|
| Core Course/2nd Year | 45      | 15       | 15        | 0                      |
| Modules/3rd year   | 56      | 14       | 12        | 6                      |
| **Total**          | **101 (62%)** | **29 (18%)** | **27(16%)** | **6(4%)** |

Perspectives on teaching and learning in clinical biochemistry

The majority of both students and faculty believed that clinical biochemistry is an important subject for medical students and that it is a difficult subject to learn. Both faculty and students preferred more student-teacher interaction.

A clear discrepancy between faulty and students perceptions was demonstrated when both groups were asked on whether they think students enjoy attending clinical biochemistry lectures. While 15% of the faculty disagreed that students enjoy clinical biochemistry lectures, and 85% were neutral, 47% of the students disagreed, while only 18% were neutral. It is sometimes perceived by the faculty that students end up memorizing large parts of the curriculum without much understanding, only to be able to pass their exams. This can be reflected on how students sometimes fail to understand the integration of the material and solve critical thinking questions. To study the perception of faculty and students on this matter, both groups were asked on how much of the curriculum do students memorize with little understanding. From the students only 4% thought they memorize all the curriculum without much understanding, 18% thought they memorize 60-80%, 27% believed they memorize from 30-60% of the curriculum without much understanding, while the majority, 50% of students, believed that they only memorize less that 30% of the curriculum without understanding. This concludes that most students believe they understand the majority of the curriculum in depth. The perception of faculty, however, seemed to divert more towards the notion that students memorize without much understanding, with 15% of faculty believing that students memorize 100% of the curriculum without understanding it, and 15% believed that students memorize 60-80% of the curriculum, and another 31% believed that students memorize 30-60%, while 38% thought that students only memorize less than 30% of the curriculum without memorizing. In addition, it appeared to be that the majority of the faculty (70%) perceived that students remember less than 30% of the curriculum one year after the exam, while only 30% of the faculty felt that students recall 30-60% of the curriculum after one year of the exam. Although the majority of students, 49% thought they remember less than 30% of the curriculum, a large number, 42%, thought they remember from 30-60%, and 7% thought they remember from 60-80% of the curriculum one year post exam (Table 3).
When asked on what is the biggest challenge in teaching clinical biochemistry, the majority of students (72%) thought that the main reason is the large content of the subject (Fig. 1). The majority of faculty (46%) believed that the main reason is the large number of students per tutor (Fig. 1).

**Figure 1. Students and faculty perspective as the biggest challenge in teaching Clinical biochemistry**

| Question                                                                 | Students (%) | Faculty (%) |
|--------------------------------------------------------------------------|--------------|-------------|
| - Think that Clinical biochemistry is important for medical students     | 73           | 100         |
| - Think that the subject is difficult to learn                           | 43           | 60          |
| - Think that the subject is difficult to teach                           | 33           | 23          |
| - Prefer having more student-teacher interaction                         | 65           | 92          |
| **- Students enjoy attending lectures**                                  |              |             |
| Disagree                                                                | 47           | 15          |
| Agree                                                                   | 18           | 0           |
| Neutral                                                                 | 34           | 85          |
| - Think that students gain 30-60% of the information given in a lecture  | 44           | 54          |
| **- How much of the curriculum does a student memories without much understanding** |              |             |
| 100%                                                                    | 4            | 15          |
| 60-80%                                                                  | 18           | 15          |
| 30-60%                                                                  | 27           | 31          |
| < 30%                                                                   | 50           | 38          |
| **- How much of the curriculum does a student remember one year post exam** |              |             |
| 100%                                                                    | 1            | 0           |
| 60-80%                                                                  | 7            | 0           |
| 30-60%                                                                  | 42           | 30          |
| < 30%                                                                   | 49           | 70          |
The majority of students, 77%, did not have any knowledge on TBL, and 85% did not participate in any previous TBL activities. As expected, the faculty had more knowledge on TBL than students, with 62% responding to have knowledge on TBL, however, only 23% seemed to participate in previous TBL activities (Table 1). When studying the perspectives of students and faculty on TBL aspects, a clear discrepancy was seen between both groups. While 77% of the faculty believed that students enjoy working in teams, only 42% of students thought the same. Similarly, 70% of the faculty thought that students enjoy SDL, on the other hand, only 37% of the students believed so. A total of 85% of the faculty thought that students enjoy solving cases and having activities during their learning session, while 53% of students thought the same. The majority of both groups, faculty and students, believed that students only study when marks are involved, 85% and 53% respectively.

