

# Team-based learning versus traditional didactic lectures in teaching clinical biochemistry; learning outcomes and student satisfaction: a case control study at King Abdul Aziz University

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## Research article

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# Abstract

**Background:** Team-Based Learning (TBL) which encourages students to become active rather than passive learners has gained world-wide popularity in medical education due to its proven positive effect on more than one aspect of the educational process. At King Abdulaziz University (KAU), clinical biochemistry is still taught in the form of didactic lectures, and while there is a need for introducing active learning, student learning response from TBL has not been explored.

**Methods:** In our case-control study, we compared learning outcomes and student satisfaction in a clinical biochemistry course taught either via TBL to second year Clinical Nutrition students (n= 33) or via traditional lectures to same year Nursing students (n=70). The same summative post-course exam was given to both student groups to assess impact on learning. Focus group discussion and a self-administered questionnaire were used to gain insight into Clinical Nutrition students' level of satisfaction with TBL.

**Results:** In the post-course exam results of recall and reasoning questions, Nursing students scored an average of  $38\% \pm 2.4$  in the recall questions while Clinical Nutrition students scored higher with an average of  $74.5\% \pm 4.3$  ( $p < 0.0001$ ). In reasoning questions, Nursing students scored lower than Clinical Nutrition students,  $23\% \pm 2.7$  versus  $40\% \pm 4.2$  respectively ( $p < 0.001$ ). In comparing results of pre- and post-test recall questions within each group, there was no significant difference between pre- and post-results for Nursing students while Clinical Nutrition students showed a significant increase in post- versus pre-test results of  $71\%$  versus  $41\%$  ( $p < 0.0001$ ). In the final summative post-course exam, Nursing students scored an average of  $60\% \pm 2.4$  while Clinical Nutrition students scored significantly higher with an average of  $78\% \pm 2.4$  ( $p < 0.001$ ). Qualitative studies revealed that accountability and team-work were positive aspects perceived by students regarding TBL and 84% of surveyed students enjoyed the experience while self-study was their main challenge.

**Conclusion:** TBL proved to be a successful, learner-centered approach for Clinical Nutrition students at KAU in their clinical biochemistry course resulting in improved learning outcomes and higher student satisfaction when compared with traditional didactic methods of teaching.

## Background

Despite acknowledging its importance, many students find studying biochemistry difficult and tedious sometimes describing the courses as dull (1-3). This is our experience at the Faculties of Medicine and Applied Medical Sciences at King Abdulaziz University (KAU) where biochemistry which is still taught in the form of didactic lectures (2). Faculty members, students, and other stakeholders also acknowledge the need for a more comprehensive understanding of the subject by students and improved retainment and practical application of the information by applying new different teaching modalities.

Twenty years ago in his research, **Al-Gindan stated that there is a great need to** make the medical education curriculum more student-centered than teacher-centered in Saudi medical schools (4). Since then with the global shift of the role of the teacher to become a facilitator through the integration of the directed self-learning approach (Harden & Laidlaw 2012), and the international accreditation initiatives, and the need to

activate the student centered learning, many attempts are welcomed to increase awareness, access and participation of active learning across disciplines. Interactive learning in both formal and higher education, however, is still relatively new in application throughout the Middle East. Most of the students were not taught how to be interactive learners and to be actively engaged in the course material, or how to assess their own work and have a student-based learning experience with the teacher being a facilitator more than a teacher.

One of the active learning modalities currently used in KAU is problem-based learning (PBL), however, this teaching method is not utilized in the Applied Medical Sciences College in KAU. In addition, PBL, can be resourceful requiring a number of teaching rooms and a reasonable staff to students ratio (5-7).

Although originally developed by Larry Michaelsen for business students in the 1970s (8), team based learning (TBL) has gained great popularity in health care education in the last two decades. And indeed several universities in the USA and in other countries around the world have adopted TBL in their curriculums, and studies have proven positive outcomes on more than one aspect of the educational process (9). TBL has the advantages of small group teaching and learning, but unlike PBL, does not require a large number of tutors since one tutor can cover more than one group at a time (9, 10). Unlike traditional education, which focuses on the instructor, TBL aims to focus on the students, making them the center of the learning process, and aims to go beyond assuring that students are covering the content, and to focus more on students' ability to apply the knowledge they've learnt in solving problems (9, 11, 12).

According to Michaelsen four essential principles govern TBL, 1) Groups must be created carefully and managed 2) Students must become accountable for their work 3) Group activities must promote both learning and team development 4) Students must have frequent performance feedback.

Overall, seven core elements have been described by experts in the field, which ideally should be found in any TBL to maximize its benefit, and to ensure ultimate learner engagement. These are 1) team formation, 2) readiness assurance steps 3) immediate feedback, 4) the sequences of in-class problems, 5) the use of the 4S process, 6) an incentive structure, 7) peer review (11, 12).

In their review article, Patricia Hrynchak & Helen Batty, explore the educational theory basis of TBL and suggest the constructivist theory as a framework that applies to this teaching method (10).

According to the constructivist theory, knowledge is constructed by the learner through his/her own experiences. Learning depends on how knowledge is encoded, stored and transferred through reflection and asking questions. New experiences modify previous understandings, thus long-term memories are continuously being reconstructed in the minds of the learners. In their review , Patricia Yrynchak & Helen batty, demonstrate that TBL applies the main principles of constructivism. The teacher acts as a facilitator that sets the objectives and provides learning material, but more importantly designs tests and problem activities that can challenge previous held understanding and constructs. The TRAT and group activities allow students to compare their own understanding with the other members of the group, making therefore new experiences which develop their learning.

Although the TBL teaching method was introduced in the Middle East a few years ago, very limited studies on it are available. Only two studies have been conducted in KSA to describe the experience (13, 14) both of which were at the same university (Alfaisal) in Riyadh. Although both studies reported a favourable impression by the students and the study by Anwar et al. (2012) showed a correlation between TBL and improved final exam scores, however such scores were compared between different cohorts and thus different exams. To our knowledge, TBL has never been implemented at the Faculty of Medicine and/or Applied Medical Sciences at KAU and as of date there is a paucity of studies in Saudi Arabia evaluating the effect of its implementation on reasoning.

