Multiple Intelligence Theory in a Science Classroom: A Study to Understand Student Preferences in Relating and Understanding Fundamental Concepts in a General Chemistry Classroom

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ABSTRACT

Current trends in science learning emphasize the integration of Howard Gardner's Multiple Intelligences Theory to improve the science curricula. This paper compares the effectiveness of Linguistic, Logical-Mathematical, Bodily-Kinesthetic, Spatial-Visual, Interpersonal, and Intrapersonal intelligences from Gardner's list of multiple intelligences in a chemistry classroom. A blend of Peer-Led Team-Learning (PLTL), online homework, laboratory, and lecture-based learning was studied to determine if the students benefit from a multi-modal approach to learning. The participants in this study included 140 City College of New York students that were enrolled in General Chemistry II (10400). The study obtained data through a Likert scale questionnaire, an open-ended survey, and individual interviews. The results showed that the students learned and retained information better when learning through different modalities. It is suggested that the science curricula can be improved if the Multiple Intelligences are observed, studied and consciously integrated to serve an increasing population of students who are unable to learn effectively and optimally in a lecture-based classroom.

INTRODUCTION

Multiple Intelligences Theory

Howard Gardner first introduced his theory of Multiple Intelligences in *Frames of Mind: The Theory of Multiple Intelligences* (1). His theory approached learning from a student-centered view, a fitting viewpoint for an increasingly diverse student population (2). Intelligence is influenced by an array of bio-psychosocial factors. These factors include personal experiences, motivation, cognitive abilities, the social environment, and culture. Gardner's *Frames of Mind* lists seven intelligences: Linguistic, Logical-Mathematical, Bodily-Kinesthetic, Spatial-Visual, Interpersonal, Intrapersonal, and Musical. More recently, Gardner added Naturalistic intelligence and proposed that an Existential intelligence may also exist (3). According to his theory, intelligence is not hierarchical – i.e., no individual intelligence is better than the other. Rather, these intelligences work together or independently to meet the needs of the individual to learn and retain information.

The current system of instruction places a premium on the Linguistic and Logical-Mathematical intelligences and both are heavily tested in intelligence tests (3). Linguistic intelligence refers to one's ability to acquire new languages, as well as use language to accomplish a goal (such as public speaking). Linguistic intelligence includes both verbal understandings as well as word facility. Word facility refers to an individual's ability to generate a number of words within a given period that meet a particular condition (e.g., words that rhyme, or words that start with the same letter). Verbal understanding is the ability to understand disparate meanings of individual words as well as their usage within a given context. This applies to both written and spoken words (3).

Logical-Mathematical intelligence, as defined by Gardner (3), is described as the ability to perform mathematical problems analytically and logically. Individuals who score high on this type of intelligence have an increased capacity to reason and study problems, as well as to conduct scientific investigations.

A high aptitude to use the body intelligently, either specific parts or the whole is Bodily-Kinesthetic intelligence. The intelligence of artists, dancers, and actors, and also surgeons, mechanics, and other craftsmen are prescribed within this category. Surprisingly, Gardner's view does not differentiate between fine motor skills - dexterity involving the hands or fingers, and gross motor skills - movement of the entire body.

Interpersonal intelligence looks at an individual's cognition of the needs, intentions, emotions, and motivations of others. High scoring individuals in this category thrive in group settings, are able to work effectively and adapt to different situations because of their ability to understand both verbal and nonverbal social cues.

Intrapersonal intelligence is the ability to understand the self. This includes understanding one's own desires, needs, fears, motivations, strengths, weaknesses, abilities, and decision-making skills. Essentially, individuals with a high score in this intelligence have a concise concept of self and are usually expected to have high self-esteem (3).

Musical intelligence encompasses musical knowledge, as well as an appreciation for musical patterns. Musical intelligence also includes recognizing rhythm, pitch, and timbre (tone). The ability to appreciate and distinguish between different tones and rhythms is a key factor for this type of intelligence. Gardner notes that this kind of intelligence requires some musical training.

