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Vygotskian Based Grouping: Utilizing the Zone of Proximal Development in a Chemistry Laboratory

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Vygotskian Based Grouping: Utilizing the Zone of Proximal Development in a Chemistry Laboratory

by

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To my beautiful wife, Dawn, for her patience, love, and prayers.

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Vygotskian Based Grouping: Utilizing the Zone of Proximal Development in a Chemistry Laboratory

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A large portion of any science major's curriculum utilizes laboratories. Many of these laboratories now incorporate cooperative learning as a result of studies attesting to its beneficial effects. However, little attention has been given to the composition of those groups, specifically at post-secondary education institutes. We have therefore investigated the effectiveness of a grouping technique based on the theories of L. S. Vygotsky and his construct of the *zone of proximal development* (ZPD) in the context of an undergraduate general chemistry laboratory course at The University of Texas at Austin. All students were responsible for the completion of a short, 11 question, pre-quiz. Depending on their respective classes, students were grouped either according to the ZPD-scheme, based on pre-quiz scores, or randomly, regardless of pre-quiz score. Achievement of the students in each of the two groups was compared in order to determine grouping effectiveness. This study was carried out for 3 semesters (spring 2003, spring 2004, and fall 2004) under two different instructors. Overall, results indicate that grouping according to the ZPD-scheme revealed higher student achievement versus random grouping. Moreover, students scoring low and average on pre-quizzes benefited far more from this grouping method than higher scoring students. The protocol for implementing this grouping scheme is straightforward and is discussed in detail.

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Introduction

Currently, students obtaining an American Chemical Society (ACS) Accredited Chemistry degree are required to complete approximately 50 % of their chemistry coursework in laboratories; various other science curriculums incorporate a similar portion of laboratory instruction. It is therefore highly relevant to examine the effectiveness of those laboratories and to devise means of improving students' understanding and performance. Many of these undergraduate science laboratories now utilize group work for various reasons (i.e., cost benefits and time) and little attention has been given to the manner in which groups are composed.

Cooperative Learning

Group work, more often called "cooperative" or "collaborative learning", has been shown on many occasions to result in positive effects in students' commitment to learning and responsibility towards coursework (Johnson, Johnson, and Holubec, 1994). In fact, several quantitative studies have been reported comparing cooperative learning and individualistic learning situations on a variety of tasks (Humphreys, Johnson, and Johnson, 1982; Johnson, Johnson, and Skon, 1979). One such study was carried out with 44 ninth grade physical science students for a period of two weeks. The results of that particular study "indicate that in both mastering and retaining the information being taught, having students work cooperatively has more positive impact than does having students work competitively or individualistically" (Humphreys, Johnson, and Johnson, 1982). Collaborative learning has also been found to improve students' overall attitudes towards science classes (Bowen, 2000). Indeed, Johnson, Johnson, Holubec, and Roy maintain from systematic study that the demonstration of five essential elements in a cooperative learning environment (positive interdependence, face-to-face interaction, individual accountability, small-group/interpersonal skills, and group self-evaluation) can help result in overall positive effects (Johnson, Johnson, Holubec, and Roy, 1984). Another researcher, Doolittle, has presented several guidelines for better utilizing cooperative learning environments and those are listed, verbatim, here:

- Teach using whole (not decontextualized components) and authentic activities.
- Create a need for what is to be learned.
- Utilize activities or exercises that require social interaction.
- Provide opportunities for verbal interaction.
- Monitor student progress.
- Provide instruction that precedes a student's development.
- Use instructional scaffolding.
- Provide opportunities for students to demonstrate learning independent of others.

- Construct activities that are designed to stimulate both behavioral changes and the congnitive/metacognitive changes upon which they are built (Doolittle, 1997).

Not only are these elements and guidelines present in the majority of undergraduate laboratories, activities which utilize these closely resemble experiences that aid in a students' future job training. The acquisition of the skills obtained from a laboratory with the proposed elements and guidelines would be of importance to a chemist's employability and success in the market (Johnson and Johnson, 1989; Tobias, Chubin, Aylesworth, 1995).

Zone of Proximal Development

Upon consideration of a cooperative learning environment one may inquire about the nature of group composition. One such grouping method has been alluded to in the theories of L. S. Vygotsky, and in particular his construct of *the zone of proximal development* (ZPD), which is defined as "the distance between the actual development level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (Vygotsky, 1978). Doolittle more recently has expanded on Vygotsky's ZPD: "Through social interactions with more knowledgeable others, such as more advanced peers and adults, children [or students] eventually develop higher mental functions" (1997). The individual development alluded to by Vygotsky and Doolittle are the result of learning within a social context. Vygotsky stresses this learning process as an internal one, only operating "when the child [or student] is interacting with people in his environment and in cooperation with peers" (1978). "Internalization" involves the processing and modifying of experiences and the integration of a new way of thinking (Doolittle, 1997). Vygotsky thus "conceptualized development as the transformation of socially shared activities into internalized processes" (John-Steiner and Mahn, 1996). What the student must do dependently with the help of other group members later becomes the task that they may complete independently (Doolittle, 1997). The process is more richly described by John-Steiner: "… learners participate in a wide variety of joint activities which provide the opportunity for synthesizing several influences into the learner's novel modes of understanding and participation. By internalizing the effects of working together, the novice acquires useful strategies and crucial knowledge" (John-Steiner and Mahn, 1996).

Ability Grouping

As can be seen from the definitions of ZPD, there always exists collaboration with a more advanced peer and a problem to solve. This leads us to our answer as to how a group should be composed according to the ZPD. With the necessary reliance on a more advanced peer, groups must be composed of students with different ability levels. That is, if groups were composed of students with the same ability no opportunity for growth would exist from the ZPD point of view. Much of the research which has been done with regards to mixed ability grouping results in a myriad of conflicting conclusions and emphasizes the importance of careful individualized considerations. The majority of findings reported were carried out at the secondary school level. Gamaron's research suggests ability grouping does not increase overall achievement of students (Gamaron, 1992). Hereford and Reglin conclude that ability grouping causes segregation and poor teaching (Hereford and Reglin, 1993; 1992). Some have concluded that ability grouping is especially useful for brighter students (Gallagher, 1993; Reglin, 1992) while some conclude, in secondary mathematics courses, ability grouping harms low and average ability students (Peterson, 1989). Others determined that high ability students did well regardless of their grouping method (Berliner and Casanova, 1988). Finally, Leonard in a sixth-grade mathematics course study found heterogeneous grouping to be most beneficial, particularly when significant cooperation between group members is evident (Leonard, 2001). Kulik summarized the overall situation upon a meta-analysis: "For every research reviewer who has concluded that grouping is helpful, another has concluded that it is harmful" (Kulik, 1993).

These numerous and conflicting conclusions reached by different researchers with regards to ability grouping emphasizes the need for specific research in each unique learning environment. Vygotsky may have predicted such a myriad of results: “Clearly, the problem cannot be solved using any one formula; extensive and highly diverse concrete research based on the concept of the zone of proximal development is necessary to resolve the issue” (Vygotsky, 1978).

Objective

This study incorporates the utilization of Vygotsky’s ZPD in a post-secondary school chemistry laboratory class with groups being composed of, at most, three students. Much research has been done attempting to utilize the ZPD particularly in secondary school courses and typical lecture style classes. Another researcher in support of utilizing Vygotsky’s ZPD, Hayward, has established three, minimum, guidelines for testing the ZPD: a pre-test in order to determine existing student capabilities, an experimental activity allowing the group work to take place, and a post-test following the activity to evaluate the new level of the student (Hayward, 1995). All of these aspects were present in all three semesters of this study. It was the goal of this study to determine the effectiveness of mixed-ability groups versus random groups within the context of an undergraduate General Chemistry Laboratory environment. More formally we wish to test the null hypothesis that students grouped randomly in an undergraduate chemistry laboratory course are not different than those grouped according to a Vygotskian based ZPD method.

Experimental

Sample and Instructional Format

Subjects for this work were students enrolled in "Introduction to Chemical Practice for the Life Sciences", CH 204 Alternate Version (AV), in the Department of Chemistry and Biochemistry, College of Natural Sciences, at The University of Texas at Austin. Students were typically freshmen or sophomores ranging in age from 18 to 22.

CH 204AV was created and first implemented in the spring semester of 1998 as an alternative credit course to the standard CH 204 course, "Introduction to Chemical Practices"; included in the curriculum for all engineering majors, science majors (except chemistry), and pre-medical students at The University of Texas at Austin. This alternative was primarily designed to accommodate life science students with a more relevant laboratory experience related to their specific field of study. CH 204AV was created with the following goals in mind:

- To provide a teaching environment to introduce students to authentic experiences in a modern chemistry laboratory.
- To train students in the basics of good measurement processes for common chemical practice in life sciences, and basics of computing and reporting analytical results.

- To educate students so they may infer from the experiments basic concepts of good chemical measurements in biological systems (Stewart, 2003).