We have previously conducted a study on second year medical students (males and females) and faculty members of the Clinical biochemistry department in KAU to explore what are their perspectives towards introducing active learning teaching methods such as TBL (2). Alarmingly, 48% of students felt that the course was not enjoyable through lectures. When studying the student and teaching faculty perceptions on some of the TBL only 42% of students thought that they would enjoy working in teams. And only 37% of the students believed that they would enjoy self-directed learning. Most interestingly when asked on what do they think might be the biggest challenge for applying TBL, 60% of the faculty believed that the biggest challenge is ensuring students preparation. On the other hand, students' responses seemed to be distributed among the other challenges including; creating the teams, designing TBL activities, preparing students assessments, students' preparation, and students' participation. As a follow up on this study, we were pushed towards introduction TBL in some of the clinical biochemistry courses, and studying whether some of the concerns and challenges perceived by students and faculty are valid concerns given the educational culture in KSA. . This study comes in alignment with the efforts planned by the government of Saudi Arabia where shifts in policy and practice resources are taking place. A major educational aim stated in vision 2030 is to develop philosophy, policy and goals of curricula, means of development, mechanism activation and connecting all these means with the programs of teacher preparation and his professional development , this study will allow other universities to capitalize on the experience in order to develop their faculty and educational system.

## **Aim Of Study**

The main objectives of this study were to:

- Evaluate in a case control manner if active learning through TBL could increase short term knowledge retention, and reasoning in the clinical biochemistry course at KAU.
- Evaluate if active learning through TBL could increase students' satisfaction in the clinical biochemistry course at KAU.
- Describe the perception and attitude of students towards their TBL experience.
- Determine any challenges KAU students could face with implementation of TBL.

The results of this study could identify successful elements from the implementation of TBL and clarify any areas that would still need to be modified for other courses and other students in the medical and applied sciences fields.

## Methods

### Ethical approval

Ethical approval was obtained from the biomedical research ethical committee at the FOM, KAU. In addition students were given relevant information on the study and a verbal consent was obtained prior to any interviews. The IRB was approved as waiver of signed consent given that the research presents no more than minimal risk of harm to subjects and involves no procedures for which written consent is normally required

### Design and participants of the study

Second year full class Nursing students (n=70), Faculty of Nursing, second year Clinical Nutrition full class students (n=33), Faculty of Applied Medical Sciences, were all part of this study. Both groups of students received the same course of Clinical Biochemistry (BCHM 207), which covered basic cell metabolism, bioenergetics and molecular biology and which was given by the same teaching staff. In a case-control manner, the same tutor (Dr. Aliaa Alamoudi) taught the same Nucleic Acid (NA) section of the Clinical Biochemistry course to both groups of students. However, the Clinical Nutrition group of students were instructed in the form of a TBL session, while the Nursing students were instructed through traditional didactic lectures. The decision of which group to receive which teaching method was based on the logistics related to each faculty e.g. administration acceptance, and availability of classroom that can support the TBL session. Both groups consisted only of female students and of similar age, and there were no male students in either faculty, thus limiting some of the variables and differences that could have existed between female and male departments.

Both groups had successfully completed the same preparatory year, a requirement by the KSA Ministry of Education, before being considered eligible to continue their bachelor qualification studies starting the second year. In addition, both groups showed similar entry level grades for their second year.

To test and ensure the equity between both groups prior to the study, students were asked to submit at the beginning of their second bachelor studies year, their university entry exam scores of Qiyas which includes the General Aptitude Test (GAT) and the Scholastic Achievement Admission Test (SAAT), and the GPA of their preparatory year. A description of each of these tests and the students' entry exam scores is described below.

#### *Qiyas tests:*

. Two main tests are mainly given by the National Centre for Assessment Qiyas as entry exams : the GAT and SAAT.

The GAT is a 120- question test that uses mathematical and verbal skills.

According to Qiyas, scores are analyzed as follows:

Student's position	Test score
Top 5%	81 and above
Top 10%	78 and above
Top 20%	73 and above
Top 30%	70 and above
The average	65 and above
Lowest 30%	60 and below

The SAAT test on the other hand measures the overall achievement of students during their whole education journey in various subjects, and is scored out of 100.

### **NA section lectures**

The NA section of the biochemistry course was given to the control arm of this study (Nursing students) in the form of traditional lectures. The section was taught via five lectures and a tutorial, covering: NA structure, DNA replication, Gene transcription, Post-transcription modification and Gene translation. Each lecture was given as a 60-minute power-point presentation to the students by Dr. Aliaa Alamoudi , and consisted roughly of 30-40 slides. Each lecture started with the expected student learning outcomes, a video related to the topic, text, graphs, and some questions related to the topic addressed. Attendance was not taken from students, however, it was estimated to reach around 70%. All lectures were given in a lecture hall, which had a capacity of around 200 students and was furnished with audiovisual equipment. In addition, all lectures and material were made available to students on blackboard (a learning management system software) 10 days prior to giving the lectures, and remained on the software afterwards.

### **TBL session design:**

The Clinical Nutrition group of students on the other hand were instructed the NA part of the course via a single TBL session. A description of all the aspects of the TBL session is described in the sections below.

#### *TBL orientation workshop*

To ensure the readiness of the second year Clinical Nutrition students to be engaged in TBL, they attended a two-hour TBL orientation workshop. The students were first asked to reflect (in pairs) on the advantages and disadvantages of traditional lectures and their findings were then discussed amongst all of them. A video demonstrating the experience of TBL in other universities was then played. Afterwards, students were introduced (via a power-point presentation) to a detailed overview of TBL including: background, the pre-reading step, the Individual Readiness Assurance Test (IRAT), the Team Readiness Assurance Test (TRAT), scoring system, references, etc. Finally, students were asked to reflect on the anticipated advantages and disadvantages of introducing TBL and any queries from the students were addressed.

### *TBL Team formation:*

Second year Clinical Nutrition students were divided based on their previous two clinical biochemistry quizzes scores into 'A', 'B', and 'C' students. Students were then divided into six groups of 5-7 students per group with each group containing equal numbers of 'A', 'B', and 'C' students. The students were distributed to their teams prior to the TBL in-class session.