When asked on what is the biggest challenge for applying TBL, the majority of faculty (60%) believed that the biggest challenge is ensuring students' preparation. On the other hand students' responses seemed to be distributed among the provided challenges including creating the teams, designing TBL activities, preparing students assessments, students preparation, and students participation (Table 4) and (Fig. 2)

**Table 4. Student and faculty perspective on TBL**

| Question                                      | Students (%) | Faculty (%) |
|-----------------------------------------------|--------------|-------------|
| -Think that students enjoy working in teams   | 42           | 77          |

**Perspectives on TBL**

The majority of students, 77%, did not have any knowledge on TBL, and 85% did not participate in any previous TBL activities. As expected, the faculty had more knowledge on TBL than students, with 62% responding to have knowledge on TBL, however, only 23% seemed to participate in previous TBL activities (Table 1). When studying the perspectives of students and faculty on TBL aspects, a clear discrepancy was seen between both groups. While 77% of the faculty believed that students enjoy working in teams, only 42% of students thought the same. Similarly, 70% of the faculty thought that students enjoy SDL, on the other hand, only 37% of the students believed so. A total of 85% of the faculty thought that students enjoy solving cases and having activities during their learning session, while 53% of students thought the same. The majority of both groups, faculty and students, believed that students only study when marks are involved, 85% and 53% respectively.

When asked on what is the biggest challenge for applying TBL, the majority of faculty (60%) believed that the biggest challenge is ensuring students' preparation. On the other hand students' responses seemed to be distributed among the provided challenges including creating the teams, designing TBL activities, preparing students assessments, students preparation, and students participation (Table 4) and (Fig. 2)
-Think that students enjoy SDL  &  37  &  70  
-Think that students enjoy solving cases and doing activities during a session  &  53  &  85  
-Think that students only study when marks are involved  &  53  &  85  

| Challenges in TBL | Students | Faculty |
|-------------------|----------|---------|
| Creating the teams | 24       | 8       |
| Designing activities for the session | 19       | 31      |
| Developing questions for assessing students | 6        | 0       |
| Students preparation to sessions | 29       | 61      |
| Students participation in sessions | 21       | 0       |

**Figure 2. Students and faculty perspective as the biggest challenge for applying TBL**

**Discussion**

The teaching strategy at the FOM-KAU is mainly teacher-centered with approximately 90% of the teaching following this strategy. Lectures comprise the highest percentage among teaching methods (62%), while SDL has the lowest percentage (4%). In this study, we assessed second year medical students and the clinical biochemistry faculty perceptions on teaching and learning in clinical biochemistry and the concept of TBL. In general, both groups seemed to appreciate the need for more student-centered active method, and that students would enjoy solving problems cases and carrying out activities during their learning session. The majority of students acknowledge that they do not enjoy clinical biochemistry lectures, and the majority of faculty felt neutral towards the matter. However, there was a clear sense from the faculty that students tend to memorize the content without much understanding and can easily forget what they have learned after one-year post exam, which denotes that the current teaching methods do not enhance the mechanism of information processing and retention. In a study conducted by the Faculty of Medicine, King Saud University, in the academic year 2008-2009, only 19% of the
students revealed that they retained most of the information from the biochemistry course. The contribution of practical sessions in enhancing theoretical understanding was acknowledged by only (21%) of students participating in the study (Alam, 2011). This result is to a great extent similar to the results obtained from our current study regarding students’ perspective of retention of information.

For clinical biochemistry to play an effective role in the curriculum, and to be an enjoyable experience for medical students, it needs to be taught using a variety of methods which enables its basics to be applied, whether in learning more advanced concepts or in application to solve medical problems. Even though the traditional lecture has a benefit in communicating and organizing concepts and facts, the lack of applying this information to make a decision and act on it, however, is one of its shortcomings that prevents students from using an optimal entire-brain process (Zull & J, 2002). It is though that the temporal lobes, which process the information in our long-term memory, are not designed to postulate possibilities and make a logical choice among them. The prefrontal area on the other hand has the ability to resort to understood information to carry out the second task. An entire-brain approach can therefore result in a greatly efficient use of the entire brain in learning.