CH 204AV, being a laboratory course, fundamentally consists of a series of laboratory units further divided into several specific experiments related to a broader topic. The following is a list of those units and their respective experiments:

1. Spectroscopy
    a. Spectra and Blanks
    b. Response Curves, Molar Absorptivities and Standard Curves
    c. Unknowns
2. Acids, pH, and Titrations
    a. pH Measurements and Effect of pH on Spectra
    b. Titrations of Strong and Weak Acids
    c. Use of Titrations as Quantitative Tools
3. Colorimetric Reactions, Part I
    a. Biuret Determination of Protein Concentrations
    b. Bromocresol Green Determination of Protein Concentrations
    c. Colorimetric Measurements in the Presence of Interfering Compounds
4. Colorimetric Reactions, Part II

a. Measurement of Glucose Content using the Glucose Oxidase Assay

b. Reverse Phase Chromatography and Quantification of Grape Soda Components

5. Continuous Enzyme Assays

    a. Assay of Alkaline Phosphatase Activity (Stewart, 2003).

Students were required to attend one one-hour lecture per week given by the course instructor, one four-hour laboratory period and one one-hour computer laboratory time for the purpose of working on laboratory reports, both facilitated by the teaching assistant (TA). All students were required to work in groups of three during laboratory and computer laboratory sessions (some classes however did not contain a multiple of three students and required one or two groups of two). These groups were established at the beginning of the semester and remained unchanged throughout the completion of the course. Class sizes typically consisted of twenty four students per section composed of a total eight learning groups. Each TA was responsible for two different laboratory sections and the corresponding computer laboratory sections. There were a total of ten sections per semester requiring five TAs.

CH 204AV students were responsible for the completion of periodic quizzes (generally 5-10 per semester), midterm examinations and a final examination. Practice homework sets and their respective answers were periodically provided. Review sessions were given prior to all examinations and attendance was optional. Final grades were determined according to the following rubric: quizzes were worth 5 %, midterm examinations 20 %, students team grade (assigned by a student's group members) 3 %, teaching assistant grades 5 %, written laboratory reports 42 %, and a written final examination 25 % (100 % possibility). The majority of quiz and examination material closely resembled problems encountered in the laboratory. Grades were earned individually by students with the exception of the portion obtained from written laboratory reports; these are reported on a per laboratory unit per learning group basis.

Independent Variable

In order to examine achievement differences, two grouping methods were considered within laboratory sessions: random and Vygotskian based.

Dependent Variable

Achievement of students on graded assignments and survey responses were the dependent variables.

Procedure

TAs were assigned two lab sections according to their schedules. One of those sections was designated the control group for that TA; that class was composed of groups using a random process. The other section was designated as the experimental class, and the groups were formed according to the following scheme.

All CH 204AV students were given a pre-quiz (Appendix A) as a means of assessing their chemistry knowledge coming into the course. The quiz (Appendix A) consisted of eleven total questions; nine of those were technical chemistry questions, each worth one point, related to important concepts covered in CH 204AV while the other two (not included in the pre-quiz score) were strictly survey questions which asked students to rate their chemistry knowledge and their previous group work experiences. Upon completion of the pre-quizzes, they were graded and each experimental section's scores were sorted from lowest to largest score; control sections' data were used for comparative purposes. The data for each experimental section were then divided into four groups identified as 1, 2, 3, and 4; these correspond to different ability groups defined as low-ability, low-mid, mid-high, and high-ability, respectively. The number of students in each ability group was determined by a Gaussian-like distribution based on the specific class size (Table 1). Thus, the low-mid and mid-high ability groups incorporated a larger number of students than the low and high-ability groups; in other words, on the basis of the pre-quiz score, there are more average ability students than low and high-ability students and the distribution reflects that condition.

Once students were designated as one of the four ability groups (designated as 1, 2, 3, and 4), students within each of these groups were assigned an additional identifier in the tenths place that represents that student's placement in order of increasing pre-quiz score (Table 1). This general scheme was used to precisely compose ZPD-oriented groups using specific students and their corresponding pre-quiz score in each experimental section.

Pre-Quiz Score	*Ability Group*	*Designator*	*Gaussian-like Distribution*
2.0	Low	1.1	4 students
2.0		1.2	
3.0		1.3	
4.0		1.4	
4.0	Low-Mid	2.1	8 students
4.5		2.2	
5.0		2.3	
5.0		2.4	
5.0		2.5	
5.5		2.6	
6.0		2.7	
6.0		2.8	
6.0	Mid-High	3.1	8 students
6.0		3.2	
6.0		3.3	
6.5		3.4	
6.5		3.5	
7.0		3.6	
7.0		3.7	
7.0		3.8	
7.5	High	4.1	4 students
8.0		4.2	
8.5		4.3	
9.0		4.4	

Table 1: Ability Group Classification

Upon designation of each student in all experimental sections, the composition of individual learning groups was considered. A few basic rules were employed at this stage:

- Groups consisted of three students, when possible.
- Groups never contained all students within the same ability group.
- Groups were composed only of students in adjacent ability groups.

These basic rules were instrumental in allowing us to utilize Vygotsky's ZPD concept; where students of some ability have the opportunity for "collaboration with more capable peers", those of a higher ability group. One of the rules perhaps instrumental in the success of the groups, attempts to utilize slight ability differences as opposed to large ability gaps (i.e. a low-ability student grouped with a high-ability student). The resulting groups were composed of some mixture of low-ability with low-mid (112, 122, and 122), low-mid with mid-high (223 and 233), and mid-high with high-ability (334, 334, and 344).

Placement of each individual student was then considered within the eight learning groups in each experimental section; the number in the tenths place in each student designator was utilized at this point. Table 2 reveals the resulting group compositions according to each individual student designator after examining differences of ability within each of the eight groups and for each experimental section.

Group Number	*Group Composition*		
1	1.1	1.4	2.1
2	1.2	2.2	2.5
3	1.3	2.3	2.6
4	2.4	2.7	3.1
5	2.8	3.2	3.5
6	3.3	3.6	4.2
7	3.4	3.7	4.3
8	3.8	4.1	4.4

Table 2: Group Compositions (according to student designators)

Neither the TAs nor the students were informed of their respective affiliation to a control or experimental group until completion of the semester being studied.

Once groups were formed, students completed the course and all of the corresponding course work in addition to student surveys (Appendix B); administered twice: upon completion of the first laboratory unit report and after the final examination. These surveys were intended to determine groups' laboratory completion times, levels of perceived student participation, and student's main source of help when questions arose.

Data Analysis

Data on pre-quiz scores and final grades were examined to determine if all distributions were normal. Upon verification of distribution normality, means were used as a measure of the central tendency throughout the study.

Single factor analyses of variances (ANOVAs) were performed comparing pre-quiz scores of experimental sections and control sections in order to determine whether the means were different for each individual TA and for all sections for each semester.

ANOVAs were then performed comparing final grades in order to establish significance of experimental sections versus control sections for each TA and all sections for each semester studied. In other words, to determine if the achievement of Vygotskian grouped sections was significantly different than the achievement of randomly grouped sections.

Bar graphs were constructed illustrating the differences of final grades between control and experimental sections and differences between students in each grouping method based on pre-quiz scores for each semester.

Likert scale responses on surveys were broken down according to percentages of responses and examined.

The experiment was conducted and all calculations were done for three different semesters: spring of 2003, spring of 2004, and fall of 2004. The semesters of spring 2003 and spring 2004 were both taught by the same person, “Instructor 1”, the third semester was taught by a different instructor, “Instructor 2”.

Results

ANOVA Tests

Means of pre-quiz scores and final grades were compared for experimental and control groups for each TA and across all TAs for a given semester. The spring semester of 2003 is represented as experiment 1, spring of 2004 as experiment 2, and fall of 2004 as experiment 3. Table 3 summarizes the results of each individual ANOVA: individual details of the analysis appear in Appendix D. P-values were obtained to determine whether the null hypothesis may be rejected and at what level of confidence. In this case the null hypothesis states that the two means (of the experimental and control groups) being compared are not different. For this study a p-value cutoff of 0.05 was chosen which corresponds to a 95 % level of confidence for the assertion. Therefore, a p-value of less than or equal to 0.05 implies the null hypothesis may be rejected; the means being compared are different at a 95 % confidence level or better.

Pre-quiz scores were used to identify students' course related knowledge at the beginning of each semester. It was therefore crucial to determine whether there were differences between the experimental and control groups. Pre-quiz score means were compared for each TA's experimental and control groups as well as across all experimental and control groups, denoted as "overall". Resulting p-values are listed in the pre-quiz score column of Table 3. In each case p-values are above the 0.05 cutoff and the means being compared are therefore not different. That is to say, all experimental groups and control groups are statistically the same before treatment.

TA	*N*	*Pre-quiz Score P-value*	*Final Grade P-value*
Experiment 1 (Spring 2003-Instructor **1**)			
1	*41*	0.533	0.561
2	*43*	0.764	0.074
3	*40*	0.832	**0.006***
4	*40*	0.674	0.299
5	*42*	0.097	0.599
Overall	*206*	**0.761**	**0.025***
Experiment 2 (Spring 2004-Instructor **1**)			
1	*39*	0.547	0.674
2	*40*	0.512	0.715
3	*40*	0.331	0.139
4	*42*	0.218	**0.001***
5	*44*	0.872	0.100
Overall	*205*	**0.194**	**0.008***
Experiment 3 (Fall 2004-Instructor **2**)			
1	*29*	0.289	0.752
2	*42*	0.086	0.859
3	*37*	0.131	0.675
4	*30*	0.242	0.287
5	*38*	0.655	0.954
Overall	*176*	**0.080**	**0.607**

Table 3: ANOVA P-values

*A P-value of less than or equal to 0.05 implies the null hypothesis may be rejected with at least a 95% level of confidence.