### *TBL Pre-class reading*

Prior to class, students were allocated compulsory readings and five power-point lectures. Each lecture was accompanied by the required student learning outcomes, detailed content, videos related to the topic, chapter of the required reference, and two to three assessment questions. This material was similar to the material provided for the Nursing students. All the material was uploaded on the blackboard online system ten days prior to the TBL in-class session. Students were informed that they could use the time slot allocated for their lecture time in the students' time table for their pre-class reading whether in class or at the campus library without any tutor supervision.

### *TBL in-class session*

TBL in-class session was conducted in two hours. The structure of the TBL in-class session was divided into the IRAT, TRAT, and problem-solving activities, similar to the classical TBL format (9, 11, 12, 15). The IRAT was given at the beginning of the session to assess the individual's knowledge of the pre-reading. The test was provided as 10 MCQs with four options to select the single best answer, and was given in 15 minutes. This was followed by the TRAT, in which the same test was repeated by the students in their teams in order to promote discussion and allow team-work in reaching the consensus. The TRAT was conducted in 30 minutes. Teams who answered correctly on their first attempt received 4 points, while those who answered correctly on second attempt received 2 points, and 1 point was given to those who answered correctly on their third attempt in each question. The TRAT test was given as a scratch-off form, which provided the students with the answers of each of the questions immediately. A small summary of the answers was provided by the tutor after the end of the TRAT, and explanation was provided to address any difficult questions. Although a formal appeal process was not provided, the discussion was opened to allow students to challenge answers and ask questions. The final 30 minutes of the TBL session was used in problem-solving activities by the team. The teams received three problem (case scenario) activities, allowing them to apply conceptual knowledge on relevant cases or scenarios that fit with the specialty of their studies. Each case scenario had four possible answer choices for the teams to select the best answer. All cases followed the standard '4S' framework in TBL (11, 12), in which all cases were a 'Significant problem', 'Same problem for all teams', 'Specific choice', and finally teams provided 'Simultaneous report'.

TBL marks were divided as follows: 2 marks for attendance, 5 marks for the IRAT, 5 marks for TRAT and 3 marks for the case activity. The overall TBL session score was calculated out of 15 marks and was considered as the third continuous assessment in the biochemistry course besides Quiz 1 (15 marks) and Quiz 2 (15 marks). Students were informed that the highest two marks out of the three assessments would be included as continuous assessment marks (30 marks) out of their total 100 marks in the course. .

### *Pre- and Post-course Test*

In order to ensure that both groups had a similar background in molecular biology before implementing our TBL experiment, a pre-course test was conducted for both groups. The test was in the form of 15 recall MCQs that covered basic information on the material, such as definitions, and basic concepts of gene expression in molecular biology, and was provided by a colleague member of the clinical biochemistry department to avoid any bias. The test was conducted by the Clinical Nutrition students prior to the start of the TBL workshop, and by the Nursing students prior to the beginning of their first NA lecture.

To evaluate whether TBL was able to produce improved student comprehension of the subject, and whether the learned information was better retained and applied, a post-course test was conducted for both groups. Similar to the pre-course test, the post-course test was a 15 MCQ test that had both recall (10 questions) and reasoning (5 questions) dimensions and was constructed by three colleague members of the clinical biochemistry department who were not involved with this study or any of the NA lectures or TBL design to avoid any bias.

The test was given to both groups as a pop quiz a week after the end of both the NA lectures and TBL. Thus there was a total of two weeks apart between the pre and post test in both groups.

### **Final Biochemistry (BHCM) course exam and NA section exam**

At the end of the term, both groups received a final summative exam made of a total of 60 MCQs based on a blue print covering all the term's BHCM course material (protein structure, enzymes, carbohydrate metabolism, lipid metabolism, amino acid metabolism and finally NA). The exam was a three-hour exam, in which students are allowed to submit their papers after one hour and a half. The same 9 NA MCQs were used in both exams and the scores of both groups in these 9 questions were then compared.

### **Focus group interview:**

One of the main aims of this study was to gain more insight into Saudi students' impression of the TBL experience, as there was not an abundance of pre-existing data regarding their experience with this method of teaching. We thought that understanding students' opinions, beliefs and disparities could help us in bridging the research results on TBL with its actual implementation in our curricula at KAU in the future thus facilitating a smoother transition.

Thus to explore the experience of students in depth, a sample of students, six students, were invited (after obtaining their verbal consent) to participate in a single semi-structured interview in a focus group meeting setting. The overall objective of the focus group meeting, the time and place, the intended themes for discussion, and the method of recording were all discussed with members of the medical Education Department prior to involving the students.

A purposive sampling of students was conducted based on the students' results in the TBL session. Students were divided into 3 categories according to their TBL session scores: high-scoring, average-scoring or low-scoring, and two students were chosen randomly from each of these categories. All students were

invited verbally to attend the focus group discussion after describing to them the main objectives of the discussion.

The focus group discussion was conducted at the Medical Education Department in the presence of Dr Aliaa Alamoudi and Dr Lana Alshawwa. The aim of the focus group discussion was first explained to the students and included:

- 1) Knowing about their experience in TBL
- 2) Guidance in conducting the student survey

Verbal consent was taken from all students to record them. The semi-structured interview consisted of a set of pre-defined open-ended questions which addressed the students' overall level of satisfaction with the TBL experience, the advantages and challenges of TBL in their opinion and whether the experience changed the way they studied.

Based on the students' response to these pre-defined questions, the interviewers were able to diverge to pursue an idea in greater detail. Students were allowed to express their thoughts in Arabic or English. However, most of the interview was conducted in Arabic.

### **TBL Survey.**

To evaluate all the Clinical Nutrition students' (n=33) perspectives on their TBL experience a 34-question on-line survey with an additional three, open-ended questions was constructed based on themes that emerged from the earlier focus group meeting discussion. The survey questions were revised by local and national experts in medical education. To ensure the clarity of the survey content and to ensure its validity, it was first tested out by a small focus group of students before being distributed to all participants via email. The survey was divided into sections as described in Table 1.

Table 1.

### **Data and Statistical analysis**

Exams scores were analysed and presented as mean  $\pm$  SD using GraphPad Prism version 5.00 for Windows, GraphPad Software, La Jolla California USA. Students' T test was used for testing the significance. A value of  $p < 0.05$  was taken as a cut-off value for significance. Qualitative data analysis was done through classification, determination of themes, and linking to present literature. The process began with identifying the main themes stemming from the research questions. A list of questions were prepared as guidance for the focus group discussion session. The basis of the questions were the research questions. Grounded theory analysis was conducted where data coding was accomplished in two stages. The first stage involved the generation of numerous category codes without limiting the number of codes where we listed the emerging ideas. Keywords that were frequently mentioned during the focus group discussions were also recorded and considered as indicators of emerging themes. The second stage involved focused coding.