Naturalistic intelligence includes identifying and categorizing various objects or stimuli. Individuals with high Naturalistic intelligence are able to assign objects to different categories based on minute differences. Examples of such individuals include bird watchers who can identify different species of birds, car aficionados who are able to recognize the make and model of a car simply from hearing engine sounds, and botanists who can classify plants through observation. Compared to other intelligences (except Musical and Existential), Naturalistic intelligence is more concrete and usually relates to a particular skill, whereas the other intelligences are harder to detect and involve abstract thought.

Individuals who score high in Spatial-Visual intelligence can readily identify visual patterns. These individuals can mentally rotate visual objects and correctly predict new conformations established after rotation. Spatial-Visual intelligence has two subcategories: spatial visualization and spatial scanning. Spatial scanning is the ability to follow a path (such as a map) visually or scan one's field of view for a particular pattern or object. Spatial visualization is the capacity to visualize movement of a theoretical object, (3) mentally.

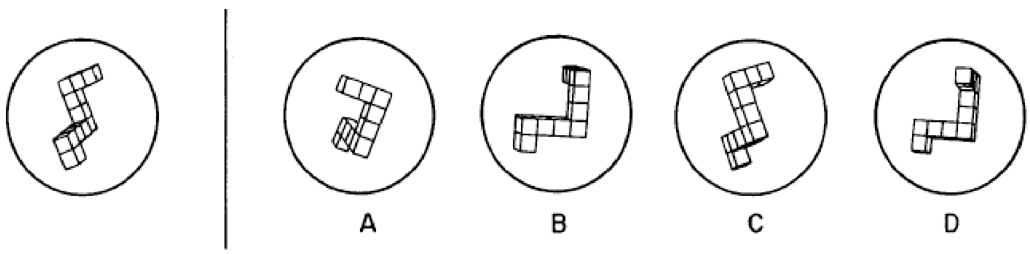

Figure 1 Sample question from Purdue Spatial Visualization Test: Rotation (PSVT:R), adapted from the Shepard-Metzler (S-M) Rotations test.

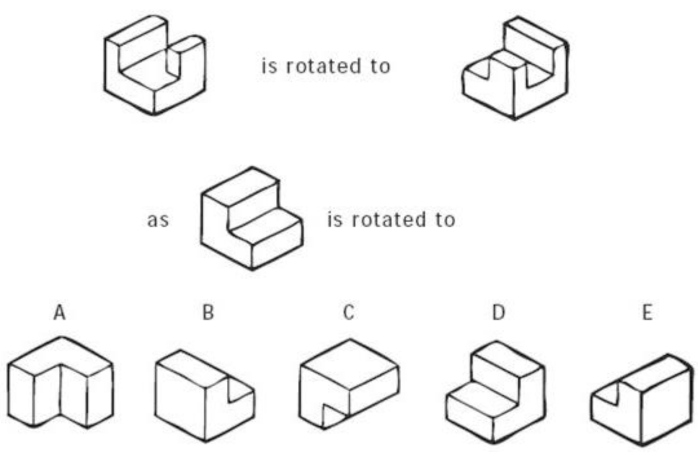

Figure 2 Sample question from Purdue Spatial Visualization Test: Rotation (PSVT:R), item 7 from the 20 item version of the ROT test.

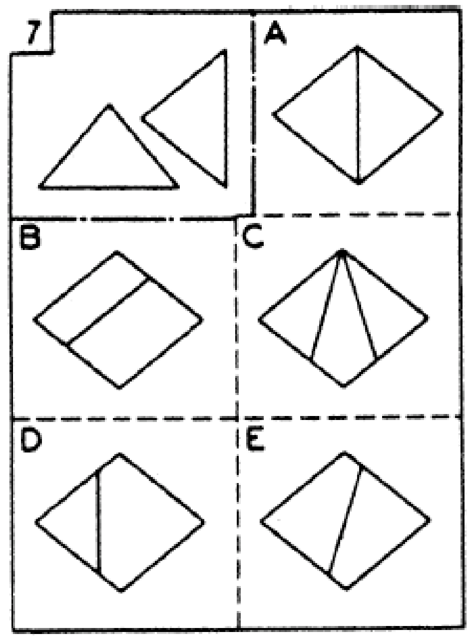

Figure 3 Sample question from Purdue Spatial Visualization Test: Rotation (PSVT:R), adapted from the MPFB test (Combine the shapes on number 7 to make a square).

