CASE-BASED TEACHING AND ITS EFFECT ON STUDENTS' CRITICAL THINKING

Reynante E. Autida
Western Mindanao State University, Baliwasan, Normal Rd., Zamboanga City, Philippines.
Contact: rey.autida@gmail.com

ABSTRACT: *Law, business, and medical schools widely use Case-Based Teaching (CBT). However, only a few have delved on the use of CBT in the physical sciences, chemistry education, in particular. Moreover, the number of studies on the effect of CBT on critical thinking is limited.*

In this current study, the researcher determined the effect of CBT on critical thinking. Two groups of classes are used to determine the effect of CBT on undergraduate students in one of the State Universities in Mindanao, Philippines. The type of teaching approach (CBT versus lecture-discussion teaching or LDT) serves as the independent variable, while the critical thinking test scores serve as the dependent variable.

The data are analyzed using t-tests (within and between groups) to compare the effects of CBT versus LDT on students' critical thinking. Results show inconclusive findings on whether or not CBT improves critical thinking of students.

The effect of CBT on critical thinking, such as teacher factor effect, student factor effect, duration of CBT implementation, case topic, and quality of educational materials used, are recommended.

INTRODUCTION

The chemistry classroom is an excellent venue where students learn chemistry concepts and principles. Moreover, it also provides an opportunity for students to understand better and appreciate related fields. However, the teaching approach used in the classroom influences student learning.

The conventional approach in teaching is through a series of didactic lectures or chalk and talk approach. The teacher provides information and introduces new materials through expository and explanatory statements. Teaching here is done *deductively*.

An alternative teaching/learning approach is the *inductive* method. Here, the approach is from the specific to general principles. In the inductive method, the students' role shifts from being passive in the conventional approach to being active in learning.

In this study, the researcher uses Case-Based Teaching (CBT) as one of the forms of the inductive method. There appears to be limited knowledge of the effect of CBT on critical thinking, especially in the chemistry education curriculum. Thus, the study aims to use CBT and to determine its effect on students' critical thinking. This study was also conducted to provide additional knowledge on this topic and also to suggest a possible model for use, research, and development on the said variables in chemistry education.

Literature Review

Teachers traditionally used Case-Based Teaching (CBT) in business, law, and medical schools. Harvard University has developed business and law case studies over one hundred years ago [1]. Their case studies have storylines that also present real-world problems that students would encounter once they graduate from the program. The students, through the case studies, are presented with dilemmas that need to be solved. These case studies are taught using classroom discussions. James B. Conant, a Harvard science educator, tried and developed an entire course around the case-based teaching technique [2]. However, Conant presented his cases all in a lecture format. This method appears to be defeating the purpose of using case studies, so not surprisingly, Conant's model did not survive him, and others who may have tried the technique are not widely known.

Meanwhile, McMaster University's Medical School used the case studies in teaching in the 1970s with a unique approach – they created the so-called Problem-based Learning (PBL) [1]. In the PBL that they used, the teacher serves as a facilitator and assigns students to small groups. The students are provided with limited information about a patient's medical problem and based on their agreed workload in the group, and the students have to look for additional sources about the case. The students then meet again to share their findings and required to come up with a conclusion regarding the case.

In 1990, the State University of New York, USA, proceeded to include case studies in their science education curriculum [2]. The students use case studies as the primary material of a course; as a component of courses where the historical story is presented and; as a non-regular material in biology lecture and laboratory courses. What they have drawn from their experiences are as follows: the case method involves learning by doing, the case method is appealing to students (95% attendance in CBT compared to 50-65% attendance in regular lecture courses), and faculty has to learn writing and to teach cases. Moreover, dissemination is needed to have maximum access to materials, and the presentation of the case method is "extraordinarily flexible."

Case Studies

Case studies are usually composed of narrative accounts of a real or imagined person or organization confronting a problem that needs to be solved. Depending on its form, the details of the information provided to the student may vary. The teacher provides the students with all the information, or at the other extreme, the teacher provides very little information, and the students are required to search the literature.

According to Cox [3], case studies represent real or true-to-life experiences or situations. It is a model with scenarios taken from the real world. Most cases are personal accounts of an individual or institution confronted with a dilemma. Students then examine the facts, analyze the problem, and as a team, suggest viable solutions. Research shows that using case studies results in significant improvement in student performance on exams and high-order thinking skills [4, 5].