Where we combined and eliminated the coding categories identified in the first stage, during this step we were trying to find wider themes connecting the codes.

## Results

### Comparing entry exam scores for Clinical Nutrition and Nursing students

When comparing GAT scores between the Clinical Nutrition and Nursing students, we could see that both groups fell in the Top 5% with a mean of 84.4% and 81% respectively ( $p < 0.001$ ) (Fig.1).

When comparing SAAT scores between the two groups, the Clinical Nutrition students scored  $87.5\% \pm 0.8$  and the Nursing students scored  $84.3\% \pm 0.5$  respectively ( $p < 0.001$ ) (Fig.1).

In this study, both groups showed a close GPA mean, with Clinical Nutrition students scoring  $4.96 \pm 0.007$ , while Nursing students scored  $4.86 \pm 0.008$  (Fig.1).

### Comparing Pre-Post course NA test results between Clinical Nutrition and Nursing students

There was no significant difference between the results of each group of students in the pre-course test ( $t = 1.129, df = 127$ ). However, the Nursing students showed a higher percentage mean of  $46\% \pm 2.4$  compared to  $41\% \pm 2$  for Clinical Nutrition students (Fig. 2). Overall this indicated that both groups showed similar basic knowledge on NA topics.

As mentioned earlier, the post-course test was a 15 MCQ test that had both recall and reasoning dimensions. Nursing students scored an average of  $38\% \pm 2.4$  in the recall questions while Clinical Nutrition students scored an average of  $74.5\% \pm 4.3$  ( $t = 7.8, df = 90, p < 0.0001$ ). Similarly, Nursing students showed a lower percentage in the reasoning questions  $23\% \pm 2.7$  compared to  $40\% \pm 4.2$  for Clinical Nutrition students ( $t = 3.44, df = 90, p < 0.001$ ) indicating that TBL did enhance the retention of knowledge and resulted in better understanding of the material (Fig.2). When analyzing the effect size of TBL, a Cohen's  $d = 10.3, r = 0.98$  for the recall section, and Cohen's  $d = 4.8, r = 0.92$  for the reasoning section was seen.

### Pre- and Post-course NA test results for Clinical Nutrition and Nursing students

To further evaluate the effect of TBL, pre- and post-test (recall sections) results were compared within each group. While there was no significant increase in post-test results for Nursing students with a mean of 38% compared to 47% for their pre-test results, Clinical Nutrition students showed a significant increase in their post-test results with a mean of 71 % compared to 41% for their pre-test results ( $p < 0.0001$ ) (Fig.3).

### NA final exam results for Clinical Nutrition and Nursing students

To further evaluate whether TBL had enabled students to acquire factual knowledge of the course and achieve better understanding of the material, we compared the results of both groups in the final exam's NA questions.

While Nursing students scored an average of 60%  $\pm$ 2.4 in these questions, Clinical Nutrition students achieved a significantly higher score, with an average of 78% $\pm$ 2.4 ( $t=3.9, df=146, p<0.001$ ) (Fig.4). A Cohen's  $d= 7.5, r=0.96$  was also seen with TBL implementation.

## **Clinical Nutrition students' perspective on TBL experience and results of the focus group discussion**

The six students were first asked about their overall impression on the TBL experience. The group agreed that it was a very good experience and concept, which enhanced their ability to depend on themselves in studying. All of the members of the group stated that they enjoyed specifically the TRAT.

The group was then asked specifically if they could pinpoint why they thought it was a good experience. Five main themes emerged from their responses: 1- variety of learning material, 2- team-solving discussion, 3- accountability and self- directed learning (SDL), 4- grade distribution, 5- preparation for final exam.

To further elaborate, students felt that they were not confined or limited in the material from which they could study. They liked the fact that accessing the educational video-links sent to them by the instructor led them to access and watch other interesting, beneficial, educational videos. The fact that the original educational videos were selected and made available by the instructor herself, made the students feel comfortable and confident of the usefulness and trustworthiness of the resources; something which they were not sure of when they chose their resources alone.

All students agreed that the team-solving discussion was an excellent experience, and they felt that there was more retention of knowledge stemming from this exercise. Peer-to-peer discussions provided them the opportunity of sharing information amongst themselves in a simplified manner. When asked specifically if this team activity helped them connect more with their classmates, students expressed that the TBL session led to them knowing their other classmates better, an opportunity which might not have been provided otherwise, and that all-in-all they enjoyed working in teams.

The third point that emerged from the group discussion was accountability and responsibility. All students agreed that they felt a great sense of responsibility and trust towards their team members during the TBL's TRAT. Although some students acknowledged the importance of self-directed and independent learning and thought it was one of the advantages of the TBL, others felt that it was a difficult process for the students and could be one of the drawbacks of TBL for them.

One of the interesting points that emerged from the focus group discussion was grade distribution. Students felt pleased that there was more flexibility with the grading distribution since the marks were divided between the IRAT, TRAT, and group activity. In addition, students enjoyed the fact that the TBL's TRAT gave them more than one chance to try to answer correctly and still get marks. They also felt that the TBL gave them the opportunity to enhance their marks without actually being under the pressure of a summative exam.

Finally, students felt that the TBL prepared them better for the NA section of the exam course, that they understood the material well and that they needed less time to study before the final exam.

The group was then asked to reflect on the challenges and/or disadvantages they experienced during the experience. Two main points emerged from the discussion. First, students stated that, at times, it was difficult to study and understand the material on their own. Most of the group agreed that they would have preferred additional texts to explain the material.

Second, students sensed that there was limited time to prepare for the TBL, especially since it was conducted at the end of the academic term. The group was asked on how they utilized their material preparation time slots set in the time-table. Students replied that unfortunately the time slots weren't used for material preparation, but rather utilized by tutors for other subjects to be able to finish any remaining curriculum before the end of term. They felt that this occurred mainly because there was no supervision from tutors during these preparation sessions. Thus, all the studying and learning related to preparation for TBL was done at home after class hours, which they felt was an extra load on them. Also, one student commented that the time allotted to do the IRAT was too short while another stated that the activity cases were difficult with a lot of depth and perhaps above their level.

