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Relationship of the Variables affecting the Students Utilizing the Peer Led Team Learning 7e Chemical Bonding Worksheets

Carina B. Orden[1,*], Maricar S. Prudente[2]

[1]Education Department, Bicol University Tabaco Campus, Tabaco City, Philippines
[2]Science Education Department, De La Salle University Manila, Manila City, Philippines
*Corresponding author: cborden@bicol-u.edu.ph

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Abstract The Peer Led Team Learning (PLTL) and 7E approaches are proven strategies in developing concepts, spatial ability, self-concept, group interaction and problem-solving skill but very few studies assessed its combined effects. The combined pedagogical approach - cognitive, psychomotor, and affective nexus needs to be assessed to support the improvement in the teaching practice of chemical bonding. Students independent variables include sex, Senior High School (SHS) track, and college entrance test science score (SS). Adapted instruments measured the dependent variables: conceptual understanding (CU), spatial ability (SA), self-concept (SC), group interaction (GI) and problem-solving approach (PSA). The score from the chemical bonding worksheet (CBW) was gathered as well. From the set of independent and dependent variables, the present study determined the relationship of sex, SHS track, SS, CU, SA, SC, GI, PSA and CBW scores. Action research paradigm was employed to 71 preservice science teachers that were divided into 10 peer groups that experienced the 30 hours activities of the CBW. The variables were tested by Pearson Correlation to show significant relationships. Results showed significant relationship between SHS track and CU, SA, SC, SS, CBW, GI and PSA. CU to SA, CBW to SA and GI, and SS to SC. Differing from most study sex was not significantly related to SA and SC. Implications of the findings to improving the CBW and teaching of chemical bonding were explained.

Keywords: *peer led team learning, 7E, chemical bonding worksheets, conceptual understanding, spatial ability, self-concept, group interaction, problem-solving approach*

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1. Introduction

The implementation of Republic Act 10553 or the Enhance Basic Education Act of 2013 in the Philippines increased the number of years for basic education with the addition of Senior High School [1]. The law was followed by the Commission on Higher Education (CHED) Memorandum Orden no. 105 series of 2017 that promulgated the acceptance of all Grade 12 graduates to enter college regardless of the track or strand taken in SHS. The decision to accept students from any track or strand led to under preparedness of science education students, hence, there is limited prior knowledge that can bridge the gap between basic chemistry and advance chemistry.

Learning chemical bonding is a sequential process and the interplay between secondary education and tertiary education contribute to concept understanding of the topic [2]. In the study, CU refers to the ability of the students to apply ideas of valence electrons, Lewis structure, VSEPR theory, molecular geometry, polarity of molecules and bonds, hybridization, sigma and pi bonds, intermolecular forces and resonance in deriving the parameters and constructing 2D and 3D molecules. Studies noted the misconceptions or wrong concepts on chemical bonding involving electronegativity and bond polarity [3,4,5]; calculation and interpretation of formal charge, resonance and hybridization [6,7,8]; understanding molecular geometry and polarity [9,10]; intermolecular forces and Lewis structure [11]; and molecules with lone pairs [12]. The difficulty of forming concepts on chemical bonding was intensified with the limited prior knowledge of the research participants.

Spatial ability is referring to the capacity of the student to draw or construct physical or mental molecular models [13]. The ability is intensified by introducing physical or virtual models with aid of worksheets [14,15]. Self-concept was defined as the "product of the reflexive activity of the self that develops in social interaction" (p. 3) [16]. The way a student view himself through self-evaluation is related to academic achievement in the subject [17].

Group interaction was defined by Hurst *et al* [18] as "meaningful dialogue among learners" (p. 376) and

students learn more during group interaction because of their active involvement in the learning process [19]. Further, small group interaction was mostly beneficial to minority or under prepared students [20]. Problem-solving approach looked into the manner the peer group answered the problems given in the worksheets, whether they simply looked for the correct answer or probed beneath the surface by digging into the principle or theory involved in the problem [21].