Final grades were used as a measure of overall achievement upon completion of the course. Comparison of the p-values associated with these final grades derived from ANOVAs was carried out in the same manner as pre-quiz scores and revealed some contrasting results. Overall results in Table 3 from experiment 1 and 2 show p-values of 0.025 and 0.008, respectively, well below the cutoff point. The null hypothesis may therefore be rejected for these semesters studied. In other words the experimental groups and control groups are different upon completion of the course, after treatment. Although the overall p-values are below the cutoff, a large contribution to these values were due mainly to TA 3 in experiment 1 and TA 4 in experiment 2 as noted by their considerably small p-values (Table 3).

Experiment 3 reveals a p-value of 0.607 overall implying the null hypothesis must be accepted. It can be further seen in Table 3 that all experimental groups and control groups are not different completion of the course for that particular semester regardless of TA; all p-values are above 0.05.

Final Grade Averages

Figure 1 illustrates the point regarding differences between experimental groups and control groups in the form of a bar graph. Standard error bars are included and account for the number of students (N) associated with each bar.

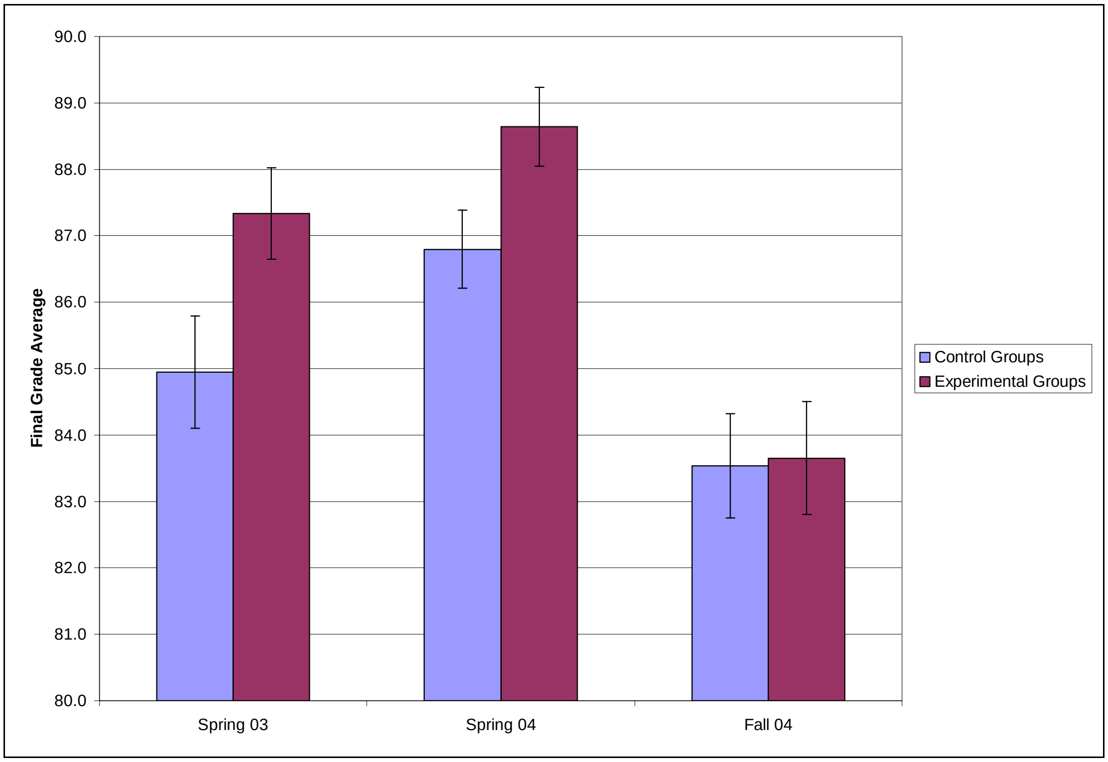

Figure 1: Final Grade Averages with Standard Error Bars

For the semesters of spring 2003 and spring 2004 the experimental groups performed significantly better in the course than did the control groups. Also, in agreement with the p-value argument, it is obvious from the bar graph that there was no significant difference between the groups for the semester of fall 2004 (experiment 3).

Achievement Based on Pre-Quiz Score

Differences among students scoring similar pre-quiz scores based on their respective grouping method are illustrated with the following bar graphs (Figure 2-Figure 7). Each semester is represented by two components, one showing both final grade averages for the experimental groups and the corresponding control groups at each pre-quiz score; the other shows the difference between those averages, experimental minus control. The first component for each semester gives an indication at what point along the grading scale improvement(s) occurred. The second component indicates at what point among pre-quiz scores the largest impact was realized after treatment. Each figure shows the number of students (N) involved in establishing the final grade averages.

Figure 2 and Figure 3 represent the two components for the spring semester of 2003 (experiment 1). It can be seen that at pre-quiz scores of 1, 3, and 7 in Figure 2 students scored at least one letter grade better than their respective control group counterparts. Letter grades of “A”, “B”, “C”, and “D” correspond to final grades of at least 90, 80, 70, and 60, respectively. Most dramatically, at a pre-quiz score of 1 there is a two letter grade increase from a “D” to a “B”. Other increases represented movement from a “C” to a “B” and a “B” to an “A”. Figure 3 shows that students in the experimental groups scoring lower on pre-quizzes generally had higher course averages than those in the control groups.

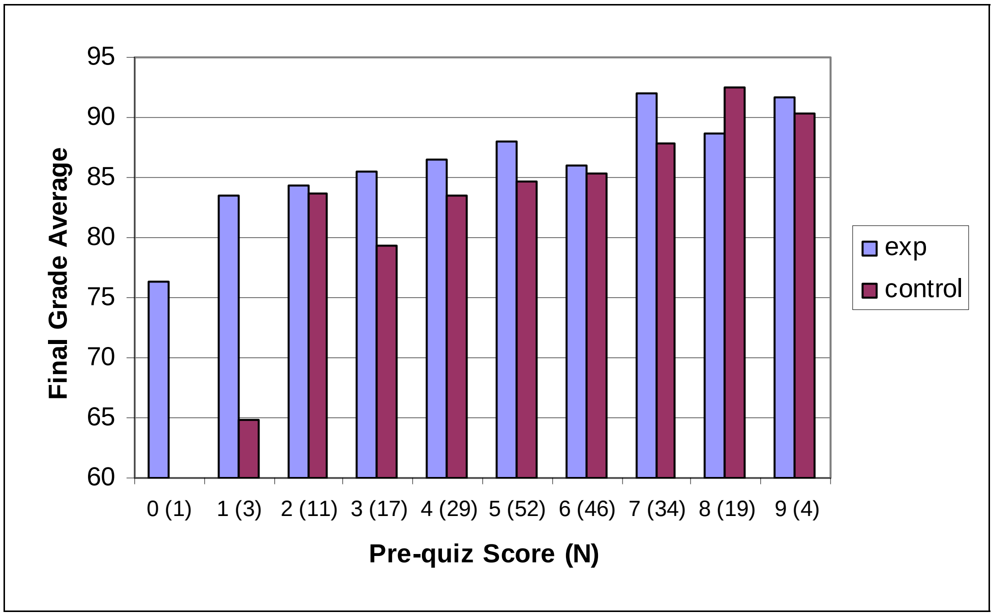

Figure 2: Spring 2003 Final Grade Averages according to Pre-Quiz Score

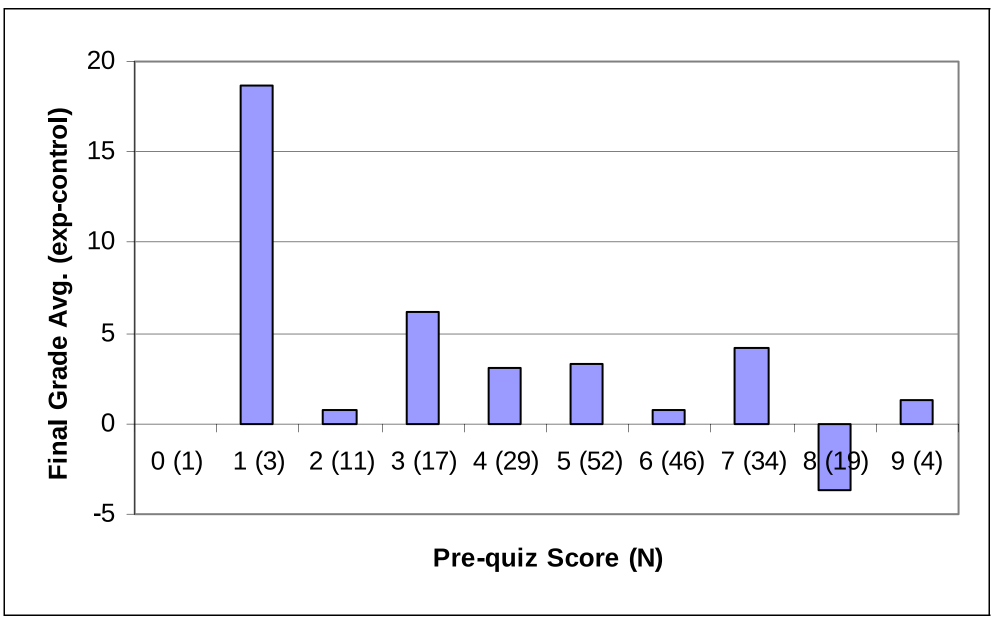

Figure 3: Spring 2003 Average Differences

Spring of 2004 is represented by Figure 4 and Figure 5 (experiment 2) and utilized the same analysis as was used in experiment 1. Letter grade improvements can be seen at pre-quiz scores of 2, 5, and 8 in Figure 4. One of these represents an increase from a letter grade of a "C" to a "B", while the other two scores represent a transition from a "B" to an "A". Again, as in the analogous data from experiment 1, Figure 5 shows students scoring lower on pre-quizzes had higher final grades in experimental groups than those in control groups.