When the students were asked about their preparation for the TBL session and whether they understood in general what was required from them, they all agreed that the objectives, videos, and word document containing detailed content for each lecture were very clear for them and that they came away from the TBL workshop understanding exactly what was expected of them. When asked if they studied the material on their own or in groups, they replied that some students studied the material in groups while others studied on their own. They also mentioned that a Whatsapp group was started and that gave them the opportunity to discuss difficult or unclear points amongst themselves. However, one student mentioned that she couldn't predict how the IRAT would be and that although she felt that she had studied hard assuming she would be able to achieve a full mark in the test, in the end she didn't.

When the students were asked how the preparation could be improved, students replied that giving them the material in advance from the beginning of the term could help, and that some sort of a formative exam before the IRAT and the application cases would be useful to prepare them for the questions.

For the sake of the future implementation of TBL, we asked students if they had used or would in the future use TBL as a method of learning or studying in other courses. They stated that so far they had not had a chance to use it since they were introduced to it was towards the end of the term. However, they thought that they would use it for other courses in the future since they found it to be a very valuable and good experience which increased their ability and confidence to study on their own. One student mentioned that she would implement it, but that she would need to understand the way to study and what the nature of the questions would be. Another student stated that the students were bored of conventional ways of teaching and spoon-feeding, and that she would recommend that TBL be introduced at least once a term after which students could decide whether they wanted to continue with TBL or not. When asked which parts of the TBL the students felt they would adopt for their learning methods, they agreed that it was team-solving activities and using educational material such as watching videos.

The final part of this group discussion focused on attitudes and beliefs. Upon asking students if they believed in the value of team-work, all of them agreed on its importance.

We also asked the students if this TBL experience had changed anything in the way they studied and the phrase "depth of learning" was mentioned several times by most of the group members wherein students agreed that TBL made them understand the importance of understanding the material in depth and that they needed to allocate more study time to achieve this.

Finally, we asked the students if they felt that they retained the knowledge learnt with the TBL experience more than with the conventional teaching technique. Most students replied affirmatively saying that they still remembered some of the information from watching the videos and from the team discussion. Only one student said that she couldn't recall the information she had learnt but she said it was because she hadn't studied very well.

At the end of the group discussion, students were thanked for their contribution, and were commended for their courage in participating in this new experience.

## **Clinical Nutrition students' perspective on TBL experience**

To explore the perspectives of all the Clinical Nutrition students towards the whole TBL experience, we conducted a survey that covered points that had emerged from the focus group discussion. Survey results are summarized in Table 2. Overall 84% of students stated that they enjoyed their TBL experience with 69% finding it to be more fun and 58% finding it to be more beneficial than lectures. 68% of the students stated that they would like to repeat the experience. Notably, all the students (100%) enjoyed solving problems together in teams. As expected, a high percentage of students (84%) stated that they enjoyed watching related video materials and 68% found that they understood better with peer-teaching. Interestingly, though, while 64% felt like they remembered the information more with TBL than with lectures, only 31% felt they understood the material better with TBL. 95% of the students preferred to have had supervised and scheduled sessions in the time-table for material preparation, and a high percentage (89%) preferred to have received the material earlier.

## **Discussion**

In this case-control study we introduced the first applied TBL model in the faculty of Applied Medical Sciences in KAU aiming to evaluate whether the TBL experience could enhance reasoning, improve knowledge retention and increase student enjoyment in Clinical Biochemistry courses.

In our study we found that TBL can be an effective instructional method that improved Clinical Nutrition students' performance on examination when compared to Nursing students' who received didactic lectures. Learning outcomes is one of the most commonly studied aspects of TBL (9, 16). However, as described previously, most of the studies on TBL have been conducted in the USA. In addition, a very limited number of studies have been conducted addressing the benefits of TBL for students who are not studying medicine (9, 16).

A few studies have shown that TBL had a positive effect on student examination performance. For example, 2<sup>nd</sup> year Medical students in Wright State University achieved higher scores on examination questions

related to content introduced via TBL than on content introduced by other methods (17). Similarly, TBL was more effective than small-group teaching in the achievement of knowledge objectives of three clinical topics in a clinical clerkship (18).

Interestingly, several studies have shown that TBL can better benefit students with lower academic performance than those with higher academic performance (17, 19).

Many aspects in TBL can explain the demonstrated improvement in learning outcomes. First of all, IRAT exams motivate students to come well-prepared and to read the material beforehand. During team discussions in TRAT and application cases, any gaps of knowledge can be exposed, and peers explaining to their team members can help minimize these gaps. In addition, the immediate availability of correct answers during the TRAT can help faculty to quickly detect difficult concepts and to clarify the; something which is not guaranteed to occur during traditional lectures. For teams to reach consensus during TRAT and application activities, the students need to learn how to listen to each other, communicate, and negotiate. This ultimately makes them more engaged with their material (17). All these elements fulfill Michaelsen's conceptual framework in which learners' engagement lies at the core of the educational process (8).

However, when reflecting on the positive results seen in our study it is worth mentioning that despite the close similarities between Clinical Nutrition and Nursing students in many aspects in our study, they are not identical. There remains to be variables that can interfere with the results for example; other courses given to the students, the level of motivation in each group, in addition to the different scores in entry levels of GAT and SAAT, all of which might impact the results.

The impact of TBL on the students' engagement in this study was reflected in the students' recorded perceptions during the focus group discussion. Students reported that during team discussions many learning gaps were exposed and that they found it easier to comprehend from a peer explaining the material (since they used simpler terminology) than if a teacher had explained. This fits with the cognitive congruence hypothesis in peer teaching, in which it is believed that the closer the level of knowledge a teacher has with the students (i.e congruence) the more effective the teacher is (20). In this setting, the peer teacher understands and relates more to the difficulties that other student peers face, and thus can explain hard concepts in a manner that peers can grasp. (20).

In our study it was clear that elements that can motivate students would help in the success of the experience. Students stated that they were very motivated to do well in the TBL session as they knew that the TBL grade could be included in the best two of three grades in place of one of the two quizzes they'd taken previously. This indicated that the timing of introducing TBL could be an important factor that could help motivate students to actively engage in it. In addition it would be important not just to set time slots during the time table for students to read the TBL material and prepare, but equally important would be that these time slots be under the supervision of the instructors or facilitators to ensure that they are used solely for this purpose.