PBL and TBL modalities are two good examples of teaching methods which utilize group based problem solving to involve the entire brain including the limbic emotions that occur when people work in teams (Fatmi, Hartling, Hillier, Campbell, & Oswald, 2013; Neville, 2009). This approach has been realized in a study by Bransford, Brown and Cocking, as one of the important components for effective learning which was published by the National Research Council. (Bransford et al., 2000)

TBL is one of the learner-centered approaches that was developed by Larry Michaelsen and adapted to health care education in the last two decades (Johnson, 2009). In TBL the teacher acts as a facilitator by providing students with opportunities to expose knowledge gaps and allows integrating new information and skills that will eventually stimulate the development of new frameworks built upon previous knowledge. This approach is active in essence, and allows the students to use relevant problems and group interaction to address exposed knowledge gaps. According to Michaelson, TBL allows the students to recognize the need not only to learn but also to apply reasoning and skills gained through critical thinking.

The importance of TBL in applying reasoning skills and critical thinking appeared to be appreciated by both the faculty and the students in our study. When asked through an open-ended question on what could be the benefits of TBL, 25% of the faculty thought that the main benefit would rely on the more comprehensive understanding of the subject by the students and that the information learned would be better retained and applied. This was also reflected in some students’ answers in which eight of the 38 students replying to this question believed that the main benefit is the better understanding of the subject and more retention of knowledge.

When addressing competencies, the Canadian Medical Educational Directives for Specialists (CanMEDS) stated that health care providers should have a common set of competencies to meet the needs of their patients. These competencies revolve around several roles: medical expert, communicator, collaborator, manager, health advocate, scholar, and professional (Frank & Danoff, 2007). Similarly, the national framework of competencies, developed by medical schools in the Kingdom of Saudi Arabia known as, Saudi Meds, has included communication and collaboration as a main domain and competency needed to be acquired by all medical students (Zaini et al., 2011). In addition to TBL addressing critical thinking, if designed properly, it aims to encourage students to work effectively in a team (collaborator).

Theoretically, working with peers as in TBL should aim to improve students’ attitudes towards teamwork, but students who are successful academically may have more negative attitudes towards TBL and prefer to learn on their own (Espey, 2010). Interestingly, this was reflected in students’ responses regarding TBL disadvantages in our study.
Out of the 31 students responding, nine expressed their fears such as irresponsibility of some team members, internal conflicts between members, and side talks during the TBL sessions. It is therefore important for the Individual Readiness Assurance Test (IRAT) to be conducted in a manner that can fairly distinguish between students who prepared well and effectively, and those who did not.

In addition, students may become less enthusiastic about peer evaluation if they feel it is not fair. Thus, peer evaluation methods must be adjusted to increase fairness (Parmelee, DeStephen, & Borges, 2009).

In our study, both the faculty and students believed that students only study when graded. This is supported by studies that have showed that IRAT marks would externally motivate student to prepare (Koles, Nelson, Stolfi, Parmelee, & DeStephen, 2005). Indeed, one of the major concerns regarding TBL, from faculty members in this study, is students’ preparation.

Assigning marks on TBL tasks is therefore crucial to improve students’ enthusiasm and guarantee students’ preparation. At KAU, this might need the involvement of authorities beyond lecturers’ authorities and thus clear communication and agreement with all stakeholders is needed.

**Take Home Messages**

We believe that the current teaching methods of clinical biochemistry at the FOM-KAU needs to be modified. Introducing TBL, as an active student centered teaching method, could address some of the challenges accompanying teaching and learning of clinical biochemistry in the current situation. However, students’ concerns such as team work, and faculty concerns such as student preparation need to be addressed carefully with the participation of all stakeholders. Workshops to teach both students and faculty the elements of TBL would be of great benefit to address any concerns.

**Notes On Contributors**

**Aliaa Alamoudi, MD, PhD**, is an Assistant Professor in the Department of Clinical Biochemistry at King Abulaziz University (KAU). Dr. Alamoudi conceptualized and designed the study, acquired and interpreted the data, drafted the initial manuscript, revised the manuscript, and approved the final manuscript.

**Mohammed Hassanien, MD,JMHPE, CMCL-FAIMER**, is associate professor of Medical Education and Clinical biochemistry and currently the Director of Assessment Centre and member of Medical Education department in Fakeeh College for Medical Sciences (FCMS) Jeddah, Saudi Arabia.

**Lana Al Shawwa, PhD** is Associate Professor in the Department of Medical Education in the Faculty of Medicine at KAU. Dr. Al Shawwa contributed to the conceptualization and revision of the manuscript.