A theory in education suggested that under preparedness, self-concept and academic ability are predictors of student attrition or retention and academic or social interaction facilitates learning [22]. Peer-Led Team Learning (PLTL) is an approach that promotes CU in a collaborative setting [21]. A study conducted in the United States proved the effectiveness of the PLTL approach in improving the academic achievement among minority or under prepared students in a biology class [20]. Another approach gives a student the chance to construct knowledge by himself or in a group setting by a series of learning cycle called the 7e (elicit, engage, explore, explain, elaborate, evaluate and extend [23]. The 7e uses worksheets for each cycle that were found to improve the conceptual understanding, group interaction and problem-solving of students in a physics class [24]. Positive correlation in science achievement and number of hours spent in worksheets was observed among under prepared students in Australia, Finland, Morocco, Norway, Qatar and the United Arab Emirates [25].

Recently, few studies examined the relationships of the variables considered that are affecting the students using chemical bonding worksheets. Further, few studies conducted in the Philippines employed the combined PLTL and 7e approach to support the development of CU, SA and SC in chemical bonding. Through correlation analysis, the study investigated the relationship of profile, CU, SA, SC, GI, PSA, and CBW score among students utilizing the PLTL 7e chemical bonding worksheets.

2. Materials and Methods

2.1. The Peer Led Team Learning 7e Chemical Bonding Worksheets

The PLTL-7e Chemical Bonding Worksheets (CBW) were designed for Bachelor of Secondary Science Education (BSEd) freshman students enrolled in Inorganic Chemistry SY - 2019 - 2020. The workshop required 30 hours in-classroom and off-classroom activities. The primary objectives are to develop comprehensive understanding on the terms associated with chemical bonding; develop the spatial ability of the students by introducing the 2D and 3D structures in the applications Lewis Lite [26], Molecular Geometry [27] and 3D VSEPR [28]; draw or illustrate accurate Lewis structure and molecular geometry and relate the Lewis structure to the VSEPR theory; relate the chemical bonding parameters to the physical and chemical properties copied from the Material Safety Data Sheet (MSDS) of the assigned molecule; and develop a positive self-concept to be able to present the Lewis Structure, molecular geometry, and molecular geometry model and the relationship between the chemical bonding parameters and the physical and chemical properties of the assigned molecule.

2.2. Research Design and Participants

The action research design - Plan, Do, Study & Act model (Figure 1) collected and analyzed the quantitative and qualitative data within 14 weeks (Aug. 2019 to Dec. 2019). An intact class of 71 BSEd (Science) students enrolled in Inorganic Chemistry SY 2019-2020 was purposively sampled for the quantitative and qualitative analyses.

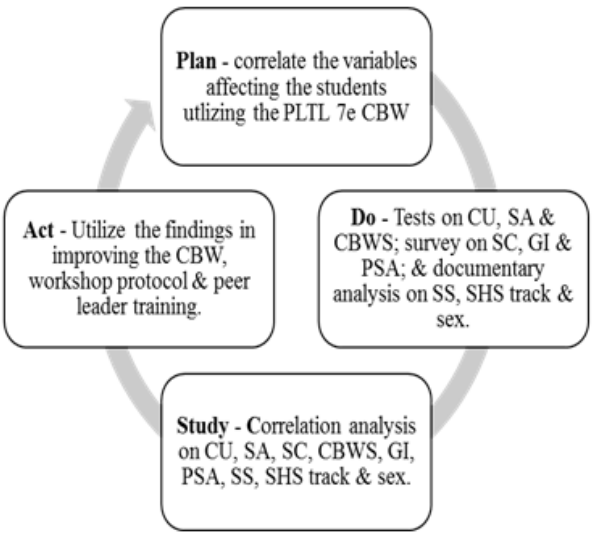

Figure 1. Research Design

2.3. Research Instruments

Conceptual Understanding was measured using Two-Tier Diagnostic Test for Molecular Geometry developed by Uyulgan *et al* [29]. The adaptive test is composed of 50 questions coming from the topic's resonance (2), structures violating the Octet rule (2), hybridization (6), molecular orbitals (2), Lewis structures (4), and relationships between Lewis and VSEPR structures (4), bond angle (4), polarity (6), molecular geometry (11), sigma and pi bonds (2), formal charge (3), and valence electrons (3). The highest possible score is 50 and lowest possible score is 0. The reliability coefficient of the test was 0.856 which mean it is highly reliable and its mean difficulty value was 0.487 after eliminating the questions with an item discriminating index lower than 0.20 [30].