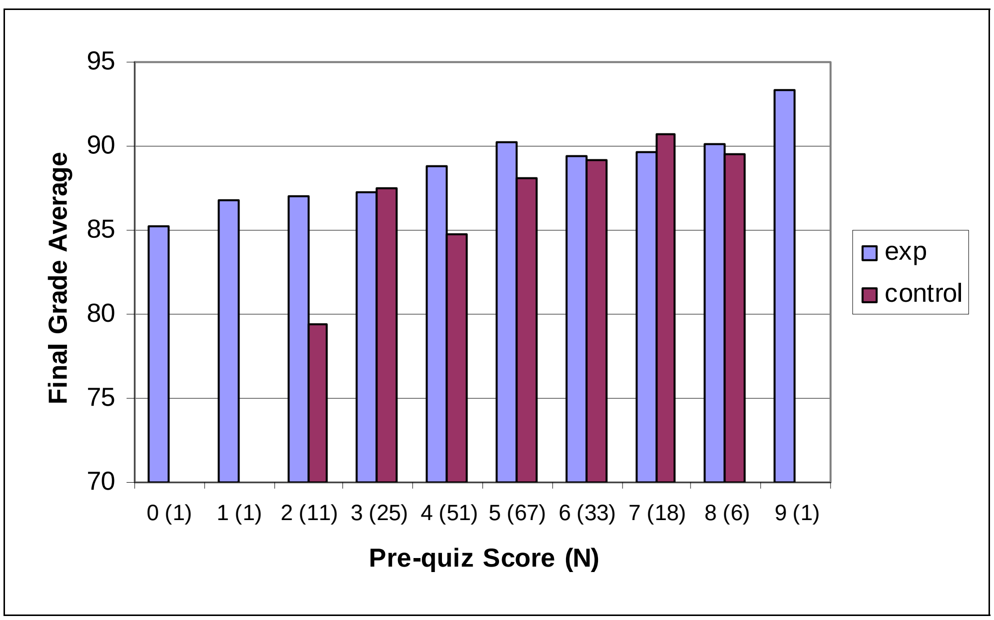

Figure 4: Spring 2004 Final Grade Averages according to Pre-Quiz Score

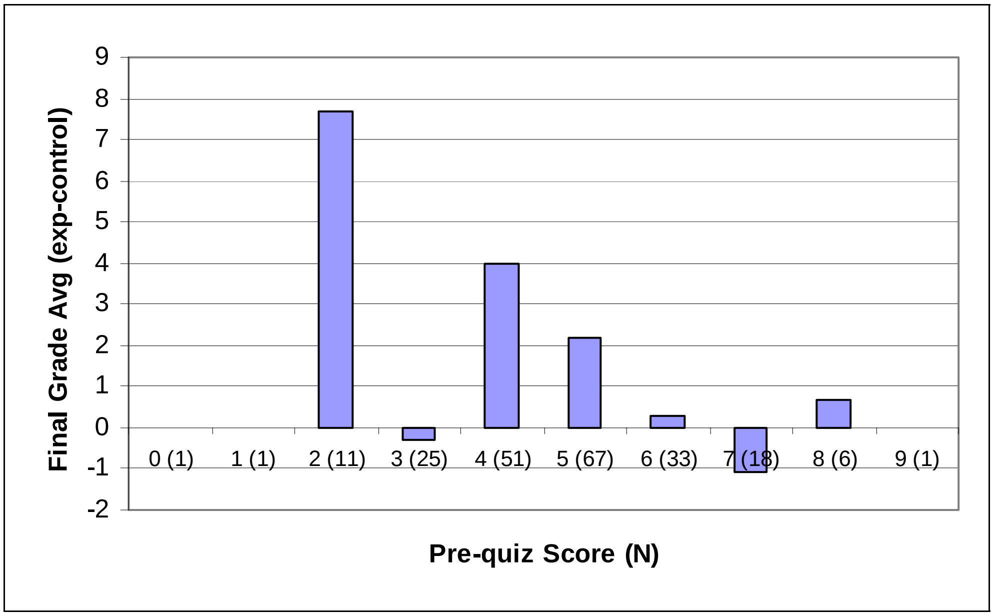

Figure 5: Spring 2004 Average Differences

Experiment 3 (fall of 2004) as represented by Figure 6 and Figure 7 revealed data inconsistent with that of the previous experiments. The trends that exist in experiments 1 and 2 are not seen in Figure 7. However there are two pre-quiz scores where letter grade improvement does occur, at pre-quiz scores of 2 and 9 from a “C” to a “B” and a “B” to an “A”, respectively.

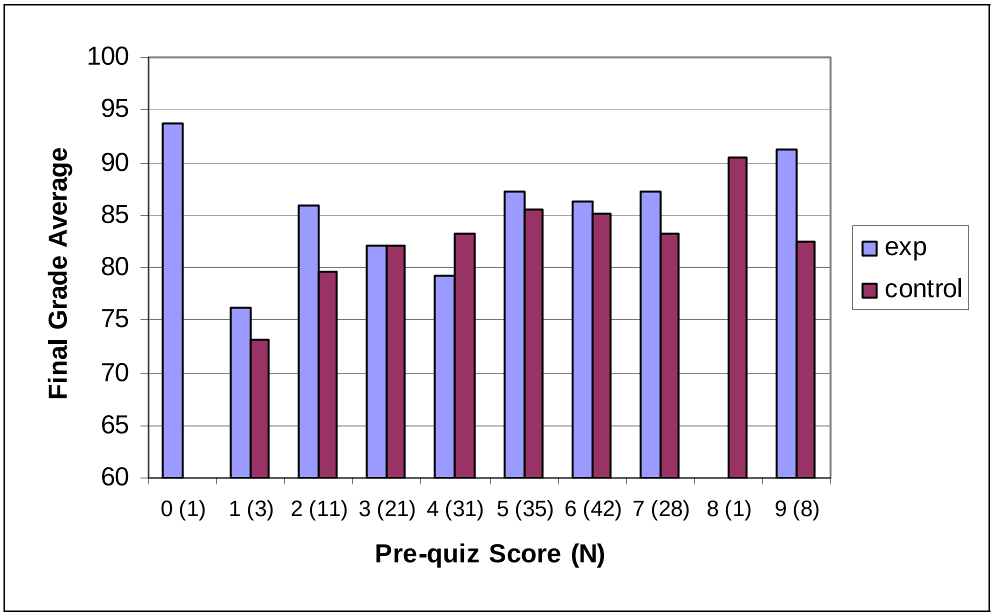

Figure 6: Fall 2004 Final Grade Averages according to Pre-Quiz Score

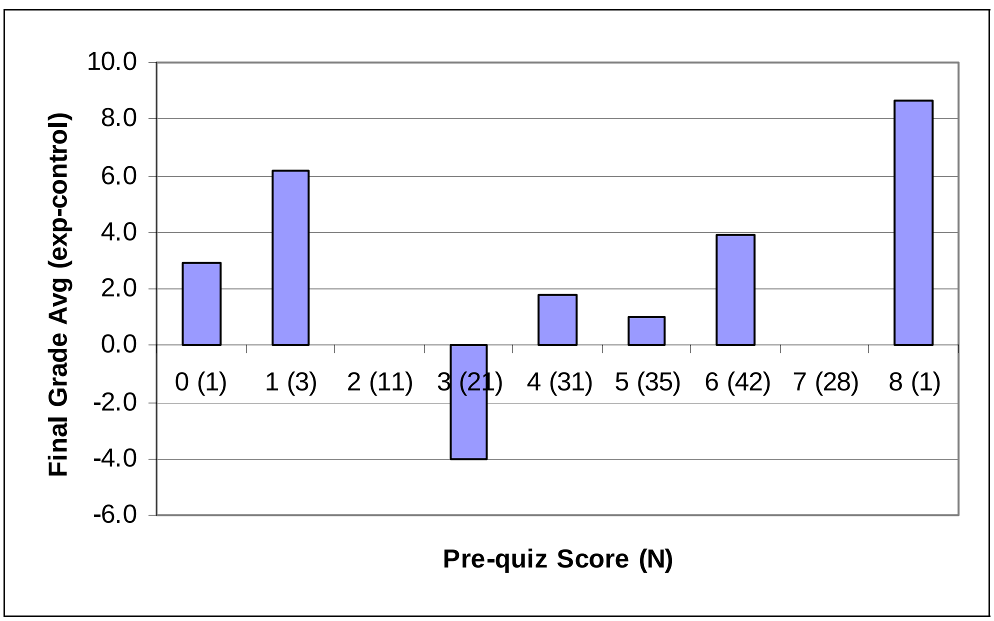

Figure 7: Fall 2004 Average Differences

Survey Analysis

Six survey questions (Appendix B) were asked of students participating in the study at least two times during a given semester. The responses were tallied and totaled for each TA's control and experimental groups and for all control and experimental groups for each semester studied. Response percentages of each TA and all TAs for each semester are broken down by question and can be found in Appendix C.