Clydee Freeman Herreid, a contemporary author of case studies and a strong advocate of CBT, defines a case study as a story with an educational method [6]. He adds that one can tell a story in different ways. In the past, most case studies are focused on the discussion mode of teaching cases. Herreid

[2], however, presented different modes of teaching cases. In all of these different modes of teaching cases, the typical approach is that the objectives are clearly in mind, the teacher gears the presentation towards developing the analytical ability of students and that the teacher prioritizes student engagement.

There are various modes in teaching case studies − debate, discussion, trial, problem-based learning, public hearing, and scientific research team [2]. Barrows [7] suggests that case-based learning is a form of PBL, while Hartfield [8] treats the two learning models as two distinct models.

Another mode of teaching case study related to problem-based learning is the *interrupted-case method* used for many years by Herreid [9]. The teacher provides the students with some questions taken from a source (e.g., scientific journal), and the students are to suggest how to design an experiment to solve the problem. The students discuss within their group and then present their experimental design in class for comments. When all groups have presented their design, the teacher then informs the class how the author attacked the problem. The students once again discuss and report what the possible solutions are and perhaps fill up some blank tables. The next phase involves providing students with the author's actual data, which the students interpret and once again report their group's output. Next involves revealing the author's results and conclusions. Lastly, the teacher or students then provide some closure of the case study by providing a summary and lessons learned.

For this current study, the *researcher uses a nondirective discussion* format for the implementation of CBT. The teacher introduces the case to class, and after working by groups outside class time, the students with the teacher discuss the case. The teacher stays in the sidelines during the discussion, thus acts as a facilitator.

Critical Thinking

Critical thinking is a complicated and abstract concept. In the literature, critical thinking involves a list of habits of mind and mental skills – cognitive skills and affective dispositions [10]. Cognitive skills include interpretation, analysis, evaluation, inference, explanation, and self-regulation. The affective dispositions include critical thinking, open-mindedness, self-confidence, cognitive maturity, inquisitiveness, analyticity, truth-seeking, and systematicity.

The use of cases improves the student's critical thinking skills [11, 12, 13]. The work of Terry [12] determined the effect of CBT on students' general and domain-specific critical thinking skills using the Watson-Glaser Critical Thinking Appraisal (WGCTA) and the domain-specific critical thinking skill instrument Claim and Evidence Assessment Tool (CEAT). The study included 40 undergraduate non-science major students in a general science course in the United States. The study revealed positive results in general critical thinking of students. Moreover, the ability of students to identify claims and evidence had also improved.

The active learning environment in CBT allows students to analyze, through discussion and debate, probable actions; and be creative in their ideas [12]. However, the study also showed that the effect of CBT on critical thinking skills on students who learned specific topics in biology provided inconclusive results.

Kaddoura [14] compared the effects of CBT and didactic teaching on the critical thinking skills of nursing students. The research included 103 students − 65 individuals from the CBT nursing program in Sharja branch (treatment group) and 38 individuals from the didactic nursing program in Fujeira branch (control group) offered by the Ministry of Health Schools of Nursing in the UAE. The two (2) branches of Institutes of Nursing were chosen in the study since both branches provide the same diploma nursing courses with similar admission criteria. In the CBT group, the participants were taught using case studies and PowerPoint slides in three years, while the control group was taught using a didactic approach through PowerPoint slides. The same teacher taught the two (2) groups, provided with the same teaching content, and the same examinations. A non-directive discussion mode of approach was implemented for CBT, wherein the teacher facilitates student learning through discovery and knowledge construction during class discussions. The critical thinking abilities of students were measured using the California Critical Thinking Skills Test (CCTST) Form B. The results showed that the CBT students obtained better critical thinking scores (deduction, induction, analysis, inference, and evaluation) compared to the didactic program students. The results indicate that students in CBT can learn to think critically than those in the traditional lecture-based education program. In CBT, students need to analyze problems, provide inferences by evaluating some data and information, and make a stand or decision, which often involves complex and conflicting issues [14]. In CBT, the student learns to construct ideas based on prior knowledge and synthesize and apply learnings to future situations.