Self-Concept ratings were taken from the Academic Self-Concept Questionnaire developed by Liu and Wang [31]. The adapted questionnaire contained 20 items purposely to measure student's self-concept. The items were closed-ended and were measured on a 5-point Likert scale. The highest score in the scale is (5) while the lowest is (1) per item. For questions with a positive stem strongly agree (SA) were scored highest (5) while strongly disagree (SD) were scored lowest (1). For those questions with a negative stem strongly agree (SA) were scored lowest (1) while strongly disagree (SD) were scored highest (5). The maximum score was 100 while the minimum was 20. The reliability coefficient was 0.90. This falls within acceptable limits for teacher made tests of 0.7 [30].

The SA scores were taken from the Spatial Ability Test designed by Carlisle [32]. The adapted test contained 20 closed-ended questions presented in a multiple-choice format with 4 stems. The highest possible score is 20 and the lowest is 0. The construct validity was established by tying the questions to cognitive factors for spatial reasoning skills based on the theory proposed by Lohman (1979). The cognitive factors represented were rotation of objects (6), rotation of molecule (4), molecular geometry (8) and polarity (2). The internal consistency and reliability of the test was 0.65. This falls within acceptable limits for teacher made tests of 0.7 [30].

The GI and PSA of the peer groups were rated using the Workshop-Group Observation Form developed by Pazos *et al* [20]. The questionnaire has 12 items; 5 items measured the group interaction; 5 items measured the problem-solving approach and 2 items measured sequential arrangement of the worksheets according to the 7e cycle. The items were closed ended and were measured on a 5-point Likert scale. For the group interaction, the group with individually oriented interaction is scored with 1 (lowest) while the group with collaborative interaction is with 5 (highest). The highest score for group interaction is 25 and the lowest is 5. For problem-solving approach, the group that showed simple approach is rated with 1 (lowest) and those with elaborated approach with 5 (highest). The highest score for problem-solving approach is 25 and the lowest is 5. The adherence to the 7e cycle has a highest of score of 10 and a lowest of score of 2. The internal consistency and reliability of the instrument was 0.94 and indicated high reliability [30].

The CBW were gathered after each workshop, the scores from the worksheets were recorded and the total number of points was converted into an equivalent score.

2.4. Data Gathering and Analysis

The posttest scores in CU, SA, and SC and CBW score were considered for the correlation analysis. The equivalent score of the test was taken as: Equivalent = Score/Total Score x 40 + 60. Sex was coded as 1 = male and 2 = female. SHS track/strand was coded as: 1 = Science, Technology, Engineering & Mathematics (STEM), 2 = Technical, Vocational and Livelihood (TVL), 3 = General Academic Strand (GAS), 4 = Humanities & Social Sciences (HUMSS), 5 = Accounting, Business & Management (ABM). The sex, SHS track and SS were copied from the documents submitted by the research participants during enrollment. Group interaction and problem-solving approach were taken from the collated Workshop Group Observation Form rated by 3 teacher-observers after each workshop. Group interaction was coded as 1 = Individual-Oriented Interaction and 2 = Collaborative Interaction. Problem-solving approach was coded as 1 = Simple Problem-Solving Approach and 2 = Elaborated Problem-Solving Approach. Pearson Correlation Analysis and Regression Analysis revealed the relationship of the variables. Nine variables were analyzed in the study. Statistical analyses were implemented through the IBM Statistics 20 (2011).

3. Results

3.1. Students' Profile

The research participants were mostly female (69%) and 31% are male. Among the research participants, 20% were from the STEM track, 35% GAS, 24% HUMSS, 14% TVL, and 7% ABM. In general, 20% belonged to the STEM track and 80% were from non-STEM tracks. All the research participants passed the college entrance science part.

3.2. Students' Scores

The mean score for the CU test was 71.90 and the standard deviation was 4.94. Notably, the average score is low and the 69, 72, and 73 scores got the highest percentage (Figure 2). The passing score in the study setting is 75 and it can be observed that 33% of the research participants passed the CU test. Non-STEM graduates or under prepared students experienced difficulty in the topic as reflected in the scores.