History of Chemistry Teaching

Chemistry, for most of the 18th century, remained a subsection of medicine. It was not until 1750, with the advent of the Industrial Revolution, that William Cullen at the University of Glasgow began teaching chemistry as it is understood today. Following Cullen, Joseph Black (1728 – 1799) pushed for a more structured instruction of chemistry to undergraduate students. In fact, many students who studied under Black were among the first professors to teach at universities in the United States! Among them was Benjamin Rush, who taught chemistry at Philadelphia University, and John Maclean, who taught chemistry at Princeton University. Black's method of teaching chemistry was so concise and well thought out that his notes remained in circulation until 1936! In short, chemistry education grew out of the Industrial Revolution era alongside public interest in the field (4).

Johnstone (4) first stumbled upon the idea that chemistry teaching needed to change when he uncovered sets of notes from 1900 that were *identical* to the notes used in 1960. He describes his finding as "chemical time [having] stood still for over half a century, [and] nothing [having] changed." He wondered why students were uninterested in chemistry and asked: "Could it have been that we had taken too much care over the chemical part and had not thought about the education part?" Essentially, in taking care not to violate the "corpus of chemistry," instructors relinquished opportunities to make the material more tangible and relatable to students.

Johnstone (4) wrote that many chemistry teachers had turned to psychology as an aid in teaching. He stated, “Every student constructs his own knowledge in his own way. Knowledge cannot be passed intact from the head of the teacher to the head of the student.” Many researchers support this idea of students constructing their own knowledge of the material taught (student-centered teaching) rather than a traditional method of teaching where students are simply expected to memorize the material (5-7). Spencer (7) broke down the role of the instructor and the role of the student, as observed in the traditional and student-focused settings. Table 1 and Table 2 set forth the mindset behind each model.

Table 1 The Role of the Student (7).

Traditional	**Student-Focused**
Asks for the “right” answer	-Explains possible solutions or answers and tries to offer the “right” explanations -Tries alternative explanations and draws reasonable conclusions from evidence -Has a margin for related questions that would encourage future investigations
Has little interaction with others	-Has a lot of interaction and discusses alternatives with other companions -Checks for understanding from peers
Accepts explanation without justification	-Is encouraged to ask questions such as “Why did this happen?” or “What do I already know about this?” -Is encouraged to explain other student’s explanations
Reproduces explanation given by the teacher/book	-Tests predictions and hypotheses -Uses previous information to ask questions, propose solutions, make decisions and design experiments.

Table 2 The Role of the Instructor (7).

Traditional	**Student-Focused**
Lectures	Acts as a consultant for the students
Explains Concepts	Asks probing questions of students to derive concepts
Provides definitive answers	Elicits responses that uncover what the students know or think about the concept
Tells the student they are wrong or right	Provides time for students to puzzle through problems

Traditional	Student-Focused
Explains to students step by step how to work out and solve a problem	-Allows students to assess their own learning and promotes open-ended discussion -Refers students to the data and evidence and helps them look at trends and alternatives -Encourages students to explain other students' concepts and definitions in their own words

Johnstone (4) concluded that in order to advance the instruction of chemistry, given that it is a fundamental aspect of a general education, three things must be re-evaluated:

- The nature and structure of teaching chemistry,
- The presentation and methods of teaching chemistry, and
- The learning processes of teaching chemistry.

Only when these three aspects are taken into account will a better method of instruction emerge to make the subject matter more salient to students.

Multiple Intelligences Theory and Chemistry Teaching

Chemistry is a visual science and training in Spatial-Visual skills improves student performance in the class (8-12) came to this conclusion after observing a number of students approach the balancing of a chemical equation. They observed that where chemists see a chemical reaction as the reaction represented by an equation, students saw the reaction as a mathematical equation that needs to be fixed. They proposed adding a computer-based visualization tool (specifically an online homework component) as well as a laboratory setting (which would utilize Bodily-Kinesthetic and Spatial-Visual intelligences).