Question 1: How long, on average, did it take before you officially began the lab work in the previous unit?

Students could select anywhere from 5 to 45 minutes (in increments of 5) or more when responding. The highest percentage of students responded with 10 minutes for control and experimental groups for experiments 1 and 2. Experiment 3 results (Appendix C) shows experimental groups responded with a 15 minute "begin time" and the control with 10 minutes. Otherwise there are no significant differences in responses when examining specific TAs.

Question 2: How long, on average did it take before you officially finished the lab work in the previous unit?

Students were given choices ranging from 0.5 hours to 4 hours (in increments of half hours) and more. The majority of students in the control group for experiment 1 selected 3 hours, while their experimental counterpart selected 2.5 hours. Students of the spring semester of 2004 selected 2 hours and

2.5 hours equally in the experimental groups and 2 hours in the control groups. The students in the last experiment selected 2.5 hours for both experimental and control groups. Most TAs' experimental and control groups responses matched closely, however TA 3 and TA 4 from experiment 1 show the greatest differences; TA 3's experimental groups responded with 2.5 hours while the control group responded with more than 4 hours, similarly TA 4's experimental group responded with 2 hours and the control with more than 4 hours.

Question 3: If problems or misunderstandings occurred, how were they usually resolved?

Students were given the choices of "TA", "group members", and/or "other groups". All sections chose "TA" as their primary means of resolving issues, ranging from a 45.1-86.2% response. Secondly, most sections chose "group members" with the exceptions of TA 4 and TA 2 control groups in the spring of 2004 semester, rating "other groups" higher than group members. Students selecting "other groups" ranged from 0 to 23.4 %, the lowest percentage response.

Question 4: How would you rate your level of participation within your group?

Students were given a 5 point Likert scale to judge their level of participation, 1 being uninvolved and 5 being very involved. All sections across all semesters, with the exception of TA 4 spring of 2004 control group, chose 5 with the highest percentage. TA 4's control group ranked 4 as the highest. All other response percentages diminished as the level of participation ranked lower.

Question 5: Rate you group members:

Students are asked to rank their group members on a scale of 1 to 5, 5 being very involved. All responses revealed the highest percentage ranking as 5 followed by 4, 3, 2, and 1 as with the previous questions' trend.

Question 6: Were the interactions in your group beneficial to your understanding of the lab?

Students were asked to rank their interactions from a 1 to 5, 5 being very beneficial. On average, at each semester, students responded mostly with a 5.

Discussion

We have, over the course of three semesters, attempted to show the effectiveness of Vygotskian based grouping at the post-secondary level where current research is minimal; with the exception of several more recent studies by Fakhreddine, Lyon, and Sparks pertaining to other teaching environments (Fakhreddine, 1999; Lyon, 2002; Sparks, 1999). Specifically, the said grouping method was examined within an undergraduate chemistry laboratory course at The University of Texas at Austin. Much of the previous research in testing and utilizing Vygotsky's ZPD has relied mainly on qualitative methods and as such lack tight experimental conditions. However, here we have utilized sound quantitative methods, involving the existence of experimental and control groups for each of the TAs in the experiment. In other words, the experiment was crafted such that certain factors (i.e. TAs, instructors) were held as constant as possible considering the academic environment in which the experiments were conducted. The proposed hypothesis, based on the effectiveness of Vygotskian based grouping, could then be tested with maximum control of possible variables characteristic of quantitative methods and the appropriate statistical analyses. In the design of the experiment, care was also given to the ease of implementation; the experiments were carried out in a manner which can be easily reproduced and implemented, regardless of the course. An instructor wishing to implement such a grouping method would simply devise a short pre-quiz of approximately 10 questions, such as the ones in Appendix A, covering material deemed critical to the success and understanding of students in his/her particular course; in general the subject matter of the pretest was that taught in CH 301, the pre-requisite for CH 204. As a consequence of a tightly designed quantitative experiment, results are simple, in the sense that it is relatively easy to determine significant and positive effects of the proposed grouping technique in a specific environment.

Using the students in CH 204AV, we have shown that a Vygotskian based grouping technique leads to overall improvement of student achievement. Moreover, when these positive differences in achievement were evident, the students who performed relatively more poorly on the pre-quiz benefited most from the ZPD grouping method. This result is in agreement with Leonard's findings for a 6th grade mathematics course, namely that average and less able students performed best in heterogeneous, or mixed-ability, grouping arrangements (Leonard, 2001). Our results also indicate that students scoring higher than average on the pre-quiz performed similarly regardless of the grouping method utilized; also in agreement with Leonard's observations (Leonard, 2001). In other words, we have clearly shown that students do benefit from this Vygotskian based grouping method, and in particular, students who are academically relatively weaker in their class reveal the largest margin of improvement.

Post Hoc Observations

Although we have noticed an overall positive effect in the achievement of students associated with the ZPD grouping method, certain observations (many qualitative) related to our study can provide an insight into these results and suggest the prospect of future work in this area. Here we address many of these observations in the forms of student effect, TA effect, and instructor effect.

Student Effect

Students and their interactions play a significant role in the learning process, specifically one which utilizes the ZPD. This learning process is best described as a mediation process. Students in the course were free to resolve any issues with their TA as well as with their respective group members, who by group design were of differing abilities. The problems encountered within groups can therefore be examined from multiple perspectives as each student brings his/her experiences to the table. Once solutions are proposed to such problems, students bear the responsibility of communicating and defending these solutions among their group members. This multi-faceted mediation process allows the students to internalize their beliefs and to test those against other, but not like minded, students' beliefs. Eventually this process must result in a single conclusion or decision to be carried out in the laboratory based on this social mediation process; the students have then, at least momentarily, risen to the level of ability close to that of the highest ability student present during the process.

Examining results in light of this mediation process provides us with evidence in support of the previous description; we have seen the lower scoring students show the greatest improvement. Although we see a large improvement among the lower scoring students, results reveal no significant difference among the higher ability students based on achievement between grouping methods (random and Vygotskian). This result is perhaps best explained by understanding that students receiving the highest letter grade, an "A", in any course have no access to a better grade to demonstrate improved achievement, they have "topped out". Therefore, if we are to seek a means of measuring improvement among the "A" students in a Vygotskian based group, we must examine other instruments as indicators of improvement. Despite our lack of significant difference within our data, we believe some unrecognized effect was present among these higher ability students, based on theories of teaching. Primarily, when considering the mediation process, we realize that students tend to rise to the level of the highest ability student present. This act can only be explained by placing that higher ability student in the temporary role of "teacher" among his/her group mates. Upon assuming this "teacher" role, that particular student must attempt to convey his/her understanding and perspective to his/her respective group members. The act of teaching in this case inherently leads to learning; indeed research reveals the most effective means of learning is teaching (Lawson, 1992).

TA Effect

One rung up the hierarchical teaching ladder leads us to examine TAs and their effects on the effectiveness of the said grouping method. Approximately 83.3 % of a student's time in CH 204AV is under the supervision of the TA, it is therefore reasonable to assume they have considerable influence on students and their perceptions of the course. This conclusion may appear intuitive, but is supported by an examination of p-value differences between pre-quiz scores and final grade scores for each TA as seen in Table 3. To illustrate the point we consider TAs 1 and 3 from experiment 1. The experimental results and associated ANOVA analyses of TA 1's experimental and control sections reveal p-values of 0.533 and 0.561 for pre-quiz score and final grade, respectively; a difference of 0.028. The same results for the sections supervised by TA 3 show p-values of 0.832 and 0.006 for pre-quiz score and final grade, respectively; a difference of -0.826. Recollection of the fact that smaller p-values indicate statistically larger differences between means (experimental and control), the difference of -0.826 in TA 3's sections, as opposed to 0.028 in TA 1's sections, would suggest the students under the supervision of TA 3 in experiment 1 benefited far more from the Vygotskian based groups than the students of TA 1 in that same semester (under the same instructor). These differences are highly suggestive of the existence of a TA effect. Furthermore, we had expected that these differences in p-values among TAs could be more effectively explained by examining responses to question 3 on the student surveys (Appendix B), namely the responses to the question, “If problems or misunderstandings occurred, how were they usually resolved?”; the percentage of students responding that they received help from their “TA”, “group members”, or “other groups” were not statistically different and the data did not contain information that elaborates on this point. It might be expected that students who received more assistance from their TA would benefit less from the ZPD grouping; those students would rely less on intra-group structure and more on the availability of a particular TA. In other words, each time a question is answered with the help of a TA, is one opportunity lost in that group to utilize its designed effective ZPD.