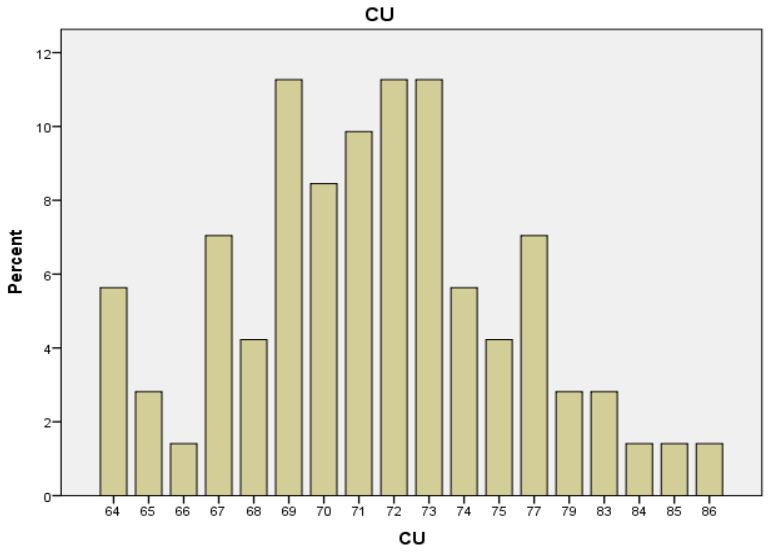

Figure 2. Scores in CU of the students

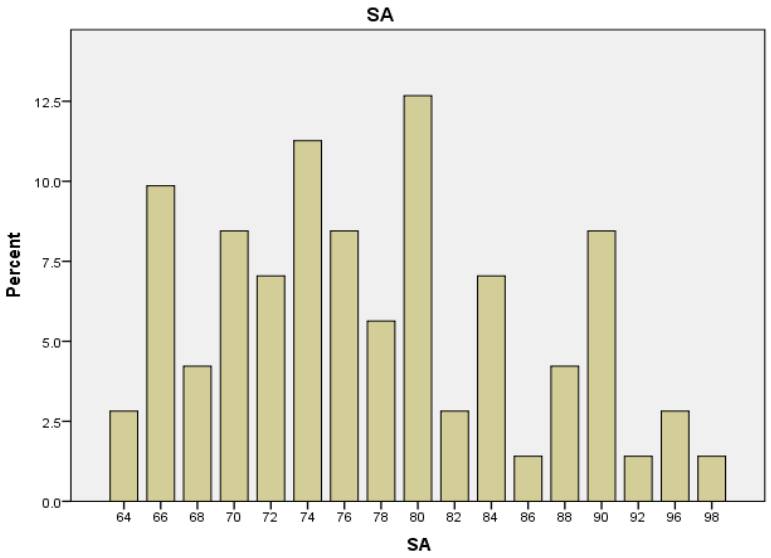

Figure 3. Scores in SA of the students

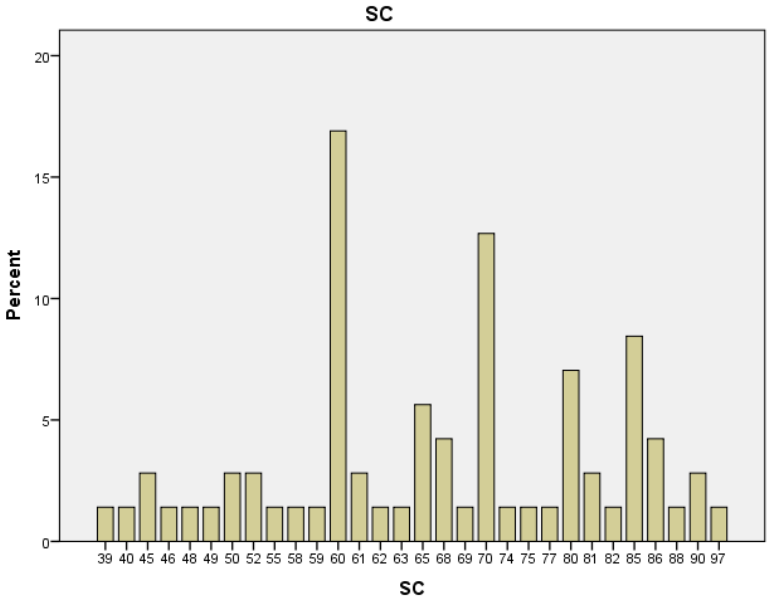

Figure 4. Scores in SC of the students

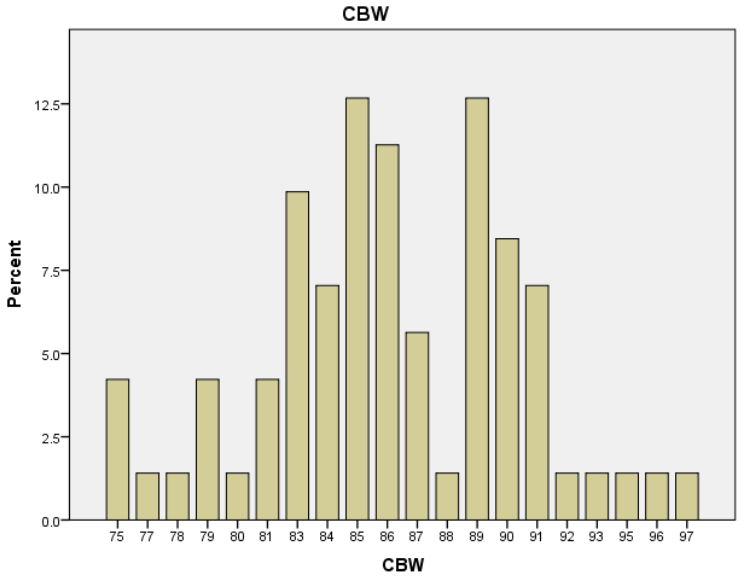

Figure 5. Scores in the CBW of the students

Further, the average score in the SA test was higher at 80, standard deviation of 3 and majority or 68% of the students passed the test. Figure 3 show the highest percentage was the average score. The SA test involves pictures of molecules and objects that are rotated at a specific axis, the students manage to rotate the objects despite of their sex and prior knowledge.

The students rated their SC with a median score of 68. The highest percentage was at 60. The scores were widely distributed as shown in Figure 4.

All of the students had a passing score in the CBW with an average score of 86 and low standard deviation of 4. The peer leader and members interacted in the group and manage to produce accurate outputs as reflected in Figure 5.

3.3. Group Interaction and Problem-Solving Approach of the Students

The peer groups were observed during the workshops and were rated as a group. Among the 10 groups, 4 groups or 4% had individual-oriented interaction. There was less student-to-student interaction and the peer leader do most of the talking and sets the direction for the group. The 6 groups or 6% had collaborative interaction or the peer leader plays the content expert and intervene only when needed. The members were actively participating by explaining or discussing among the group members [20].