Spatial-Visual intelligence is applied to understanding chemistry as spatial orientation and spatial visualization (13). Spatial orientation pertains to the ability to rotate a stimulus mentally and obtain the correct result. Spatial visualization is the ability to organize, retain, and recall configurations of particular molecules in rotatory motion, such as the R and S configurations in organic chemistry (14). Oliver-Hoyo and Babilonia-Rosa (10) noted that when special attention is given to teaching spatial skills, students and teachers are better able to learn spatial skill concepts that are fundamental to organic chemistry.

Another study, developed by Baker and Talley (15), concluded that to excel in a chemistry classroom, visualization of chemical reactions is critical to understanding and analyzing chemical concepts. This study looked at the Spatial-Visual aspect of the Multiple Intelligences Theory and found that integrating this intelligence (in addition to the standard Linguistic and Logical-Mathematical intelligences) improves students' understanding of the concepts. Baker and Talley theorized that the underlying factor for students failing to master basic chemistry skills and concepts was due to their inability to visualize these concepts.

Recently, Conway (16) conducted a study to assess the difference in learning when students are taught in a lecture-based classroom versus a guided-inquiry style of learning. Conway based her study on research that indicated that group learning is more conducive for learning compared to a traditional lecture. She hypothesized that group learning facilitates discussion among students about the problems and helps them better synthesize and memorize the information. In her study, guided learning led to an overall positive shift in the class grade. Feedback from students at the end of the year showed an overwhelming enthusiasm for the guided-inquiry method of learning. Stockwell, Stockwell and Jiang (17) found that even when students stated that they did not prefer to learn as a group, they did better when tested individually after they learned in a group setting. They found that when students were asked to solve novel problems, they did better after participating in group learning. They hypothesized that students understood the material at a deeper level when asked to collaborate in small groups.

RESEARCH HYPOTHESIS

This study asks if the integration of many of the intelligences from the Multiple Intelligences Theory in a science classroom would enhance students' learning. Much of the existing research conducted in chemistry focuses solely on one aspect of the Multiple Intelligences Theory - Spatial-Visual intelligence. This study looks at the other intelligences already present in a chemistry classroom. A general chemistry classroom has several of the intelligences of the Multiple Intelligences Theory incorporated in its pre-existing curriculum. These components include lecture setting, textbook assignments, Peer-led Team-learning (PLTL), online learning and laboratory work.

A typical lecture setting utilizes Linguistic and Logical-Mathematical Intelligences. The textbook assignment uses both Interpersonal and Linguistic intelligences. Interpersonal skills are developed during group activities in peer-led workshops. Finally, a laboratory setting employs bodily-kinesthetic and spatial-visual intelligences. This study looks at student preference for methods of study that helped them retain information.

METHODS

Materials

Information for this study was obtained using three methods. Anonymous Likert scale and open-ended questionnaires were provided to all participants. Students chosen at random were interviewed to gain a more thorough understanding of their answers to the open-ended questionnaire.

The Likert scale questionnaire included two to four questions for each section of the six intelligences (Linguistic, Logical-Mathematical, Bodily-Kinesthetic, Spatial-Visual, Interpersonal, and Intrapersonal). The five-point scale for the Likert questionnaire is as follows: (a) mostly disagree, (b) slightly disagree, (c) neutral, (d) slightly agree, and (e) mostly agree. Each question was then averaged to collect data on the type of intelligence that students utilized and learned from optimally.

Table 3 Questions used in the Likert questionnaire.

Statements	Type of Intelligence
It is easy to write papers	Linguistic
I like word searches.	
I enjoy reading the textbook.	
It is easier for me to obtain information from the textbook rather than a lecture.	
It is easy for me to remember telephone numbers.	Logical-Mathematical
My favorite subject is math.	
Chemistry problems help me learn the theory better	
I like solving chemistry problems.	
I can solve problems better when I am moving around.	Bodily-Kinesthetic
I have good hand-eye coordination.	
I like being outdoors and playing sports.	
I remember theories better in lab.	
I like seeing the chemistry molecules in 3D on the computer.	Visual-Spatial
Picturing an object in 3-D helps me learn better.	