Another important consideration is raised when noticing the existence of the effects on the overall final grade ANOVA data of TAs 3 and 4 from the spring 2003 and spring 2004 semesters, respectively. Indeed, the inclusion of the data for those particular TAs results in an overall p-value of 0.013 for all three semesters combined (well within the 95 % confidence limit). These significantly low p-values of 0.006 and 0.001 from Table 3 might be considered as outliers of a sort. Excluding these data from the ANOVA analysis yields a significantly different p-value of 0.187; certainly not to be considered as a significant difference between the experimental and control sections based on final grades.

Although we may contribute these large fluctuations in p-values strictly to an individual TA effect we should consider the following as suggestive that other factors may be at play. TA 3 and 4 of Experiment 1 were the same person and reveal drastically different final grade p-values of 0.006 and 0.299. More proof is evident considering TA2 of Experiment 1, TA 3 of Experiment 2, and TA 3 of Experiment 3 were also the same person and the corresponding final grade p-values were 0.074, 0.139, and 0.675, respectively. It may be that even changes in times of day influence a TAs performance and ability to perform their tasks. Perhaps more logically, TAs may simply develop better teaching methods to utilize with their second section in a given week based on their first encounter with students in a given laboratory exercise.

Instructor Effect

Lastly, and perhaps most intuitive we consider the individual instructor and his/her effect on the implementation of Vygotskian based grouping. Specifically, we have utilized this grouping method under two distinct instructors, Instructor 1 in experiments 1 and 2 and Instructor 2 in experiment 3, using similar course materials. An examination of the final grade averages associated with each of the three experiments (Figure 1) reveals a striking dichotomy. On one hand, data for experiments 1 and 2 show experimental groups outperforming their control group counterparts in final grade averages by 1.8-2.4 %; statistically significant, especially considering the n-values of 205 and 206 for experiments 1 and 2, respectively. Whereas, on the other hand, data for experiment 3 lacks the same statistical significance found in the previous two semesters.

Primarily, we realize the largest difference between experiment 1 and 2 and experiment 3 is due to the change of instructor. Instructor 1, the course creator, was seen as very experienced and has had decades of teaching experiences in varying environments from industry to academia. These rich and long-lasting experiences allow for the gradual development of teaching philosophies, which are not quickly or easily established in the teaching profession. Perhaps more importantly, Instructor 1 has expressed, on multiple occasions, a deep belief in group work and the cognitive apprenticeship model (Collins, Brown, and Newman, 1989) as it impacts laboratory teaching. Such beliefs have allowed Instructor 1 to convey the value of certain teaching philosophies simultaneously in context with course material. Such values, conveyed naturally, encourage students to incorporate them into their view of the subject matter.

In contrast to experiments 1 and 2, experiment 3 was taught by a novice instructor using virtually the same course material as that used by Instructor 1. However, the course was delivered without the same connection in the cognitive apprenticeship structure, implied in the presentation by Instructor 1. Being a novice, Instructor 2's teaching philosophies were probably aligned primarily with a conventional lecture-oriented style, namely, one size fits all, and the teacher's job is to supply information. Students taught by an instructor believing in a traditional lecture-oriented environment typically lack the opportunity for group work and therefore lack a fundamental belief of the efficacy of group work, in effect devaluing a system of teaching designed to encourage group participation and involvement. Indeed, the logical interpretation of the results of experiments 1 and 2 compared to those of experiment 3 points directly to an instructor effect, a conclusion supported by the relative maturity and characteristics of the instructors involved in the course.

Implications

We have described three major effects influencing the course and the implementation of Vygotskian based grouping. These "effects" can more easily be classified as "teacher" effects at various levels providing some influence on students. We conclude that the implementation of the said grouping method is simple but should be done when participants (instructors, TAs, and students) understand the theory and nuances of utilizing the ZPD. In other words, if an instructor wished to utilize Vygotsky's ZPD, an understanding of the theories could be critical to the overall success of the involved students. A teachers' role should most importantly require the understanding of personal classroom (or laboratory) decisions and the eventual goals hoped for. Lastly, we have discussed possible effects of a long-term instructor, Instructor 1. This observation reveals the importance for continual course involvement by an individual who is highly devoted to instruction, particularly group work, for an extended period of time. An unstable class environment, as a result of continual instructor fluctuations, sets the foundation for uninvolved students who realize a perceived lack of value in their education.

Recommendations for Future Work

Although here we have used a pre-quiz as a means of grouping students, the validity of utilizing other student-associated characteristics may be considered (such as age, gender, and/or temperament). Perhaps more suitable to ability levels, IQ scores could also be used. All or none of these could prove a more effective means of utilizing Vygotsky's ZPD. Alternative means of examining achievement may also be developed to reflect deeper levels of learning and might be utilized in lieu of typical grading rubrics. One such example might involve completion of pre and post concept maps in order to better determine a student's change in thought pattern and learning as the semester progresses through increasingly more difficult laboratory tasks. Perhaps upon examination of such concept maps more effective grouping methods may be developed with regards to different evident thought patterns.

Data from experiments, such as those done here, introduce the possibility of an investigation of a gender effect as it pertains to Vygotskian based grouping. Although the gender of each student was not considered, learning groups would have been composed of one of four possible gender combinations (FFF, FFM, MMF, and MMM). Examination of these gender groupings and their respective course achievement may reveal differences in success based on a group's respective make up. Such a study can provide us with insight into the social tendencies and academic ramifications of specific gender groupings. Moreover, groups may respond differently based on the gender of their instructor, TA or course instructor.

Although this study was done in three separate experiments in the same course, the possibility exists for similar longitudinal studies. It is expected that the students grouped according to the ZPD grouping method have acquired a deeper level of understanding related to the course and that the knowledge and experience would carry over into future academic endeavors. This may indeed be a possibility for future investigations; however certain problems arise when considering the appropriate means of assessment across courses of drastically different approaches to problem solving.

Application

Generally, we have imposed a ZPD structure through the use of a short pre-quiz and simple sorting algorithm in a laboratory environment where tasks lend themselves nicely to group work. These more complex tasks, such as those found in CH 204AV laboratory experiments, are typically in contrast to specified and individualized problems encountered in other venues such as during lectures and recitations. The nature of such a complex task relies more heavily on the need for socialization among students to reach a conclusion, as the solution is generally not trivial. Students carrying out this socialization often require guidance towards more effective group work. Finally, at some point the students' knowledge must be wholly assessed. That is, if students learn to complete complex tasks, they should be tested on similarly difficult material. In other words, a similar ZPD technique may be applied in other venues, imposing a ZPD structure similarly, provided assigned tasks are more complex in nature leading to the need for group socialization towards a solution. Furthermore, supervision of groups during their social mediation process can improve the outcome of such a grouping method.

Appendix A: Pre-quiz

CH 204AV Pre-Quiz

Name:______________________Course Unique No.:___________________

This quiz is to gather information about how much you remember from CH 301 or any other previous chemistry courses. You will get credit for attempting the questions. Showing your work is helpful.

1. You have 50 g of Compound X. How many mg do you have?

2. The molecular weight for Compound X in question 1 is 200 g/mol. How many moles of Compound X do you have?

3. You have 100 mL solution that is 25 mg/L of Compound Y. How many grams of Compound Y are present?

4. What is the µM concentration of the solution in question 3 if the MW of Compound Y is 500 g/mole.

5. You take 5 mL of your 25 mg/L Compound Y solution and dilute it to 50 mL. What is the concentration of Compound Y in the new solution?

6. Write the chemical equation for the reaction of sodium hydroxide and hydrochloric acid.

7. What is the concentration of a hydrochloric acid solution if 2 mL of a 1-M sodium hydroxide solution is needed to neutralize 0.5 mL of a hydrochloric acid solution?

8. A solution has hydrogen ion concentration of 0.001 M. What is the pH of this solution? *(set up the calculation, solve it if you can)*

9. An equation for a straight line is given below

   $$y = 4x + 0.5$$

   If y equals 3.3, what is the value of x?

10. How would you rate your overall knowledge of chemistry

    1 2 3 4 5

    None Very Knowledgeable

11. If you have been involved in group work situations, how would you rate your experiences?

    1 2 3 4 5

    Not Enjoyable Very Enjoyable

    1 2 3 4 5

    Not Beneficial Very Beneficial

Appendix B: Student Survey

Name ________________

Unique # _____________

Date _________________

CH 204AV Student Survey

Note: This remains voluntary and you may discontinue participation in this research project at any time.

Where applicable circle the appropriate response.