A qualitative study by Harman and co-researchers [13] determined the effect of CBT on student's critical thinking in one of the public universities in the United States. About 426 students participated in the study using purposive sampling enrolled in the upper-level undergraduate nutrition education courses during fall 2010 or spring 2011. The CBT approach was used for the entire semester duration by a single instructor trained in using a CBT approach. The researcher conducted three (3) focus-group interviews (FGI's) (semi-structured and audiotaped) among the participants. All responses were coded adequately by research team members under the supervision of the principal investigator and external auditor review; triangulated using phenomenology and Bloom's taxonomy, and finally analyzed. The study showed that the development of critical thinking skills is affected by the participants' ability to see the *big picture* and to realize *critical awareness*.

The work of Harman and co-researchers [13] thus, gives a qualitative understanding of higher-order thinking that is associated with CBT. The researchers, however, caution that CBT demands careful planning by the teacher-implementer. The teacher has to consider the application of CBT in class and what are the expected student outcomes. Some suggested strategies include: 1) plan clear course objectives to maximize student participation; 2) explain the importance of CBT and working in groups; 3) use regularly the CBT approach; 4) use of good cases; 5) use of permanent student small groups; and 6) let students construct their learning.

In CBT, students need to work on all the facts and analyze the problem. Each student in a group has to grasp the multifaceted issues to arrive at sound, and acceptable

conclusions — this process of internalizing starts at a personal level, and eventually, students share this among group members. Working in groups exposes students to similar or alternative views, which help validates the student's views or will require them to defend it. In such a scenario, the use of CBT ushers improved the critical thinking of students.

METHODS

General Chemistry II is a compulsory and terminal chemistry course taken during the second semester by regular freshman General Engineering students at a University in Zamboanga City, the Philippines, where the researcher teaches. General Chemistry I is its prerequisite course, which is taken by students during their first semester at the university. General Chemistry II has a three-unit lecture component and a one-unit laboratory component with separate final grades reported by lecture and laboratory teachers, respectively. The lecture classes meet for one-and-a-half hours twice a week and usually delivered through the traditional 'chalk and talk' approach, while the laboratory classes meet three hours once a week.

The General Chemistry II lecture course covers the following topics: 1) Solutions, 2) Molecules and Materials, 3) Energy and Chemistry, 4) Chemical Equilibrium, 5) Chemical Kinetics, 6) Acids and Bases, 7) Electrochemistry, and 8) Nuclear Chemistry. Only topics 1 and 7 were not supplemented with case materials.

Two (2) groups of classes were used (control and treatment groups). The independent variable was the type of teaching approach (case-based teaching as a treatment variable and lecture-discussion teaching or LDT as a control variable), while the exam score served as the dependent variable.

Sample

The sample consisted of first-date year General Engineering students enrolled in four (4) intact General Chemistry II lecture classes in one University in Mindanao, Philippines. These classes were the first four (4) General Chemistry II sections for Engineering students and were assigned to the researcher by the Head of the Chemistry Department, College of Science, and Mathematics, where the researcher has been teaching undergraduate chemistry classes for more than ten years.

Two (2) classes (N=66) served as the treatment group, while the other two (2) classes (N=61) served as the control group. The researcher only included the first-year students and first-time takers of the lecture course in the study. The researcher did not include students who dropped out during the study.

Table 1 shows the schedule of CBT and LDT implementation for the whole semester. During the first half of the semester, group 1 served as the CBT group (treatment), while group 2 served as the LDT group (control). During the second half of the semester, the researcher reversed the groups - group 2 served as the CBT group (treatment), while group 1 served as the LDT group (control).

Table 1: Schedule of CBT and LDT implementation in groups of classes

Group	Group Type	
	First-half of Semester	Second-half of Semester
1	CBT	LDT
2	LDT	CBT

Critical Thinking Skills Tests

The researcher adopted two (2) critical thinking skills tests [15]. The topics covered for the *Critical Thinking Skills Test I* include molecules and materials, chemistry and energy, and chemical kinetics. The topics covered for the *Critical Thinking Skills Test II* include chemical equilibrium, acids and bases, and nuclear chemistry.

Instrument and Procedures

Case Teaching Materials

Six (6) case teaching materials were developed and used for the study (Table 2). Each topic of case teaching materials consists of a fictional short story with a central character(s) facing real-world problems. The researcher provides the students with cases with actual documents like scientific/chemistry articles, images, graphs, tables, and figures obtained from various sources like books, published journals, newspaper articles, online news articles, reports, and others.