Statements	Type of Intelligence
My friends always come to me for advice.	Interpersonal
I like group work and team sports.	
I am good at helping others solve their disagreements.	
Peer-led workshops were helpful.	
I learn better in workshop through my peers.	
I like working by myself.	Intrapersonal
Workshop was not helpful.	
I like working by myself.	
I like setting goals and planning for the future.	

To better understand which of the multiple intelligences students prefer to learn fundamental chemistry concepts, an open-ended short answer questionnaire was provided to the participants. The survey consisted of seven questions, each targeting a different aspect of the study. The open-ended questions were utilized to gauge what the students' personal opinions were about the different modalities – in this case: PLTL, online homework, lecture, and laboratory work. A rubric scaled their results on a scale of one to five. One was given to answers that were completely negative, while five was given to answers that were completely positive. Two was given if students provided an overall negative answer but included something positive in their response, and a four was scored if the answer was overall positive but included something negative. Finally, a score of three was given if the answer was completely neutral.

Table 4 shows the questions as presented to the students. Each question was scaled as per the previously mentioned rubric. Question 8 took students' answers and grouped them in categories of student preference.

Table 4 Questions used in the open-ended survey.

Question
1. How do you study when you are by yourself? Is it helpful? 2. How is attending lecture helpful?
3. Please explain if working in a group helps you? How? 4. Did you like workshop (PLTL)? Why? 5. Why are weekend reviews helpful?
6. Does doing the lab activities help you learn the theories from class better? How has it helped you?

Question
7. Is online homework helpful? Why? 8. List a couple of aspects of the class that helped you learn the most and pushed you to do better in class (i.e., PLTL, lab, lecture, online homework, textbook, etc.).

Finally, interviews were conducted with ten students chosen at random. The interviewer asked the same questions posed in the open-ended survey. The interview allowed the student to freely discuss the answers and permitted follow-up questions to the survey that may not have been expanded upon or were unclear in the general questionnaire.

For the purposes of this study, Musical and Naturalistic intelligences was not tested or evaluated.

Procedure

The procedure for conducting this study is as follows: During the last month of classes, the Likert-type survey was distributed to the students after collection answers were analyzed. After one week, the open-ended questionnaire was distributed. Interviews were conducted on the following few days. Data collected from all three methods were analyzed.

DATA ANALYSIS, RESULTS, AND DISCUSSION

Participants

The participants in this study were selected by a convenience sampling of students enrolled in General Chemistry II in Spring 2012 at The City College of New York (CCNY). The average age of the participants is 21.1 years of age, ranging from 17 to 44. There were a total of 77 (55%) females and 63 (45%) males surveyed (n=140). Moreover, there were a total of 39 Freshmen (27.8%), 48 Sophomores (34.3%), 29 Juniors (20.7%), 9 Seniors (6.4%), and 15 Other (10.8%) – which included students in their 5th year, second degree, post-bac, and part-time students.

It was expected that the participants would learn more in group settings and use their Interpersonal intelligence to a greater extent than the Bodily-Kinesthetic scales of intelligence. As predicted, students averaged higher in the Interpersonal intelligence scale (4.12). The lowest score was seen in the Bodily-Kinesthetic intelligence (2.5) as seen in Figure 4.