Further, 6 groups or 6% had simple problem-solving approach where the group works to get the answers to the worksheet questions, but does not go beyond solving problems in order to discuss concepts or theories. While the 4 groups had elaborated problem-solving approach where the students discuss the concepts behind the problem and the peer leader addresses a particular solution to the problem [20].

3.4. Correlation Analysis

The Pearson correlation coefficient between CU score and SA score showed significant positive correlation. The r value for the paired factor was 0.575. Positive correlation existed between college entrance test SS score and SC rating (r = 0.435). Further, the CBW score was positively correlated with the SA score (r = 0.659). However, significant negative correlation existed between the SHS track and the variables CU score, SA score, SC rating, CBW score, GI category, and PSA category. The r values for the six paired factors were -0.568, -0.814, -0.661, -0.665, -0.357, and -0.480 respectively.

4. Discussion

The SA score showed significant relationship with the CU and CBW score. The finding suggests that SA specifically, the ability to rotate mentally molecular models predicted the CU score. A study conducted among adolescent students suggested that the spatial skills monitored in the students will predict their success in the STEM arena [33]. Further, an Earth Science educator noted that students who could perform mental rotation can acquire accurate concepts in the subject [34]. The CBW introduced 3 applications that helped the students visualize the molecular model in 2D and 3D. The molecules were introduced in increasing difficulty. The first 2 worksheets covered simple molecules without nonbonding electrons and the molecules strictly followed the Octet Rule. The difficulty was increased as the students covered Worksheets 3 to 7. The assistance of the peer leader and interaction in the peer group enabled the students to produce accurate molecular models that led to the high score in the CBW.