Table 2: Case-based teaching material description

Case	Title	Topic
1	The Good, the Bad, and the Ugly - Nanotechnology	Molecules and Materials ▪ Uses and applications of nanotechnology ▪ Risks in nanotechnology
2	To Burn or Not to Burn - Coal-Fired Power Plant	Energy and Chemistry ▪ Coal and its uses ▪ Process of producing electricity from coal ▪ Impacts of coal-fired power plant
3	Here Now, Gone Later – Ozone Depletion	Chemical Kinetics ▪ Ozone-depleting substances and the ozone layer ▪ Chapman cycle: formation and destruction of ozone ▪ Ozone depletion: Effects and solutions
4	The Balancing Act - Fertilizer Use	Chemical Equilibrium ▪ The Haber process ▪ Uses of ammonia ▪ Effects of using fertilizer ▪ Solutions to fertilizer misuse
5	Not So Neutral View - Acid Rain	Acids and Bases ▪ Effects of acid rain. ▪ Solutions to alleviate acid rain.
6	Exterminating the Enemies –Food Irradiation	Nuclear Chemistry ▪ The advantages and disadvantages of food irradiation. ▪ How food irradiation facility works.

Two (2) chemistry experts reviewed the questionnaires, and an evaluation form was answered by each of the experts to test the validity of the instrument. Each test consisted of six (6) items. The *Critical Thinking Skills Test I* consisted of the following critical thinking sub-areas: 50% (3 items) *interpretation*, and 50% (3 items) *explanation* with Alpha

Cronbach reliability of 0.766. The *Critical Thinking Skills Test II* consisted of the following critical thinking sub-areas: 33% (2 items) *inference*, 33% (2 items) *interpretation*, and 33% (2 items) *explanation* with Alpha Cronbach reliability of 0.610.

Implementation of CBT and LDT

The researcher gave the students the freedom to choose their small group. The students worked by a group outside their scheduled General Chemistry II class. The groups submit their outputs on the scheduled class meeting during which the teacher, together with the class, answered the assignment questions. The discussion of case answers took about 45 minutes. Meanwhile, intact classes without case supplement had class drills; that is, graded participation in solving problems on the board. The table below shows the typical CBT and LDT class sessions (Table 3).

Table 3: Sessions of case-based teaching (CBT) and lecture-discussion teaching (LDT)

Total Class Time: 1.5 hours	CBT	LDT
1. Background	Case material is given to each of the small-group on the weekend before the submission of the assignment.	Problem set given as an assignment to small-group on the weekend before the individual graded participation.
2. Three (3) Minutes	Preliminary recall	Preliminary recall
3. Forty-two (42) Minutes	Lesson proper: Lecture-Discussion	Lesson proper: Lecture-Discussion
4. Forty-five (45) Minutes	Non-directive discussion of the case material & Q&A	Graded class drill/Board recitation based on assignment

Data Analysis

Test statistic *t*-test (within/between groups) was used to determine the effects of CBT versus LDT on the chemistry achievement score of students. The researcher considered a p-value of < 0.05 as the criterion of significance. The researcher recorded the results as means, standard deviations, and percentages.

RESULTS AND DISCUSSION

Critical Thinking Skills Test I

Table 4 shows the *Critical Thinking Skills I* pre-test and post-test results of both LDT and CBT groups, while *Table 5 shows the t*-test results for the *Critical Thinking Skills Test I*.

Table 4: Descriptive statistics for critical thinking skills test I

Group	N	Test	Mean	Standard Deviation	Standard Error
CBT	66	Pre	6	2.767	.341
		Post	8	3.159	.389
LDT	61	Pre	6	2.720	.348
		Post	7	2.860	.366

Table 5: t-test results for critical thinking skills test I (N: CBT=66, LDT=61)

Test	Group	*t*	df	p
Pre	CBT	.068[a]	125	.946
	LDT			
Post	CBT	.196[a]	125	.845
	LDT			
Pre	LDT	-2.260[b]	60	.027
Post	LDT			
Pre	CBT	-2.052[b]	65	.044
Post	CBT			

