CONSTRUCTIVISM AND THE TECHNOLOGY OF INSTRUCTION IN A CHEMISTRY CLASS

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ABSTRACT: *This study investigated the effect on the efforts of integrating technology in the classroom within the context of a constructivist framework. With this aim, Outcomes-Based Teaching and Learning – Computer Assisted Instructional Material (OBTL – CAIM) was developed and implemented in chemistry classes. The development and design of OBTL-CAIM were specialized with the following essential features: based on students' alternative conceptions on chemical bonding, anchored on Outcomes-Based Teaching and Learning (OBTL) utilizing the framework of constructive alignment theory, and integrated with Computer Assisted Instructions (CAI). The study utilized a mixed–method research design; the quantitative part involved determining the pre-test and post–test gain of two intact classes of Electrical Engineering (EE) general chemistry students. The qualitative part involved audiotapes of focus group discussions (FGD), interviews, activity sheets, learning journals, and assignments. Results of the study revealed that prior to the implementation of OBTL – CAIM, students' had misconceptions about the meaning of covalent bonds and shapes of molecules. During the implementation, two groups of EE general chemistry student participants were taught using the developed OBTL-CAIM. Data were gathered on how effective the OBTL-CAIM to remediate students' alternative conceptions and to assess whether the Intended Learning Outcomes (ILOs) have been successfully achieved by the students. The findings indicated that that OBTL – CAIM is effective in achieving students' conceptual understanding on covalent bonding and molecular structures. Student participants have changed or transformed most of their alternative conceptions into scientifically correct conceptions. This implied that they have developed a better understanding of covalent bonding and molecular structures as a result of OBTL-CAIM intervention.*

Keywords: *Constructivism, Technology Instruction, Alternative conceptions, Outcomes-Based Teaching, and Learning*

1. INTRODUCTION

Chemistry is one of the most important subjects in science [1]. Important concepts under this area should be understood so that one is able to apply the knowledge to situations in everyday life. However, chemistry has been regarded as a difficult subject by many students at all levels of schooling because this is a conceptual subject and most of the concepts are abstract [2,3,4]. Thus the challenge to chemistry education is how to actively engage the students in learning chemistry and be able to understand deeply the underlying concepts. This is a conceptual subject that involves abstract topics. One of the basic and abstract concepts in chemistry is chemical bonding. Researchers have found that students had difficulty learning this concept and often fail to integrate their mental models into a coherent conceptual framework [5]. Covalent bonding and molecular structures in chemical bonding are the topics that students develop a lot of misconceptions maybe because of its microscopic view like the atomic structure and reaction of these atoms with other atoms [5,6]. Students' alternative conceptions must be addressed properly through a simple constructed mode of learning concept delivery. This encompasses the reframing, reconstruction, or substituting of the students' prior conceptions to appreciate newly discovered paradigms and this method has been termed conceptual change [7, 8]. This conceptual change is a scientific approach that represents an alternative method designed to cultivate encouragement for students to remodify pre-conceptual alternatives [9]. Thus, the researcher devised an objective to discover if employing an Outcomes-Based Teaching and Learning (OBTL) approach in the classes could nurture the learners' conceptual change and remediate this with accurate conceptions about chemical bonding. This is also to provide learning inputs in this area since there is still no studies that had been conducted on this particular topic [10].

Outcomes-Based Education (OBE) as an approach is one of the educational reforms in the higher education sector. Commission on Higher Education (CHED) emphasizes its focus and organization of the academic paradigm on the essentiality of learners to comprehend, appreciate and apply their knowledge to attain a healthy and desirable degree of competence [11]. The "outcomes-based teaching and learning" (OBTL) is a version of OBE [12] at the level of classroom practice which gives emphasis on students being at the midpoint of the academic procedures. In OBTL, constructive alignment is the means of enhancing teaching and learning. This means that the focus is now on the students' attainment of competencies based on the prescribed learning outcomes. Numerous academic papers scrutinized the integration of computer technology and acknowledged its effectivity to enhance the students' learning outcomes [13-15] The emphasis on the significance of visualizing ideas to accommodate the students' intent to learn chemical bonding concepts is prominent in the collaborative instructional strategies whereby a computer is managed to deliver concepts and inspect the learning that transpires [16, 2] conveyed that integrating computer-supported learning resources can be meaningful functional tools to enhance students' conceptual understanding of chemical concepts. This is a type of approach (student-centralizing pedagogy) that is being widely suggested by authors [,14, 15, 17] to assist and develop effectiveness in academic instructions to attain appropriate learning results from the students. In their recommendations, it was proposed to further expound their prepositions and integrate this with other teaching modalities to be comprehensively functional in improving learning concepts for there were still some alternative conceptions bumped into after the enactment [2]. Hence, this perspective urged the researcher to devote to the development of Computer Assisted Instructional Material (CAIM) to be leveraged in an OBTL approach and the conduct of this study is fitted out to evaluate and measure the effectiveness of the OBTL anchored Computer-Assisted Instruction on students' conceptual understanding of covalent bonding and molecular structures.