1. How long, on average, did it take before you officially began the lab work in the previous unit?
5 10 15 20 25 30 35 40 45 more (specify) ____ **minutes**

2. How long, on average, did it take before you officially finished the lab work in the previous unit?
0.5 hr. 1 hr. 1.5 hr. 2 hr. 2.5 hr. 3 hr. 3.5 hr. 4 hr. more

3. If problems or misunderstandings occurred, how were they usually resolved?
TA group members other groups

4. How would you rate your level of participation within your group?
1 2 3 4 5
uninvolved very involved

5. Rate your group members:
1 2 3 4 5
uninvolved very involved

1 2 3 4 5
uninvolved very involved

6. Were the interactions in your group beneficial to your understanding of the lab?
1 2 3 4 5
not beneficial very beneficial

Note anything that may seem exceptional, positive or negative, below.
Comments:

Appendix C: Student Survey Results

question		Spring 2003											
		TA1		TA2		TA3		TA4		TA5		overall	
#1	Min. to begin work?	exp%	control%	exp%	control%	exp%	control%	exp%	control%	exp%	control%	exp%	control%
	5	15.63	10.53	16.36	12.50	12.73	8.70	55.00	28.07	10.94	13.64	19.78	15.08
	10	35.94	35.09	20.00	33.33	25.45	23.91	25.00	38.60	21.88	34.09	25.90	33.33
	15	29.69	21.05	21.82	25.00	25.45	41.30	10.00	17.54	25.00	29.55	23.38	26.19
	20	7.81	15.79	16.36	16.67	25.45	13.04	5.00	1.75	9.38	15.91	12.95	12.30
	25	1.56	1.75	5.45	2.08	1.82	0.00	2.50	3.51	17.19	0.00	6.12	1.59
	30	1.56	8.77	16.36	6.25	3.64	0.00	2.50	5.26	12.50	4.55	7.55	5.16
	35	3.13	0.00	1.82	2.08	1.82	2.17	0.00	3.51	0.00	2.27	1.44	1.98
	40	1.56	1.75	0.00	0.00	0.00	2.17	0.00	1.75	3.13	0.00	1.08	1.19
	45	3.13	5.26	1.82	2.08	3.64	8.70	0.00	0.00	0.00	0.00	1.80	3.17
	more	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
#2	Hrs. to complete lab?												
	0.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	1	4.35	0.00	3.64	6.00	1.85	4.26	9.76	0.00	1.59	0.00	3.90	1.95
	1.5	15.94	3.51	10.91	6.00	5.56	14.89	21.95	13.56	7.94	2.27	12.06	8.17
	2	13.04	22.81	12.73	10.00	18.52	21.28	31.71	18.64	9.52	11.36	15.96	17.12
	2.5	20.29	31.58	21.82	28.00	27.78	21.28	12.20	16.95	14.29	38.64	19.50	26.85
	3	21.74	26.32	32.73	20.00	22.22	8.51	0.00	20.34	17.46	25.00	19.86	20.23
	3.5	11.59	8.77	7.27	10.00	9.26	0.00	7.32	1.69	14.29	15.91	10.28	7.00
	4	5.80	3.51	0.00	0.00	1.85	4.26	14.63	6.78	22.22	4.55	8.87	3.89
	more	7.25	3.51	10.91	20.00	12.96	25.53	2.44	22.03	12.70	2.27	9.57	14.79
#3	Problems resolved by?												
	TA	46.25	45.12	58.67	60.61	48.54	63.33	75.00	51.76	49.47	53.97	53.37	54.21
	group members	41.25	43.90	25.33	31.82	32.04	31.67	18.75	36.47	32.63	23.81	31.17	34.27
	other groups	12.50	10.98	16.00	7.58	19.42	5.00	6.25	11.76	17.89	22.22	15.46	11.52
#4	Level of participation?												
	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.56	0.00	0.35	0.00
	2	1.47	1.75	1.82	1.85	0.00	0.00	0.00	0.00	4.69	0.00	1.75	0.77
	3	2.94	14.04	16.36	14.81	3.45	6.52	7.32	1.69	3.13	4.55	6.29	8.46
	4	29.41	28.07	21.82	33.33	22.41	23.91	14.63	27.12	34.38	34.09	25.52	29.23
	5	66.18	56.14	60.00	50.00	74.14	69.57	78.05	71.19	56.25	61.36	66.08	61.54
#5	Member involvement?												
	1	0.00	0.93	0.00	3.13	0.00	0.00	2.63	7.27	1.64	1.23	0.72	2.69
	2	2.90	2.80	5.66	3.13	0.88	2.25	2.63	1.82	7.38	4.94	3.96	2.90
	3	9.42	9.35	4.72	12.50	5.31	5.62	1.32	7.27	9.02	12.35	6.49	9.32
	4	25.36	22.43	18.87	19.79	17.70	14.61	10.53	17.27	25.41	23.46	20.54	19.46
	5	62.32	64.49	70.75	61.46	76.11	77.53	82.89	66.36	56.56	58.02	68.29	65.63
#6	beneficial interactions												
	1	0.00	3.45	3.64	2.00	1.72	4.35	4.88	3.39	7.94	2.33	3.50	3.13
	2	0.00	5.17	9.09	8.00	6.90	0.00	0.00	3.39	6.35	6.98	4.55	4.69
	3	8.70	8.62	5.45	12.00	12.07	8.70	9.76	11.86	20.63	9.30	11.54	10.16
	4	37.68	24.14	27.27	32.00	39.66	39.13	21.95	16.95	34.92	46.51	33.22	30.47
	5	53.62	58.62	54.55	46.00	39.66	47.83	63.41	64.41	30.16	34.88	47.20	51.56

	Spring 2004											
	TA1		TA2		TA3		TA4		TA5		overall	
Min. to begin work?	exp%	control%	exp%	control%	exp%	control%	exp%	control%	exp%	control%	exp%	control%
5	11.11	4.35	13.33	17.07	0.00	10.34	11.11	17.24	42.50	21.43	15.27	21.43
10	4.44	19.57	37.78	41.46	43.48	20.69	40.74	37.93	37.50	32.14	32.02	32.14
15	33.33	36.96	37.78	21.95	23.91	31.03	29.63	6.90	10.00	7.14	27.09	7.14
20	35.56	23.91	8.89	2.44	15.22	20.69	18.52	24.14	5.00	21.43	16.75	21.43
25	8.89	4.35	0.00	7.32	2.17	6.90	0.00	10.34	5.00	7.14	3.45	7.14
30	4.44	6.52	2.22	2.44	10.87	6.90	0.00	0.00	0.00	7.14	3.94	7.14
35	0.00	0.00	0.00	4.88	2.17	3.45	0.00	0.00	0.00	0.00	0.49	0.00
40	2.22	4.35	0.00	2.44	0.00	0.00	0.00	0.00	0.00	0.00	0.49	0.00
45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.45	0.00	3.57	0.00	3.57
more	0.00	0.00	0.00	0.00	2.17	0.00	0.00	0.00	0.00	0.00	0.49	0.00
Hrs. to complete lab?												
0.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	2.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.50	0.00	0.99	0.00
1.5	4.44	4.44	8.89	2.44	4.35	17.86	7.41	10.34	20.00	3.45	8.87	3.45
2	11.11	8.89	24.44	12.20	19.57	17.86	22.22	24.14	42.50	31.03	23.65	31.03
2.5	26.67	33.33	42.22	24.39	26.09	17.86	55.56	41.38	27.50	31.03	33.99	31.03
3	13.33	31.11	13.33	39.02	15.22	28.57	14.81	10.34	5.00	20.69	12.32	20.69
3.5	22.22	13.33	8.89	12.20	21.74	14.29	0.00	13.79	2.50	10.34	12.32	10.34
4	17.78	8.89	2.22	9.76	10.87	0.00	0.00	0.00	0.00	3.45	6.90	3.45
more	2.22	0.00	0.00	0.00	2.17	3.57	0.00	0.00	0.00	0.00	0.99	0.00
Problems resolved by?												
TA	73.08	64.06	60.32	54.69	62.32	65.71	86.21	72.97	62.50	85.71	66.54	85.71
group members	17.31	25.00	31.75	21.88	24.64	20.00	13.79	10.81	28.57	14.29	24.54	14.29
other groups	9.62	10.94	7.94	23.44	13.04	14.29	0.00	16.22	8.93	0.00	8.92	0.00
Level of participation?												
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	2.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.49	0.00
3	6.67	6.52	6.52	9.76	4.35	3.45	11.11	10.34	0.00	3.45	5.39	3.45
4	42.22	32.61	43.48	26.83	36.96	41.38	40.74	48.28	30.00	44.83	38.73	44.83
5	48.89	60.87	50.00	63.41	58.70	55.17	48.15	41.38	70.00	51.72	55.39	51.72
Member involvement?												
1	2.35	4.40	2.25	0.00	2.17	1.75	0.00	0.00	0.00	0.00	1.50	0.00
2	3.53	1.10	4.49	1.22	0.00	5.26	0.00	1.72	1.25	0.00	2.00	0.00
3	5.88	1.10	5.62	9.76	1.09	12.28	7.41	10.34	1.25	0.00	4.00	0.00
4	31.76	18.68	23.60	17.07	27.17	22.81	29.63	39.66	11.25	12.07	24.50	12.07
5	56.47	74.73	64.04	71.95	69.57	57.89	62.96	48.28	86.25	87.93	68.00	87.93
beneficial interactions												
1	2.22	0.00	0.00	0.00	0.00	6.90	0.00	6.90	2.50	0.00	0.98	0.00
2	4.44	0.00	4.35	0.00	2.17	3.45	0.00	13.79	0.00	0.00	2.45	0.00
3	8.89	8.70	8.70	7.32	8.70	6.90	11.11	13.79	5.00	17.24	8.33	17.24
4	35.56	19.57	36.96	36.59	30.43	31.03	40.74	34.48	27.50	31.03	33.82	31.03
5	48.89	71.74	50.00	56.10	58.70	51.72	48.15	31.03	65.00	51.72	54.41	51.72