[a] Independent-Samples
[b] Paired-Samples

Table 4 shows that the *Critical Thinking Skills I* mean pre-test scores of both LDT and CBT groups are about the same. Statistical analysis using *a t*-test (comparison between groups) shows that the LDT and CBT groups are not significantly different ($p > 0.05$) concerning their *Critical Thinking Skills I* mean pre-test scores (Table 5). Table 4 also shows that both groups have higher *Critical Thinking Skills I* mean post-test scores relative to their respective mean pre-test scores. Statistical analysis using *a t*-test (comparison within-group) also shows that both LDT and CBT groups have significantly different ($p < 0.05$) *Critical Thinking Skills I* mean scores concerning their pre-post results (Table 5). Both groups (LDT group, $p < 0.05$; CBT, $p < 0.05$) obtained higher *Critical Thinking Skills I* mean post-test scores than their respective mean pre-test scores. These indicate that both LDT and CBT can improve the critical thinking skills of students. Lastly, Table 4 shows that the post-test scores of both groups are comparable. The between-group analysis shows that the LDT and CBT groups are not significantly different ($p > 0.05$) concerning their *Critical Thinking Skills I* mean post-test scores (Table 5). These indicate that the effects in critical thinking skills test I of students concerning CBT and LDT are comparable.

Results show that the use of LDT significantly improved the *Critical Thinking Skills Test I* of students. This finding on LDT may be a little surprising considering the criticisms of its approach [16, 7, 18]. The finding of this recent study is contrary to Nair et al. [18], who state that the traditional approach does not improve the students' critical thinking skills. The traditional approach in teaching allows students to be passive, depending only on the information provided by the teacher instead of actively involving the student in the learning process. Brand [19] also shows that the use of the traditional approach does not lead to any change in the critical thinking of students.

One of the disadvantages of the traditional approach is that in this passive learning environment, students have less opportunity to critically analyze the information and learn to apply it in different contexts [20]. Browne and Freeman [21], based on a review of the literature, assert that aside from having an active learning environment, the other primary elements to a classroom that promotes critical thinking include frequent student questions, developmental tension, and contingency of conclusions. The presence of these four characteristics alone does not promote critical thinking, but it is the combination of these characteristics, which promotes such development. It may be possible, therefore, that in LDT, students were still involved in the learning process although

less actively; along with the probable presence and combination of the other said characteristics, ushered to the improved *Critical Thinking Skills Test I*.

Results also show that the use of CBT significantly improved the *Critical Thinking Skills Test I* of students. The finding on CBT is consistent with the findings of Terry [12] and Harman et al. [13]. The use of cases facilitates active and reflective learning by exposing students to life-like situations, providing them with the opportunities to discuss, debate, and create and discover novel ideas [12]. The use of cases allows students to develop their analytical and critical thinking skills [11]. Gou [4] states that the learning environment in CBT demands the use of critical thinking.

Results indicate that the extent of effects of both LDT and CBT on *the Critical Thinking Skills Test I* are the same. This finding corroborates with the work done by Brand [19]. He explains that the possible reason why students did not perform well in CBT as expected is due to the possible sensitivity issue of the instrument used. Brand [19] used the Watson-Glaser Critical Thinking Assessment in his study, and accordingly, this test has high reliability and norms established for eleventh and twelfth-grade students. He mentioned that the instrument might not have been sensitive enough to fully access critical thinking development in the population of students in his study.

Meanwhile, Choi and co-workers [22] also show that the effects on critical thinking using the traditional approach is not significantly different from the other closely related student-centered approach of CBT – the Problem-Based Learning (PBL). Their results are different from Rowles and Brigham [23] and Kaddoura [14] who both contend that using cases is better than the traditional approach in improving critical thinking skills. Choi et al. [22] explain that even if students favor the PBL approach, students did not obtain a better result in critical thinking than the PBL approach because of the limited duration allotted for their PBL program. Secondly, the difficulty of students in adapting to PBL teaching and learning styles was also another consideration why their student-centered PBL approach did not do well as expected. Meanwhile, other works show that PBL does not affect critical thinking [22].

Critical Thinking Skills Test II

Table 6 shows the *Critical Thinking Skills II* pre-test and post-test results of both LDT and CBT groups. While *t*-test results are shown in Table 7 for *Critical Thinking Skills Test II*.

Table 6: Descriptive statistics for critical thinking skills test II

Group	N	Test	Mean	Standard Deviation	Standard Error
CBT	58	Pre	6	2.514	.330
		Post	6	2.288	.300
LDT	64	Pre	6	2.012	.251
		Post	6	2.000	.250

Table 6 shows that both groups appear to have comparable *Critical Thinking Skills II* mean pre-test scores. Statistical analysis using *a t*-test (comparison between groups) shows that the LDT and CBT groups are not significantly different ($p > 0.05$) concerning their *Critical Thinking Skills II* mean pre-test scores (Table 7).