Students agreed that one of the main challenges was the difficulty of studying the material on their own especially that they felt there was limited time to study. This was consistent with our previous study which

showed that the faculty perceived students' preparation would be the biggest challenge for applying TBL (2). There are different forms of active learning that not only ensure students' engagement but help to effectively prepare students with skills useful for their future careers. Self directed learning (SDL) for example, was described by Kowles as a process led by the individual which includes identifying their learning needs, setting a plan to achieve it, and evaluating and measuring their own learning outcomes (21). In a culture in which students have not been exposed to being in charge of their own learning process, extra support and resources might be required to implement active learning, including SDL. It might be important, therefore, to have lectures that introduce students to the concepts and models of active learning before formally implementing TBL. Instructors might specifically need to fulfill the role of coaches to help students in this process (21). Students need to be guided on how to select educational resources they think they need to fulfill their learning objectives and also on ways to measure their learning outcomes.

Team-work is a core element in TBL. Students start appreciating that by working in teams, they develop better chances for achieving higher marks in TRAT and in application cases (22). However, the literature is controversial on the effect of TBL on students' perceptions on team-work. While some studies have shown that students' perception of team-work improved significantly after TBL (23), other studies have shown that there was little or no change (15, 24). However, most of the studies have relied purely on student self-reporting. Given the impact TBL can have on a wide range of skills other than those usually measured, such as the ability to resolve conflicts, negotiate with others, and work in a team, further objective ways to measure these skills will be needed.

One of the key elements of a successful TBL is incorporating an application exercise that can promote critical thinking and ensure students' engagement. Application exercises are often considered the most challenging aspects of TBL. A useful way to achieve this is to use the backward design when designing the course, and the application exercises. The instructor should think about what skills and knowledge their students should acquire and have by the end of the course and accordingly create exercises with practical problems that the students could encounter in their lives as health professionals. It is therefore not enough to ask what information should Clinical Nutrition students know about molecular biology, but also why would they need to know it, and how would it help them in their future career. Ideally, the designing of beneficial application exercises would entail proper engagement from various departments and/or different stakeholders and would require more time and a clear cooperation process which would require the support of senior administration (heads of departments, vice-deans, and deans).

Assignments not only need to promote learning but to also ensure in-depth group interaction which assures students' engagement. Very importantly, the assignments should enhance critical thinking, analysing and high-order thinking as described in Bloom's revised taxonomy (Michaelsen and Sweet 2008). What could contribute to this is the evoking of interactive discussions between students by providing assignments with a set of various solutions each of which could be plausible to an extent.

It is therefore crucial to ensure that the staff designing the TBL can develop effective assignments and discern between effective versus ineffective ones. It is essential that training workshops addressing specifically this important aspect of TBL are conducted for faculty members.

Although we attempted to limit as much as possible the variables between the two cohort of students in our study by selecting students in their same study year (2<sup>nd</sup> year bachelor studies), by having the same tutor teach the same NA material, and by giving the same set of post-course questions to both groups, however, the existence of other variables could have limited the validity of the results of this study. For example, other courses being taught simultaneously to the students, other tutors teaching them, and the overall motivation and morale of each group.

## Conclusions

TBL proved to be a successful, learner-centered approach for Clinical Nutrition students at KAU in their biochemistry course resulting in improved learning outcomes and higher student satisfaction when compared with traditional didactic methods of teaching.

Accountability and team-work were two main positive aspects of TBL perceived by students in this study in alignment with Parmelee and Michaelson's (2010) framework for TBL. The ability to self-study was the biggest challenge students faced in implementing TBL and preparing the students well prior to the TBL was a key element for the success of the experience.

**In the future, TBL can be introduced as an alternative teaching modality in the Faculty of Medicine and Applied sciences in KAU to overcome some of the disadvantages of didactic lectures and to enhance students' engagement. TBL would be especially appealing in settings in which there are challenges (such as the need for high faculty/student ratio, the need for multiple teaching rooms, and the short duration of some courses) that preclude the implementation of other group-teaching methods. Overall we believe that the following can be the main recommendations of this study:**

- Introduction of practical, hands-on TBL workshops for faculty members and students is important and recommended to educate them on the important aspects and procedures required to successfully implement TBL.
- University stakeholders should invest in teaching students self-directed learning skills as this can motivate them in enhancing their confidence to study on their own and in overcoming any fears or doubts they may have when exposed to new active-learning teaching modalities.
- A multidisciplinary approach should be used when designing the courses and application cases in TBL to ensure that applicable and relevant material is introduced to students, and that the cases represent real-life problems which they could face in their future career.
- Workshops on effective application assignment design using the '4S' principle should be conducted for teachers of TBL.

# Declarations

## Ethics approval and consent to participate

Ethical approval was obtained from the Biomedical Research Ethical Committee at the Faculty of Medicine (FOM) at KAU. In addition, students were given relevant information on the study and verbal consent was obtained prior to any interviews.

## Consent for publication

A recorded verbal consent was obtained from participating students prior to focused group discussion. Recorded verbal consent is available from corresponding author upon request.

## Availability of data and material

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

## Competing interests

The authors declare that they have no competing interests.

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# Authors' contributions

**AA, MD, PhD**, conceptualized and designed the study, acquired and interpreted the data, drafted the initial manuscript, revised the manuscript, and approved the final manuscript.

**LA, PhD**, contributed to the conceptualization and revision of the manuscript conducting and analyzing focused group data.