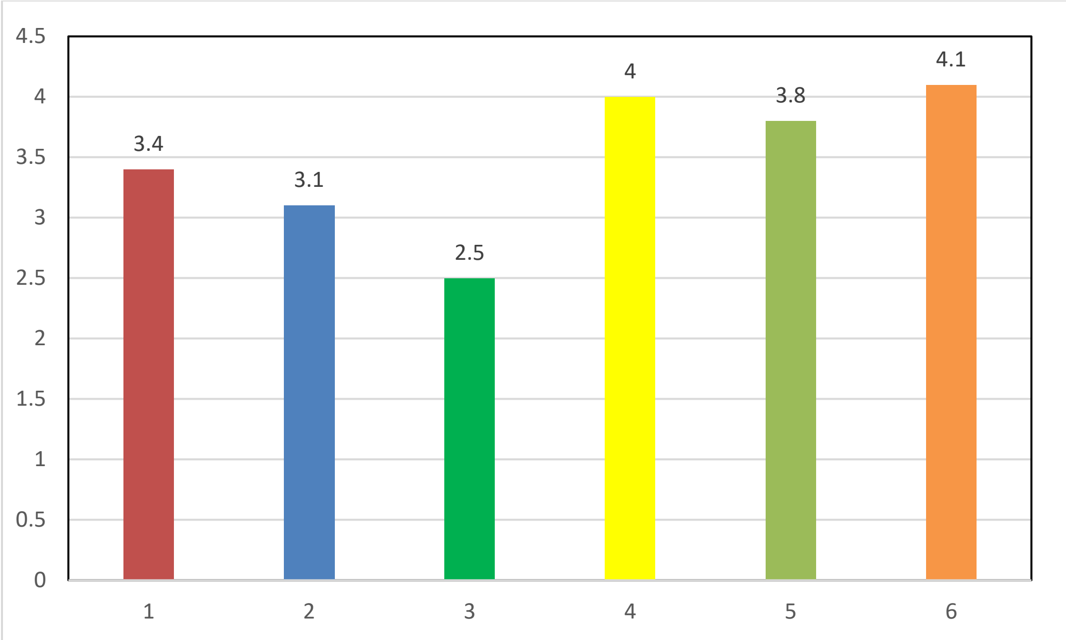

Figure 4 Averages of Multiple Intelligences students used to learn fundamental concepts in general chemistry (Likert-Type Questionnaire).

The lack of use of visualization and computer simulations in general chemistry is clearly demonstrated in the students' responses to the Likert-type questionnaire, where the spatial-visual intelligence score is 2.5. It is noteworthy that linguistics and logical-mathematical intelligence scores are well below that of bodily-kinesthetic, interpersonal, and intrapersonal. PLTL students stated, helped them visualize reactions better. Additionally, PLTL also aided students by interacting with others; they were able to notice their mistakes and learn from their peers – which is a more useful learning tool. This is evident by the interpersonal intelligences being ranked highly. The lab part of the course plays a significant role in addressing the bodily-kinesthetic intelligence.

Figure 5 represents the average scores on the short answer open-ended questionnaire. As can be seen in the graph, students found PLTL to be the most helpful learning tool (Questions 3 and 4). The second most helpful learning took the online homework (Question 7). Finally, a third helpful learning tool for this sample size was weekend review sessions (Question 5). It is important to note that laboratory work (Question 6) was viewed as least helpful in making the chemistry theories learned in class more salient and easily recalled.