**Abdulhadi Bima, MD, PhD**, is an Assistant Professor in the Department of Clinical Biochemistry at King Abulaziz University (KAU) contributed in the revising and writing of the manuscript

**Hoda Gad, MD, PhD** , is an Associate Professor in the Department of Clinical Biochemistry at King Abulaziz University (KAU) contributed in the study design and interpretation of data
Ara Tekian, PhD, MHPE is Professor in the Department of Medical Education at the University of Illinois College of Medicine at Chicago. Dr. Tekian contributed to the conceptualization and revision of the manuscript.

Acknowledgements

The authors thank master program faculty members in Medical Education Department at KAU for their help in revising the study questionnaire. Also, authors would like to thank faculty members in Clinical Biochemistry Department, at College of Medicine, King Abdulaziz University and second and third year medical students for their support and help in collecting the required data of the current study.

Bibliography/References

Alam, A. (2011) How do medical students in their clinical years perceive basic sciences courses at King Saud University? Ann Saudi Med, 31(1), 58-61.  
https://doi.org/10.4103/0256-4947.75780

Bransford, J. D., Brown, A.L., Cocking, & R.R. (2000) How People Learn: Brain, Mind, Experience, and School. National Academy Press: Washington, D.C.

Burgess, A. W., McGregor, D. M., & Mellis, C. M. (2014) Applying established guidelines to team-based learning programs in medical schools: a systematic review. Acad Med, 89(4), 678-688.  
https://doi.org/10.1097/ACM.0000000000000162

Espey, M. (2010) Valuing teams: What influences student attitudes. NACTA Journal, 54(1), 31-40.

Fatmi, M., Hartling, L., Hillier, T., Campbell, S., & Oswald, A. E. (2013) The effectiveness of team-based learning on learning outcomes in health professions education: BEME Guide No. 30. Med Teach, 35(12), e1608-1624.  
https://doi.org/10.3109/0142159X.2013.849802

Finnerty, E. P., Chauvin, S., Bonaminio, G., Andrews, M., Carroll, R. G., & Pangaro, L. N. (2010) Flexner revisited: the role and value of the basic sciences in medical education. Acad Med, 85(2), 349-355.  
https://doi.org/10.1097/ACM.0b013e3181c88b09

Frank, J. R., & Danoff, D. (2007) The CanMEDS initiative: implementing an outcomes-based framework of physician competencies. Med Teach, 29(7), 642-647.  
https://doi.org/10.1080/01421590701746983

Hrynchak, P., & Batty, H. (2012) The educational theory basis of team-based learning. Med Teach, 34(10), 796-801.
Johnson, C. (2009) Team-Based Learning for Health Professions Education: A Guide to Using Small Groups for Improving Learning. J Chiropr Educ, 23(1), 47-48.

Koles, P., Nelson, S., Stolfi, A., Parmelee, D., & DeStephen, D (2005) Active learning in a year 2 pathology curriculum. Medical education, 39(10), 1045-1055.

Neville, A. J. (2009) Problem-based learning and medical education forty years on. A review of its effects on knowledge and clinical performance. Med Princ Pract, 18(1), 1-9.

Parmelee, D. X., DeStephen, D., & Borges, N. J. (2009) Medical students’ attitudes about team-based learning in a pre-clinical curriculum. Med Educ Online, 14(1), 1-7.

Phadtare, S., Abali, E., & Brodsky, B. (2013) Over the counter drugs (and dietary supplement) exercise: a team-based introduction to biochemistry for health professional students. Biochem Mol Biol Educ, 41(6), 384-387.

Sawatsky, A. P., Berlacher, K., & Granieri, R. (2014) Using an ACTIVE teaching format versus a standard lecture format for increasing resident interaction and knowledge achievement during noon conference: a prospective, controlled study. BMC Med Educ, 14, 129.

Seifert, S. G. C. J. W. P. W. E. (2011) The Role and Value of the Basic Sciences in Medical Education (with an Emphasis on Biochemistry). Medical Science Educator Volume 20(3), 3.

Svinicki, M. D (2004) Learning and motivation in the postsecondary classroom.

Zaini, R. G., Bin Abdulrahman, K. A., Al-Khotani, A. A., Al-Hayani, A. M., Al-Alwan, I. A., & Jastaniah, S. D. (2011) Saudi Meds: a competence specification for Saudi medical graduates. Med Teach, 33(7), 582-584.

Zull, & J. (2002) The art of changing the brain: Sterling, VA: Stylus Publishing, LLC.

Appendices

Declaration of Interest

The author has declared that there are no conflicts of interest.