2. MATERIALS AND METHODS

A mixed-method design was utilized in this study which combines quantitative and qualitative methods. The quantitative research design was used to compare the pre-test and post-test results to determine the conceptual understanding of students about covalent bonding and molecular structures. While the qualitative research method was employed to describe a smaller group of students in both experimental groups (EG) in terms of their conceptual changes through interviews, learning journals, and class activities to obtain more comprehensive, robust, and meaningful findings.

First-year Electrical Engineering (EE) students from the College of Engineering and Information Technology (CEIT) in one of the universities in the Caraga region who took general chemistry subjects during the second semester were the participants of the study. There were two intact classes that were used in the study. The first section had 20 students while the second section contains 33 EE students. Three students from each class were followed throughout the intervention. Three students code -named Jx, Jy, and Jz were taken from the first section belonged to the first focus group while students Nx, Ny, and Nz from the second section to the second focus group. These students participated in in-depth interviews and their journal entries and activity sheets were utilized to further describe how the conceptual change evolved.

Collection activities were aligned according to the problem statements of the study. In determining students' alternative conceptions on chemical bonding, literature from national and international science education researches that are related to this problem were collected and reviewed. Pre-test and pre-interviews were administered in diagnosing the students' preconceptions before the implementation of OBTL-CAIM were conducted. To follow and describe the conceptual evolution of students during the different stages in implementing the OBTL-CAIM; the results of interviews, learning journals, activities, and assignments were gathered properly during the different phases of the entire research procedure.

To assess students' conceptual understanding of chemical bonding in terms of the prescribed Intended Learning Outcomes (ILOs) as stipulated in the OBTL-CAIM, the student's performance on every assessment task was evaluated. Grading criteria or rubrics were generated to describe what outcome may be for each task and for each ILO. Hence, the results of their activities, assignments, performance tasks were the basis in the assessment. After the implementation of the implementation, the students took again the same tests which serve as the posttest.

The data collected from the pre-post-test and interview were the basis in diagnosing students 'conceptual understanding of covalent bonding and molecular structure concepts as well as in evaluating the changes of students' conception together with their learning journal, activity results, and assignments. These were collected and analyzed to seek answers to the problems which were investigated in this study.

3. RESULTS AND DISCUSSIONS

In this discussion of results, two sections are presented. The first section presents the students' alternative conceptions on chemical bonding which focused on the topic of covalent bonding and molecular structure and the second section shows the students' conceptual changes based on their conceptual understanding after utilizing the OBTL – CAIM in addressing students' alternative conceptions in covalent bonding and molecular structures.

3.1 Students' Alternative Conceptions On Covalent Bonding and Molecular Structure

The identification of students' alternative conceptions on covalent bonding ad molecular structure was diagnosed by administering the pre-test utilizing the two-tier multiple-choice diagnostic test (Part B) developed by Tan and Treagust (1999).

Table 1. Concepts Tested in Covalent Bonding Held by First Year Electrical Engineering (EE) Students (n= 53)

Concept Tested	Item No.
The octet rule is used to determine the number of bonds an atom forms	4
The distribution of shared electron pair in the covalent bonds	5
The role of valence electrons in bonding	6
Lewis structure of covalent compounds	7
Molecular shapes	8&9

Concepts tested in covalent bonding are summarized in Table 1 together with the item number where this concept was being mainly highlighted. Each item was evaluated for both correct and incorrect response combinations selected by the students. Once students select incorrect response combinations, this will provide data on students' alternative conceptions related to the concept being emphasized in each item. If the incorrect response occurred in at least 10% of the student sample, this will

be considered as alternative conceptions held by the students (Peterson, 1986).