**HG, PhD**, contributed in designing the TBL for the study and in interpreting the data.

**AT, PhD**, contributed to the conceptualization and revision of the manuscript

# Abbreviations

KAU : King Abdulaziz University

TBL: Team-Based Learning

KSA: Kingdom of Saudi Arabia

PBL: Problem-Based Learning

MCQ : Multiple Choice Question

IRAT: Individual Readiness Assurance test

TRAT: Team Readiness Assurance test

SDL: Self-Directed Learning

NA: Nucleic Acid

GAT: General Aptitude Test

SAAT: Scholastic Achievement Admission Test

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## Tables

**Table 1. Clinical nutrition students' TBL experience survey**

Section	NO of Questions
Overall experience	4
Setup	5
Advantages	13
Disadvantages	5
Future implementation	5
Attitude and beliefs	2
Open ended questions	3

**Table 2. Clinical nutrition students' perspective on TBL experience**

	<b>% Strongly agree/agree</b>	<b>% Strongly disagree/disagree</b>	<b>%Neutral</b>
Enjoyed TBL experience	84	0	16
TBL more fun than lectures	69	5	26
TBL more beneficial than lectures	58	21	21
Like to repeat the experience	68	11	21
TBL steps were clear	79	5	16
Objectives and given material were clear	100	0	0
Preferred to have more material explanation in PPT	74	5	21
Preferred to have a formative exam prior to TBL session	72	17	11
Preferred to receive material earlier	89	11	0
Enjoyed solving together in teams	100	0	0
Enjoyed studying together in teams	73	16	11
Enjoyed having different material to study from	69	5	26
Enjoyed watching video material	84	5	11
Enjoyed self studying	58	26	16
Understood more with peer teaching	68	21	11
Felt like you understood material more with TBL than lectures	31	37	32
Felt like you remembered the information more with TBL than with lectures	63	11	26
TBL taught you how to depend on yourself in studying	84	5	11
TBL helped you study more deeply	74	5	21
TBL helped you be prepared for your final exam	52	11	37
Mark distribution of TBL was good	73	11	16
TBL helped you know your classmates better	89	0	11
Felt it was difficult to study the material on your own	47	16	37
Needed more time to prepare for the material	79	21	0
Felt that there was not enough time for IRAT test	58	10	32
Felt that the IRAT represented the material you studied	67	5	28
Preferred to have supervised and scheduled sessions in time table for material preparation	95	0	5
Would use this method in other courses	69	15	16
Recommend TBL to other students	74	11	16
Like to have TBL as part of every course	42	31	26
Believe in team-work	78	11	11
TBL changed the way you now study	42	21	37

## Figures

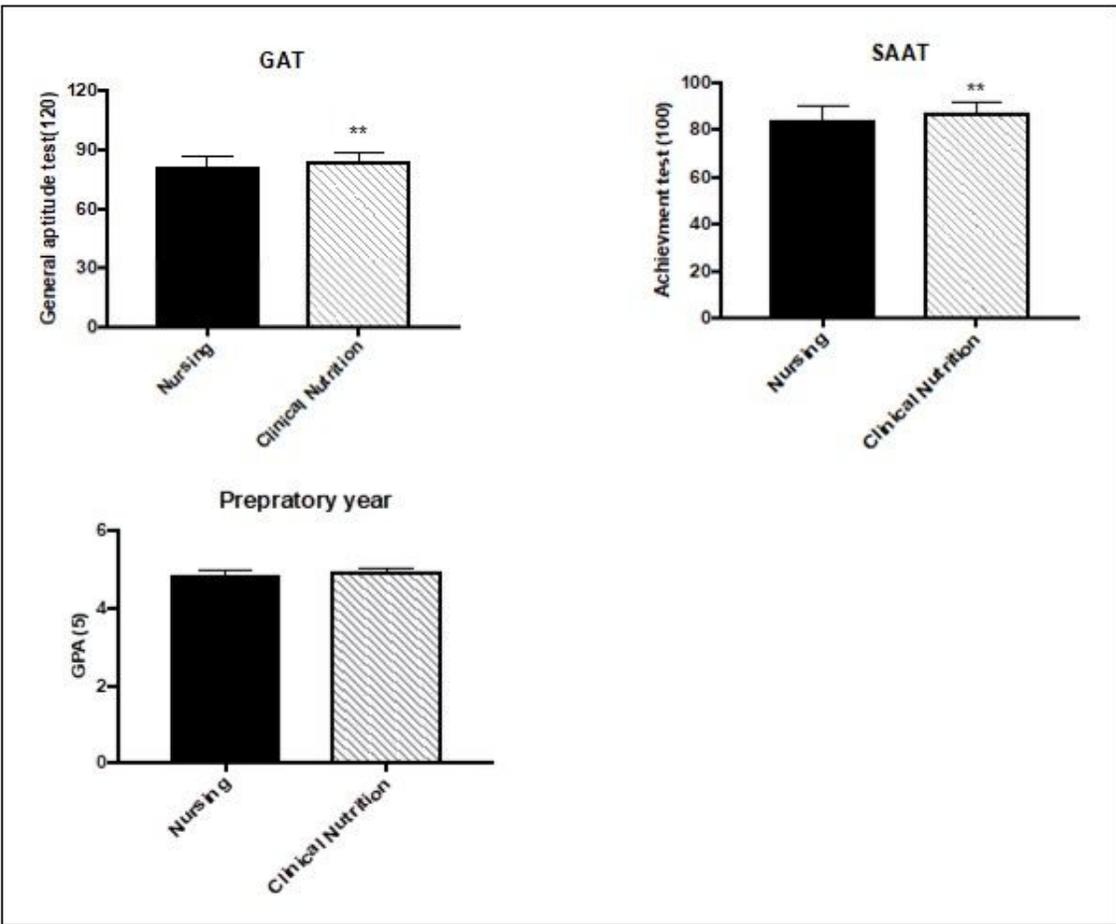
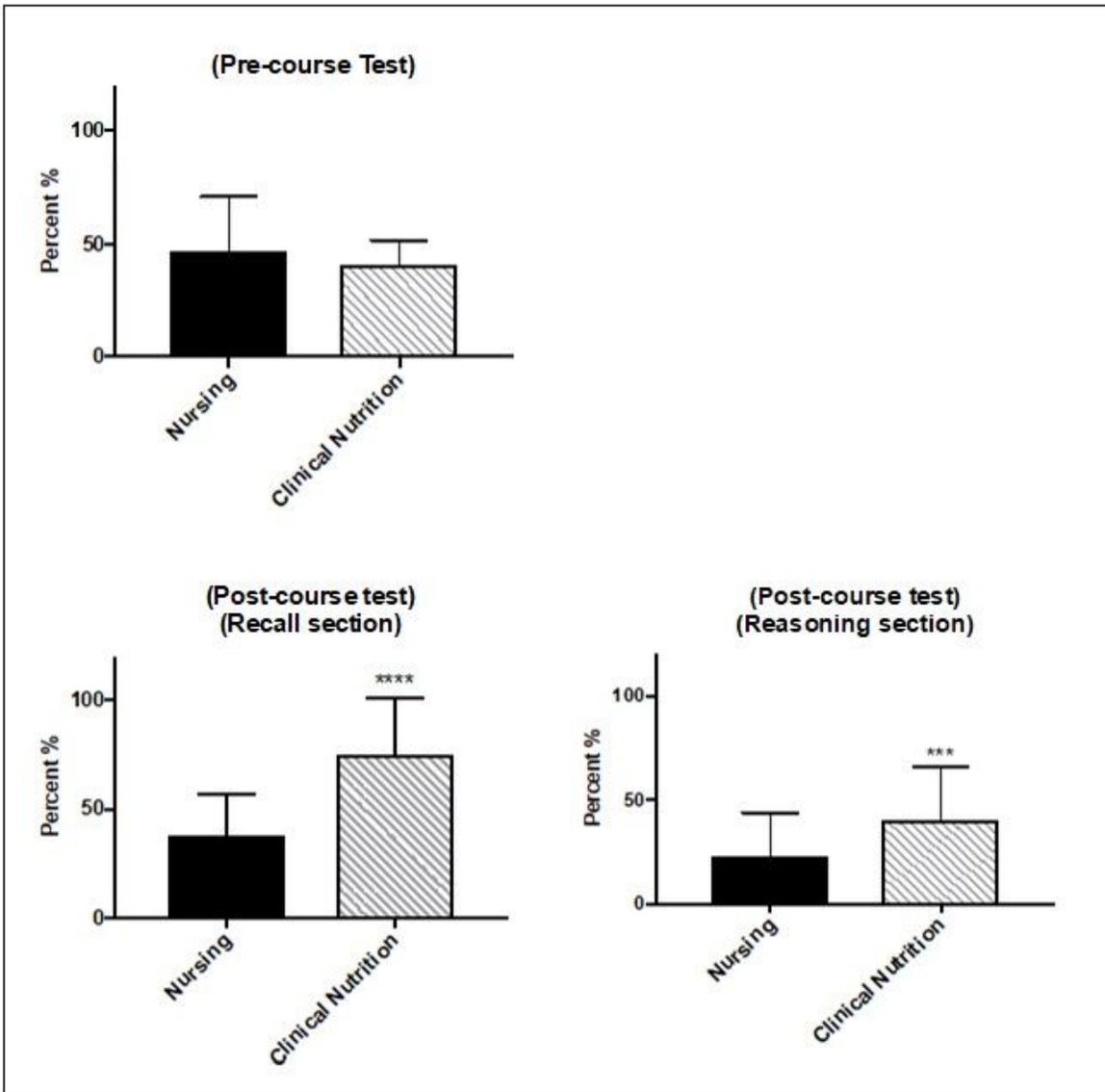