Table 7: t-test results for critical thinking skills test II (N: CBT =58, LDT=64)

Test	Group	*t*	df	p
Pre	CBT	-.011[a]	120	.992
	LDT			
Post	CBT	.364[a]	120	.717
	LDT			
Pre	LDT	-.302[b]	63	.763
Post	LDT			
Pre	CBT	.120[b]	57	.905
Post	CBT			

[a] Independent-Samples

[b] Paired-Samples

Table 6 also shows that the LDT group had higher *Critical Thinking Skills II* mean post-test score relative to its mean pre-test score, while the CBT group had lower *Critical Thinking Skills II* mean post-test score relative to its mean pre-test score. Statistical analysis using *a t*-test (comparison within a group) shows that the LDT and CBT groups are also not significantly different ($p > 0.05$) concerning their *Critical Thinking Skills II* mean pre/post-test scores. These indicate that both LDT and CBT do not affect the critical thinking skills of students. Lastly, Table 7 shows that the *Critical Thinking Skills II* mean post-test scores are different in favor of the LDT group. However, between-group analysis shows that the LDT and CBT groups are not significantly different ($p > 0.05$) concerning their *Critical Thinking Skills II* mean and post-test scores (Table 7).

The finding that the use of LDT does not affect students' *Critical Thinking Skills Test II* is in agreement with that of Nair et al. [18]. Moreover, this also supports the claim of Hutchinson [16] and Lord [17] that the exposure of students in the passive learning environment of a traditional teaching approach does not foster their critical thinking skills.

Results also show that the use of CBT does not affect students' *Critical Thinking Skills Test II*. The finding on CBT is not consistent with the findings of Terry [12] and Harman et al. [13], who all assert that the use of cases improves the critical thinking skills of students. With regards to PBL, Choi, and Yang [22] show that PBL does not affect critical thinking. The finding on *Critical Thinking Skills Test II* is actually in line with the previous two studies dealing with the closely related student-centered approach.

The above results indicate that the effects of CBT and LDT on *Critical Thinking Skills Test II* are the same. This result is the same as a result obtained in *Critical Thinking Skills Test I*. Studies in agreement with this finding is quite limited, yet Choi and co-workers [22] show that the effects on critical thinking using the traditional approach is not significantly different from the other student-centered approach − PBL. Choi et al. [22] justify that the limited duration (*i.e.*, one semester or about four months) allotted for their PBL program may be the contributory factor why their work did not obtain a favorable result towards PBL. The researcher also implemented the current study with the same duration – about four months. An empirical study has documented a significant improvement in critical thinking in a student-centered environment in a much longer duration of implementation [22]. Another factor provided by Choi and co-workers why their student-centered PBL approach did not do well as expected is the difficulty of students in adapting to PBL teaching and learning styles. The teacher-centered

approach made students accustomed to this approach such that a new approach may have been a challenge to the students. Such an explanation may also be correct concerning the second phase of this current study. The new treatment group (exposed to CBT) may have experienced difficulty to adapt to the new approach provided by CBT and were not able to acquire the skills needed such that they did not do well on their *Critical Thinking Skills Test II* results.

CONCLUSION

This study determined the effects of CBT on the critical thinking of college students. Two groups of classes were used to determine the effects of CBT on the critical thinking skills of undergraduate students in one of the State Universities in Mindanao, Philippines. The independent variable was the type of teaching approach (CBT versus lecture-discussion teaching or LDT), while critical thinking (exam scores) served as the dependent variable. The effects of CBT versus LDT on students' critical thinking were determined using t-tests (within and between groups). Results showed inconclusive findings. The researcher noted the positive results for *Critical Thinking Skills Test* 1, both for LDT and CBT. However, no improvements were noted for *Critical Thinking Skills Test II*, both for LDT and CBT.