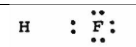
Percentages of students' responses in each item of the two-tier multiple-choice diagnostic test are depicted in Table 2. Alternative conceptions possibly found in each item are discussed under the categories as presented in Table 1.

The following students' misconceptions were generated from the analysis of the pre-test results and initial interviews transcriptions on covalent bonding and molecular structure:

- Octet rule was defined as the number of bonds formed which equal the number of the electron in the outer shell.
- SO_2 and CO_2 molecules are bent because they both contain double bonds.

- SCl_2 is linear because two sulfur – chlorine bonds are equally repelled to a linear position.
- Covalent bonding is the transfer or sharing of electrons; could never tell that the bond refers to the force.
- The paired electron in nitrogen is for sharing and the three unpaired electrons are for bond formation.

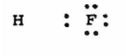
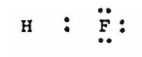
Table 2. Item Analysis of the Two-Tier Multiple Choice Diagnostic Instrument on Covalent Bonding

Item No.	Question	Answer Chosen	Reason Chosen and the % of Chemistry students (n=53) selecting each response combination			
			1	**2**	**3**	**4**
4	The octet rule is used to determine the ____.	A. shape of a molecule	9.43	1.89	11.32	0.00
		B. number of bonds an atom forms	**50.94***	20.75	0.00	5.66
5	Which of the following best represents the position of the shared electron pair in the HF molecule?	 A.	11.32	20.75	**9.43***	18.87
		 B.	7.55	15.09	7.55	9.43
6	Nitrogen belongs to Group VA, how many maximum numbers of electrons it can share?	A. 1	22.64	5.66	0.00	5.66
		B. 2	0.00	33.96	0.00	0.00
		C. 3	1.89	**11.32***	13.21	5.66
7.	Which of the following Lewis structure best represents the structure of N_2Cl_4?	A.	7.55	5.66	15.09	11.32
		B.	3.77	3.77	18.87	1.89
		C.	1.89	3.77	**11.32***	1.89
		D.	1.89	1.89	5.66	3.77
8	Which of the following statement is true for SO_2 and CO_2 molecules?	A. Molecules of both SO_2 and CO_2 are bent	11.32	1.89	22.64	3.77
		B. Molecules of both SO_2 and CO_2 are linear	15.09	1.89	3.77	5.66
		C. An SO_2 is bent while CO_2 molecule is linear	7.55	16.98	1.89	**3.77***
		D. A CO_2 is bent while SO_2 molecule is linear	0.00	0.00	1.89	1.89
9	The molecule SCl_2 is likely to be	A. V-shaped	**9.43***	9.43	9.43	7.55
		B. Linear	9.43	1.89	43.40	9.43

Notes: ***This indicates the correct answer for the item

Table 3. Pre-test and Post-Test Results of the Two-Tier Multiple Choice Diagnostic Instrument on Covalent Bonding and Molecular Structure

Item No.	Question	Answer Chosen	Reason Chosen and the % of Chemistry students (n=53) selecting each response combination								
			1	**2**	**3**	**4**	**1**	**2**	**3**	**4**	
			Pre-test				**Post-test**				**% Dif**
4	The octet rule is used to determine the ___.	A. shape of a molecule	9.43	1.89	11.32	0.00	3.77	1.89	5.66	3.77	
		B. number of bonds an atom forms	**50.94***	20.75	0.00	5.66	**79.25***	1.89	1.89	1.89	*28.31*
5	Which of the following best	A.	11.32	20.75	**9.43***	18.87	3.77	3.77	**77.36***	3.77	*67.93*