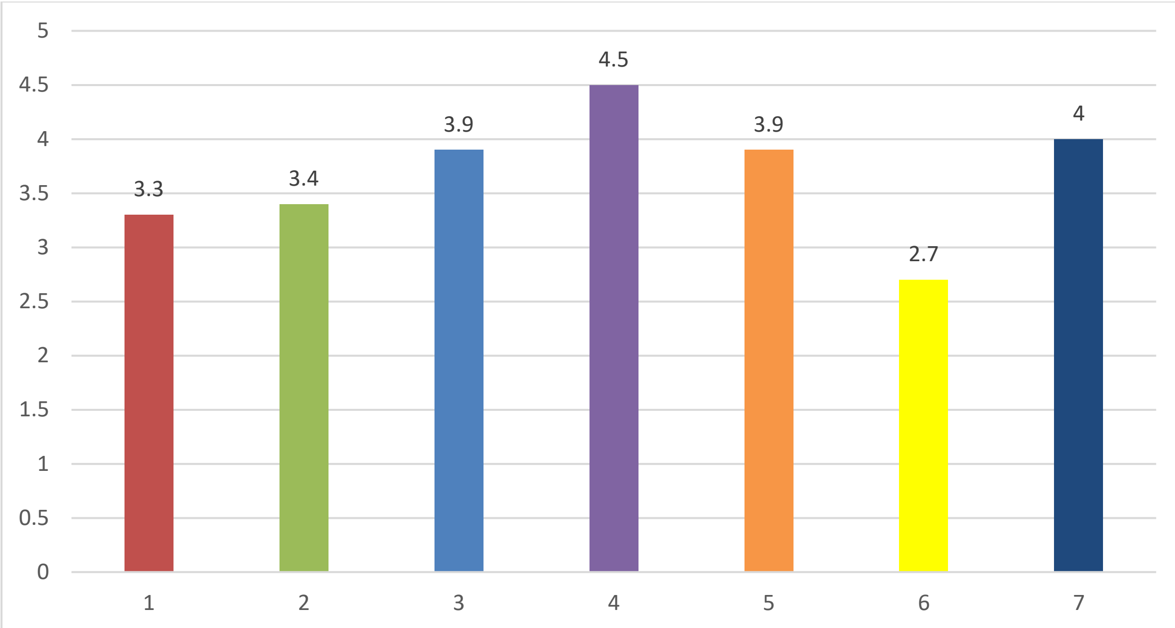

Figure 5 A plot of question number versus average number of responses for the open-ended questionnaire.

Figure 6 is a pie chart depicting the students' responses to Question 8, which asked which aspect of the class they found to be the most helpful in them succeeding in the course.

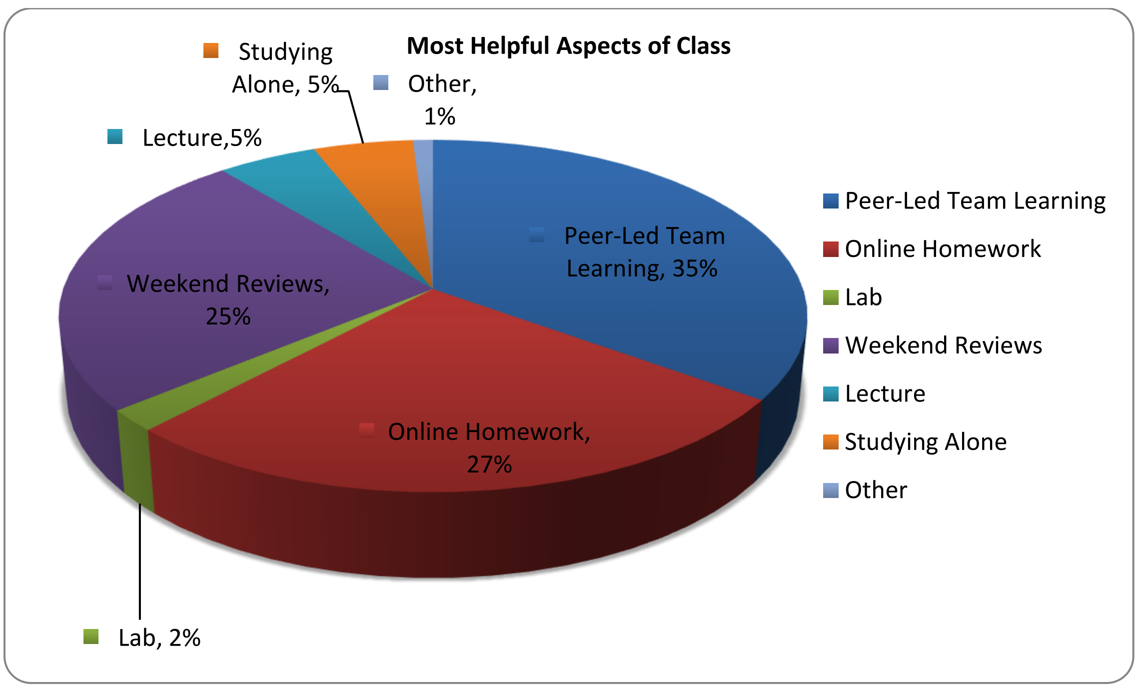

Figure 6 Most helpful aspects of class pie chart.

The most interesting result from the pie chart is that the students do not value the lecture and laboratory part of the course. Most traditional courses are taught with lecture and laboratory components. Students value group studying activities such as PLTL and using online resources, which seems to be their comfort zone.