REFERENCES

1. Herreid, C. F., "ConfChem Conference on Case-Based Studies in Chemical Education: The Future of Case Study Teaching in Science," *Journal of Chemical Education*, **90**(2):256(2013)
2. Herreid, C. F., "Case Studies in Science – A Novel Method of Science Education," *Journal of College Science Teaching*, **23**:221-229(1994)
3. Cox, S., "Learning and Teaching Guides – Case Studies for Active Learning," Commissioned and funded by the Higher Education Academy Network for Hospitality, Leisure, Sport, and Tourism, 40(2009)
4. Gou, B., "Contemporary Teaching Strategies in General Chemistry," *The China Papers*, 39-41(2003)
5. Chaplin, S., "Assessment of the Impact of Case Studies on Student Learning Gains in an Introductory Biology Course," *Journal of College Science Teaching*, 72-79(2009)
6. Herreid, C. F., "Clicker Cases: Introducing Case Study Teaching into Large Classrooms," *Journal of College Science Teaching*, 43-47(2006)
7. Barrows, H. S., "A Taxonomy of PBL Methods," *Medical Education*, **20**(6):481-486(1986)
8. Hartfield, P. J., "Reinforcing Constructivist Teaching in Advanced Level Biochemistry through the Introduction of Case-Based Learning Activities. *Journal of Learning Design*, **3**(3):20-31(2010)
9. Herreid, C. F., "The Interrupted Case Method," *Journal of Science Teaching*, **35**(2):4-5(2005)
10. Facione, P. A., "Critical Thinking: What It Is and Why It Counts," *Measured Reasons*. The California Academic Press, Millbrae, CA(2011)
11. Davis, C. M., "The Successful Use of Case Studies in Nutritional Biochemistry," *Georgis Journal of Science*, **62**(2):79-86(2004)
12. Terry, D. R., "Using the Case Study Teaching Method to Promote College Student's Critical Thinking Skills," Doctoral dissertation, State University of New York at Buffalo)(2007)
13. Harman, T., Bertrand, B., Greer, A., Pettus, A., Jennings, J., Wall-Bassett, E., Babatunde, O.T., "Case-Based Learning Facilitates Critical Thinking in Undergraduate Nutrition Education: Students Describe the Big Picture," *Journal of the Academy of Nutrition and Dietetics*, **115**(3):378-388(2015)
14. Kaddoura, M. A., "Critical Thinking Skills of Nursing Students in Lecture-Based Teaching and Case-Based Learning," *International Journal for the Scholarship of Teaching and Learning*, **5**(2), Retrieved from http://www.georgiasouthern.edu/ijsotl(2011)
15. Sharp, I. R., "The Role of Critical Thinking Skills in Practicing Psychologists' Theoretical Orientation and Choice of Intervention Techniques," Doctoral dissertation, Drexel University(2004)
16. Hutchinson, J. S., "Teaching Introductory Chemistry Using Concept Development Case Studies: Interactive and Inductive Learning," *University Chemistry Education*, **4**(1):3-9(2000)
17. Lord, T., "Society for College Science Teachers: Revisiting the Cone of Learning - Is It a Reliable Way to Link Instruction Method with Knowledge Recall?," *Journal of College Science Teaching*, **37**(2):14-17(2007)
18. Nair, S. P., Shah, T., Seth, S., Pandit, N., & Shah, G. V., "Case-Based Learning: A Method for Better Understanding of Biochemistry in Medical Students," *Journal of Clinical and Diagnostic Research*, **7**(8):1576-1578(2013)
19. Brand, L. G., "Evaluating the Effects of Medical Explorers: A Case Study Curriculum on Critical Thinking, Attitude toward Life Science, and Motivational Learning Strategies in Rural High School Students," Doctoral dissertation, Ball State University)(2010)
20. Paris, C., "Lecture Method: Pros, Cons, and Teaching Alternatives," Retrieved from https://blog.udemy.com/lecture-method/(2014)
21. Browne, M. N., & Freeman, K., "Distinguishing Features of Critical Thinking Classrooms," *Teaching in Higher Education*, **5**(3):301-309(2000)
22. Choi, E., Lindquist, R., & Song, Y., "Effects of Problem-Based Learning vs. Traditional Lecture on Korean Nursing Students' Critical Thinking, Problem-Solving, and Self-Directed Learning," *Nurse Education Today*, 34:52–56, Retrieved from http://dx.doi.org/10.1016/j.nedt.2013.02.012(2014)
23. Rowles, C. J., & Brigham, C. G., "Strategies to Promote Critical Thinking and Active Learning," In Billings, D. M., & Halstead, J. A. (Eds.). *Teaching in Nursing: A Guide for Faculty*, St. Louis. MO: Elsevier(2005)