	represents the position of the shared electron pair in the HF molecule?										
		B. 	7.55	15.09	7.55	9.43	5.66	1.89	3.77	0.00	
6	Nitrogen belongs to Group VA , how many maximum numbers of electrons it can share?	A. 1	22.64	5.66	0.00	5.66	1.89	3.77	0.00	0.00	
		B. 2	0.00	33.96	0.00	0.00	1.89	3.77	0.00	0.00	
		C. 3	1.89	**11.32***	13.21	5.66	0.00	**84.9***	1.89	1.89	*73.59*
7	Which of the following Lewis structure best represents the structure of N_2Cl_4?	A.	7.55	5.66	15.09	11.32	1.89	0.00	1.89	0.00	
		B.	3.77	3.77	18.87	1.89	0.00	5.66	3.77	0.00	
		C.	1.89	3.77	**11.32** *	1.89	1.89	3.77	**77.36***	3.77	*66.04*
		D.	1.89	1.89	5.66	3.77	0.00	0.00	0.00	0.00	
8	Which of the following statement is true for SO_2 and CO_2 molecules?	A. Molecules of both SO_2 and CO_2 are bent	11.32	1.89	22.64	3.77	3.77	3.77	0.00	0.00	
		B. Molecules of both SO_2 and CO_2 are linear	15.09	1.89	3.77	5.66	0.00	0.00	3.77	1.89	
		C. An SO_2 is bent while CO_2 molecule is linear	7.55	16.98	1.89	**3.77***	0.00	43.4	1.89	**39.62***	*35.85*
		D. A CO_2 is bent while SO_2 molecule is linear	0.00	0.00	1.89	1.89	0.00	0.00	1.89	0.00	
9	The molecule SCl_2 is likely to be	A.V-shape	**9.43***	9.43	9.43	7.55	**81.13***	1.89	1.89	1.89	*71.7*
		B.Linear	9.43	1.89	43.40	9.43	3.77	3.77	3.77	0.00	

Notes: ***This indicates the correct answer for the item

3.2Students' conceptual changes after utilizing the OBTL – CAIM

The same two-tier multiple-choice diagnostic test instrument was administered during the post-test. Comparison between pre-and post-test results on the covalent bonding and molecular structure concepts were examined (Table 3). Table 3 presents the results of the post–test. Each item was analyzed to identify the students' final conception on covalent bonding.

Item number 4 (Table 3) tested the student's understanding of the octet rule. The post-test result shows that 79.25% [B1] of the students had now a correct understanding of the octet principle. There was an increase of 28.31% who answered the question of this item correctly. The distribution of the shared electron pairs in the covalent bonds is another concept that was dealt with in item number 5. A high percentage difference between the students who answered the item correctly (67.93%) was observed during their post-test results. This means that 77.36% of the students were able to correctly choose the content and reason choice on the position of the shared electron pair in the HF molecule.

The role of valence electrons in bonding is one of the important concepts that should be learned by the students to know how to draw the correct Lewis structure and geometry of the molecule. This concept was highlighted in item number 6. Table 3 reveals that a high percentage of the class (84.91%) corrected their wrong conception about valence electron, a gain of 73.59 % was shown in this item. Most of the students had correctly demonstrated their understanding of the Lewis structure of nitrogen and were able to explain why nitrogen can share a maximum of three electrons only.

In item number 7, the concept tested is about the Lewis structure of covalent compounds. Results in the post-test reveal that 77.36% chose the appropriate response combination [C3] of this item. They were able to correctly demonstrate the Lewis structure of N_2Cl_4 and ascertain that the structure is due to the repulsion between the four electron pairs (including bonding and nonbonding pairs) on the nitrogen atom.

In the pre-test results, it was noted that most of the students have an unsatisfactory ability in predicting the molecular shapes as measured in items number 8 and 9. Post-test results for item number 8 depict that most of the students (83.03%) selected the correct content choice however get confused on the reasoning part. Most of them (82.62%) correctly identified the bent molecular shapes of SO_2 and the linear shape of CO_2. However, only 39.62% [C4] had chosen the correct response combination, they correctly believed that the reason for having of such molecular shapes because of the bonding and non-bonding pairs that indicate the shape of the molecule. The rest of 43.40 % [C2] mistakenly assumed that the reason for this phenomenon is due to the two lone pairs on the central atom of SO_2 and no lone pairs of CO_2. This indicates that students had imagined the shapes of these molecules but inaccurately pictured the number of lone pairs that the SO_2 has. The questions are in multiple-choice types, students may not have tried to write the Lewis structure and draw the correct shape of the SO_2 molecule prior to selecting their choice of answer.