On average, the students expected a B/C grade, with most of the students surveyed having missed lectures 1 - 3 times during the semester. In reviewing the open-ended answers, many students stated they had a difficult time relating the laboratory work to the theories learned in class, which may also be a factor as to why Bodily-Kinesthetic intelligence could be low. Furthermore, a number of students stated that they preferred working by themselves, reading their own notes and textbook chapters, but that Peer-Led Team Learning was one of the most helpful aspects of the class. The workshop, they stated, helped them visualize reactions better and also aided students in interacting with others. They were able to note their mistakes and learn from their peers. This is evident by Spatial-Visual and Intrapersonal intelligences being ranked as the second and third highest scores (3.96 and 3.78, respectively).

CONCLUSIONS

A universal definition of intelligence does not exist. Consequently, there should be a move from the idea that all individuals only learn in a typical classroom and textbook setting. Students come to the classroom skilled in various ways of learning. Each of these different methods of learning should be observed and studied in-depth to understand the most optimal method of instruction. A more comprehensive teaching style incorporating multiple types of intelligences as described by Gardner (1), is advised. Current studies focus on only one aspect of Multiple Intelligence Theory - Spatial-Visual intelligence. Although it is a step in the right direction, a more comprehensive integration would be more beneficial to a wider range of students. Integration of Linguistic, Logical-Mathematical, Bodily-Kinesthetic, Spatial-Visual, Interpersonal, and Intrapersonal through existing, cost-effective programs like peer-led workshops, laboratory settings, and online homework make the application and study of Multiple Intelligence easier now more than ever.

Future studies can be done to look at the benefits of including workshops such as the current peer-led workshop available for chemistry to other classes and other departments overall. Studies can also look at how various intelligences are used in other chemistry classes. Observing organic chemistry classes using the methods outlined in this paper may provide unique results that add to the results seen in a general chemistry classroom. The science classroom itself can become less lecture-based and include sections of time where students solve problems in small group settings.

The advent of technology and the availability of online videos such as Khan Academy to learn chemistry and other sciences opens up the undergraduate classroom for more collaborative work. By exposing students to different learning styles and environments, the student might be better able to retain and apply information learned in the classroom.

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REFERENCES

1. H. Gardner, Frames of Mind: the Theory of Multiple Intelligences. London Press, Fontana (1993). (Originally published in 1983).
2. P. Daniels, (2010). An Overview of Gardner's Multiple Intelligences, Kagan's Structures and Tomlinson's Differentiated Instruction and Their Correlation to Nunley's Layered Curriculum. Dr. Kathie Nunley's Layered Curriculum Web Site for Educators. (2010). Help4teachers. Web. 01 Dec. 2011. http://help4teachers.com/PatPaper.htm.
3. H. Gardner, Intelligence Reframed: Multiple Intelligences for the 21st Century. New York: Basic (1999).
4. A. H. Johnstone, J. Chem. Educ. 70(9), 701 (1993).
5. D. Gabel, J. Chem. Educ. 76(4), 548 (1999).
6. D. Kember, Learn. and Instru. 7(3), 255 (1997).
7. J. N. Spencer, (1999). J. Chem. Educ. 76(4), 566 (1999).
8. M. Harle and M. Towns, (2011). J. Chem. Educ. 88(3), 351 (2011).
9. J. H. Mathewson, Sci. Educ. 83(1), 33 (1999).
10. M. Oliver-Hoyo and M. A. Babilonia-Rosa, J. Chem. Educ. 94(8), 996 (2017).
11. M. D. Patrick, G. Carter, E.N. Wiebe, J. Sci. Educ. Technol. 14(3), 353 (2005).
12. H. Wu, and P. Shah, P. Sci. Educ. 88(3), 465 (2004).
13. C. L. Habraken, J. Sci. Educ. Technol. 13(1), 89 (2004).
14. S. L. Coleman and A. J. Gotch, J. Chem. Educ. 75(2), 206 (1998).
15. S. R. Baker and L. Talley, L. J. Chem. Educ. 49(11), 775 (1972).
16. C. J. Conway, J. Chem. Educ. 91(4), 480 (2014).
17. B. R. Stockwell, M. S. Stockwell, E. Jiang, E. ACS Cent. Sci. 3, 614 (2017).