Positive correlation existed between the college entrance test science score (SS) and SC. The SS score is an indication of prior knowledge in science, a study on the capacity of students to learn computer related lesson showed that students with high self-concept and adequate prior knowledge on computer manipulation achieved higher score in the in the retention test [35]. The scope of the college entrance test in science in the study covered science concepts from Grade 7 to 10. The students were given equal opportunity to pass the test whatever track or strand they have taken in SHS.

Negative correlation existed between all the variables except sex and SHS track, what could be the explanation of the result? The students were classified into 1 (STEM), 2 (TVL), 3 (GAS), 4 (HUMSS), and 5 (ABM). The order was according to decreasing mean score in the college entrance science score. The mean scores of the students per strand or track are 90.6, 89.1, 88.6, 87.5, and 87.0 respectively. Suggesting that prior knowledge is inversely proportional with the order.

An investigation of the SHS curriculum revealed the academic strands require Earth and Life Science and Physical Science as Core Subject, the subjects are given for 80 hours (lecture and laboratory) every semester. Along with science are other core subjects whose total number of hours is 1,200 hours in the SHS. The specialized subjects for each track have a total number of 1,280 hours in the SHS. Of the academic tracks, only the STEM track had General Chemistry 1 and 2 as specialized subjects - STEM Track 7 and 8 [36].

The negative correlation of SHS track or strand on the CU and SA scores confirmed the preparedness of the graduates from the STEM track on chemical bonding. As mentioned earlier, learning chemical bonding is a sequential process [2]. Students self-concept is affected by his preparation to the subject [17]. The inverse proportionality of self-concept rating and SHS track proved that uncertainty or anxiety exist when a student presumes under preparedness.

The CBW required calculation and interpretation of chemical bonding parameters and construction of accurate molecular model. The essential skills needed in answering the activities in the CBW are cognitive (conceptual understanding), affective (self-concept), and psychomotor (spatial ability). Negative correlation on the variables SHS track and CU, SA scores and SC rating were established in the statistical analysis. Therefore, the negative correlation between SHS track or strand and CU and SA score and SC rating confirmed that limited CU and SA and low self-concept produces low score in the CBW.

Group interaction was coded as 1 (individual-oriented interaction) and 2 (collaborative interaction) while problem-solving approach as 1 (simple problem-solving approach) and 2 (elaborated problem-solving approach).

The student coded as 1 in group interaction belonged to a group that was observed to have less student-to-student interaction with a dominant peer leader or peer member who does all the talking. While those coded with 2 are in a group with observed student-to-student interaction and equal chances were given to each member to talk or interact in the group. The negative correlation predicted that most of the STEM graduates interacted collaboratively in the group because they know the topic and were confident to share their idea to the group.

Problem-solving approach was coded as 1 (simple problem-solving approach) and 2 (elaborated problem-solving approach). The negative correlation showed that most of the STEM graduates belong to a group that went beyond the task of looking for the right answer. These students were able to apply the principles and offered alternative solution other than what was given in the lecture as observed by the teacher-researcher.

The sex of the research participants was not associated to any of the variables. The probable reason is the balance distribution of the gender or sex in the SHS track. The study differs on the result suggesting female students have significantly higher self-concept [31]. The association between SC and SA was not observed in the study. Differing to the study that related significant difference in the manner female students solve problems as compared to their male counterparts [37].

The results and findings in the study may serve as basis for examining the CHED Memo. Order No. 105 series of 2017 because mismatch in the SHS track and course taken in college cause low performance and frustration among students in the tertiary department. The provision of bridging courses must be considered to provide remediation measures to under prepared students. Further, the topics Lewis Structure, VSEPR, resonance, dipole moment and hybridization had the lowest scores in the CU and SA. Revision of the PLTL 7e must be done to emphasize the topics mentioned. Lastly, the PLTL 7e CBW was implemented to a diverse group of students enrolled in Inorganic Chemistry, the situation is unique because of the recent implementation of the K to 12 program in the Philippines. Results may vary when the CBW will be implemented to a different set of students.

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