Figure 1

Comparing entry exam scores for Clinical Nutrition and Nursing students



**Figure 2**

Comparing Pre and Post course test results for Clinical Nutrition and Nursing students

**Figure 3. Comparing Pre and Post course test results within each group**

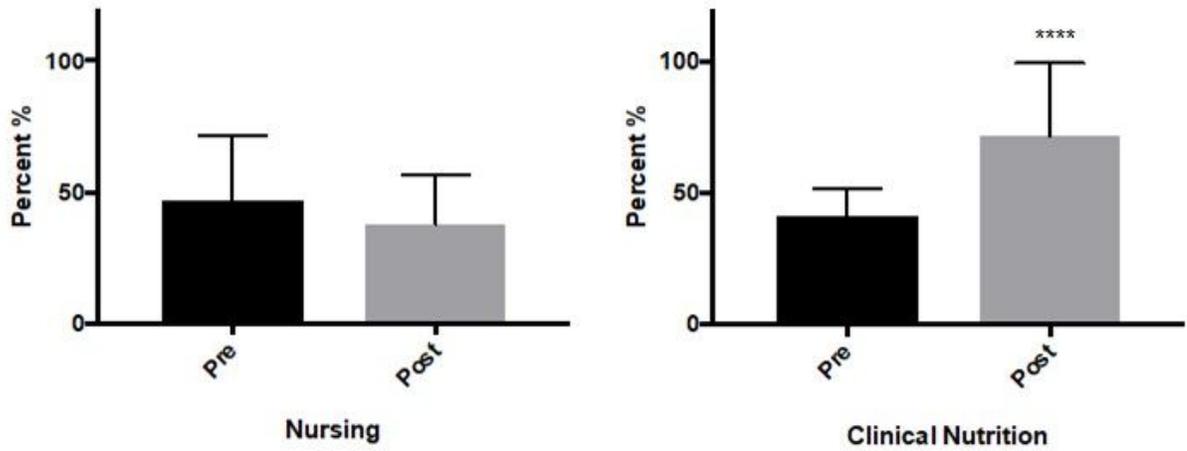
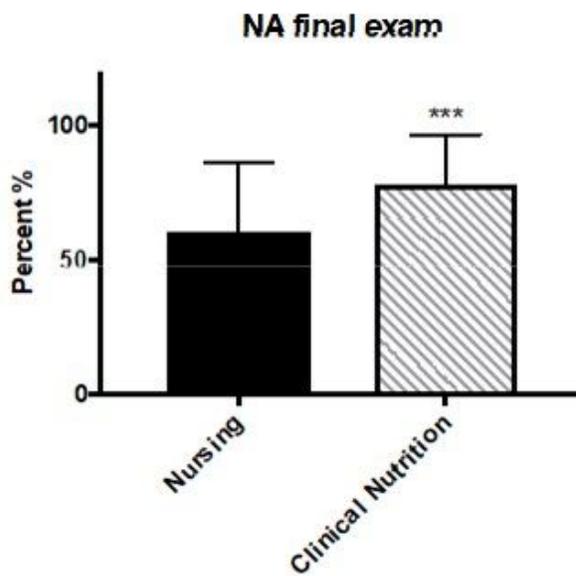


Figure 3

Comparing Pre and Post course test results within each group

**Figure 4. Comparing NA final test results for Clinical Nutrition and Nursing students**



## Figure 4

Comparing NA final test results for Clinical Nutrition and Nursing students