Another way of comparing the pre – and post-test scores of the students is to analyze the results quantitatively using SPSS. Pre- and post-test had total items of 29 in both parts of the diagnostic instrument. The mean scores of the students are compared using a paired t-test. Hence, to determine if there were statistically significant differences between the pre-test and post-test results of the two EE chemistry classes (n=53), a paired t-test was employed using SPSS at the 0.05 level of significance.

Furthermore, students' scores from their pre-and post-test results are presented in Table 4. Diagnostic instrument of chemical bonding which contains Part A and Part B was the test administered as pre-and post-test having a total of 29 items.

Table 4. Comparison of the Percentages of the Students' Pre-and Post-Test Results (n=53)

Range of Scores	% of the Students' Pre-Test Scores	% of the Students' Post-test Scores
25-29	-	23
20-24	19	36
15-19	19	34
10-14	11	8
5-9	38	-
0-4	11	-

Table 4 shows that students got a higher score in the post-test than in the pre-test after engaging themselves in OBTL-CAIM as an intervention. Post-test results reveal that 23% of the chemistry students got range scores of 25 - 29, having the highest score of 28, while none of them got these scores during the pre-test. The lowest scores obtained by the students (8%) were within the range of 10 - 14 in the post-test, having 11 as the lowest score while in the pre-test 11% of the students got a range of scores within 0 - 4 and the lowest score obtained was 1. This implies that these results contribute to more evidence on the effectiveness of the OBTL-CAIM on students' understanding of chemical bonding.

Students' conceptual changes were determined from students' activity results, responses to interviews, learning journals, assignments, and post-test results. Findings revealed that most of them were able to change their misconceptions about the correct scientific concepts about chemical bonding. However, in tracking the transformation of students' conception, it was found out that focus group students had different learning pathways in understanding the concepts.

Moreover, all six students sample Jx, Jy, Jz, Nx, Ny, and Nz showed only a limited understanding of concepts and possessed misconceptions at the beginning of the lessons. The three students, for example (student Nx, Jz, and Nz) from the focus groups showed difficulty in learning the molecular geometry concept. However, the entire duration of the intervention of OBTL-CAIM revealed the successful learning process that despite their struggles in understanding this concept, students in the focus groups admitted that CAIs helped them to finally grasp the target concepts specifically on molecular geometry.

4. CONCLUSION AND RECOMMENDATIONS

The main purpose of the study was to evaluate the effectiveness of the OBTL anchored Computer-Assisted Instruction on students' conceptual understanding of covalent bonding and molecular structures. Computer-Assisted Instructional Material (CAIM) in an OBTL approach was developed in this study and assisted in attaining successful learning outcomes through a more comprehensive and thorough understanding of the concept and promoted conceptual change; clearing out misconceptions to the desired scientifically precise paradigms.

Based on the findings, this study concludes that the developed OBTL – CAIM is effective in achieving students' conceptual understanding on covalent bonding and molecular structures. Students have changed or transformed most of their initial misconceptions into scientifically correct conceptions after they were exposed to OBTL – CAIM. It can be deduced from this study that students acquired a correct understanding of chemical bonding as depicted in the increase of percentages of the students who got correct answers during the post-test than in the pre-test. Thus, this study further concludes that OBTL – CAIM provided meaningful experiences among learners by remediating their misconceptions on covalent bonding and molecular structure in particular.

Outcomes-based instructional material helps the students achieve their desired outcomes; it means that we can also achieve the desired outcomes of education worldwide which include lifelong learning and developing strategies to learn. Thus, there are excellent opportunities by which the research findings in this study can be incorporated and applied in any learning environment.

Based on the conclusions of the study, a recommendation is given. OBTL-CAIM is one of the effective approaches in teaching concepts that are considered difficult and abstract in chemistry. However, there were still some wrong concepts that are found to be resistant to change among a low-performing group of students, especially since these misconceptions have already been instilled in their minds during their previous chemistry lessons or high school chemistry. Thus, researchers may improve this approach by integrating new teaching methods by subjecting them to further research; utilizing this OBTL – CAIM, and comparing this to other suggested strategies and pedagogical approaches. The results will somehow contribute to more evidence on the effectiveness of the OBTL – CAIM especially on addressing students ‘misconceptions.

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