question		Fall 2004											
		TA1		TA2		TA3		TA4		TA5		overall	
#1	Min. to begin work?	exp%	control%	exp%	control%	exp%	control%	exp%	control%	exp%	control%	exp%	control%
	5	3.85	24.32	21.21	17.07	2.56	21.05	17.14	15.15	12.50	38.89	11.46	23.24
	10	19.23	24.32	24.24	48.78	28.21	21.05	28.57	48.48	37.50	25.00	27.39	33.51
	15	46.15	37.84	42.42	14.63	23.08	23.68	25.71	18.18	29.17	25.00	32.48	23.78
	20	11.54	13.51	6.06	7.32	15.38	21.05	14.29	15.15	4.17	2.78	10.83	11.89
	25	0.00	0.00	0.00	0.00	17.95	5.26	5.71	0.00	0.00	8.33	5.73	2.70
	30	11.54	0.00	6.06	12.20	10.26	5.26	8.57	0.00	16.67	0.00	10.19	3.78
	35	3.85	0.00	0.00	0.00	2.56	0.00	0.00	3.03	0.00	0.00	1.27	0.54
	40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	45	0.00	0.00	0.00	0.00	0.00	2.63	0.00	0.00	0.00	0.00	0.00	0.54
	more	3.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.64	0.00
#2	Hrs. to complete lab?												
	0.5	0.00	0.00	0.00	0.00	0.00	0.00	5.56	0.00	0.00	0.00	1.27	0.00
	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.86	0.00	0.00	0.00	0.53
	1.5	0.00	5.41	6.06	0.00	0.00	2.56	5.56	5.71	4.17	25.71	3.16	7.49
	2	46.15	10.81	6.06	2.44	35.90	17.95	19.44	25.71	12.50	22.86	24.05	15.51
	2.5	30.77	35.14	15.15	29.27	23.08	51.28	25.00	17.14	50.00	31.43	27.22	33.16
	3	11.54	40.54	27.27	41.46	28.21	17.95	33.33	17.14	12.50	8.57	24.05	25.67
	3.5	11.54	5.41	21.21	19.51	5.13	5.13	11.11	20.00	8.33	8.57	11.39	11.76
	4	0.00	0.00	24.24	7.32	0.00	5.13	0.00	8.57	12.50	0.00	6.96	4.28
	more	0.00	2.70	0.00	0.00	7.69	0.00	0.00	2.86	0.00	2.86	1.90	1.60
#3	Problems resolved by?												
	TA	57.14	70.73	68.29	61.11	63.46	68.75	65.96	74.42	82.14	73.33	66.50	69.26
	group members	40.00	21.95	26.83	27.78	26.92	29.17	25.53	20.93	17.86	20.00	27.59	24.24
	other groups	2.86	7.32	4.88	11.11	9.62	2.08	8.51	4.65	0.00	6.67	5.91	6.49
#4	Level of participation?												
	1	0.00	0.00	3.03	0.00	0.00	0.00	0.00	0.00	0.00	2.33	0.63	0.51
	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.33	0.00	0.51
	3	11.54	2.70	6.06	4.76	17.50	7.50	14.29	0.00	0.00	2.33	10.76	3.57
	4	26.92	43.24	30.30	33.33	32.50	32.50	31.43	23.53	29.17	18.60	30.38	30.10
	5	61.54	54.05	60.61	61.90	50.00	60.00	54.29	76.47	70.83	74.42	58.23	65.31
#5	Member involvement?												
	1	0.00	2.70	1.52	1.30	1.28	1.30	0.00	1.64	0.00	3.08	0.67	1.89
	2	0.00	8.11	7.58	5.19	0.00	1.30	0.00	0.00	0.00	3.08	1.68	3.15
	3	2.13	5.41	1.52	5.19	3.85	1.30	0.00	8.20	0.00	3.08	1.68	4.42
	4	29.79	37.84	28.79	32.47	30.77	27.27	36.36	18.03	12.50	23.08	28.96	27.13
	5	68.09	45.95	60.61	55.84	64.10	68.83	63.64	72.13	87.50	67.69	67.00	63.41
#6	beneficial interactions												
	1	0.00	0.00	3.03	4.76	0.00	2.50	0.00	0.00	0.00	2.78	0.63	2.01
	2	0.00	0.00	0.00	0.00	5.00	0.00	0.00	8.57	0.00	2.78	1.27	2.01
	3	11.54	8.70	3.03	19.05	12.50	2.50	14.29	8.57	4.17	2.78	9.49	8.54
	4	53.85	19.57	39.39	35.71	40.00	40.00	25.71	37.14	16.67	30.56	35.44	32.16
	5	34.62	71.74	54.55	40.48	42.50	55.00	60.00	45.71	79.17	61.11	53.16	55.28

Appendix D: ANOVA Results

Spring 2003 Results (overall)

Pre-quiz

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
control	105	552.5	5.261905	2.971612
exp	111	576	5.189189	3.150246

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.285308	1	0.285308	0.093133	**0.760528**	3.885276
Within Groups	655.5746	214	3.063433			
Total	655.86	215				

Course Grade

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Control	105	8938.7	85.13048	78.40618
Exp	111	9707.1	87.45135	37.59307

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	290.6445	1	290.6445	5.06107	**0.025487**	3.885276
Within Groups	12289.48	214	57.42748			
Total	12580.12	215				

Spring 2003 TA1 Results

Pre-quiz

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
TA1-control	19	92.5	4.868421	1.578947
TA1-exp	24	125	5.208333	4.302536

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.225265	1	1.225265	0.39438	**0.533489**	4.078544
Within Groups	127.3794	41	3.106814			
Total	128.6047	42				

Course Grade

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
TA1-control	19	1669.6	87.87368	57.09205
TA1-exp	24	2079	86.625	40.90543

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	16.5349	1	16.5349	0.344393	**0.560522**	4.078544
Within Groups	1968.482	41	48.01175			
Total	1985.017	42				

Spring 2003 TA2 Results

Pre-quiz

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
TA2-control	22	121.5	5.522727	4.20184
TA2-exp	23	123	5.347826	3.373518

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.343972	1	0.343972	0.091045	**0.764307**	4.067047
Within Groups	162.456	43	3.778047			
Total	162.8	44				

Course Grade

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
TA2-control	22	1793.9	81.54091	184.0492
TA2-exp	23	2012.8	87.51304	58.01482

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	401.0487	1	401.0487	3.35419	**0.073968**	4.067047
Within Groups	5141.359	43	119.5665			
Total	5542.408	44				

Spring 2003 TA3 Results

Pre-quiz

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
TA3-control	19	104.5	5.5	5.194444
TA3-exp	23	129.5	5.630435	2.777668

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.177019	1	0.177019	0.045798	**0.831631**	4.08474
Within Groups	154.6087	40	3.865217			
Total	154.7857	41				

Course Grade

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
TA3-control	19	1648.3	86.75263	21.79041
TA3-exp	23	2090.7	90.9	20.36455

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	178.9688	1	178.9688	8.519816	**0.005743**	4.08474
Within Groups	840.2474	40	21.00618			
Total	1019.216	41				

Spring 2003 TA4 Results

Pre-quiz

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
TA4-control	24	118.5	4.9375	1.158967
TA4-exp	18	92	5.111111	2.486928

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.31002	1	0.31002	0.179894	**0.673737**	4.08474
Within Groups	68.93403	40	1.723351			
Total	69.24405	41				

Course Grade

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
TA4-control	24	1996.7	83.19583	67.81172
TA4-exp	18	1540	85.55556	30.2132

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	57.27383	1	57.27383	1.104982	**0.299485**	4.08474
Within Groups	2073.294	40	51.83235			
Total	2130.568	41				

Spring 2003 TA5 Results

Pre-quiz

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
TA5-control	21	115.5	5.5	3.15
TA5-exp	23	106.5	4.630435	2.618577

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	8.300395	1	8.300395	2.890477	**0.0965**	4.07266
Within Groups	120.6087	42	2.871636			
Total	128.9091	43				

Course Grade

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
TA5-control	21	1830.2	87.15238	32.87662
TA5-exp	23	1984.6	86.28696	25.93391

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	8.221532	1	8.221532	0.281174	**0.598725**	4.07266
Within Groups	1228.078	42	29.23996			
Total	1236.3	43				

Spring 2004 Results (overall)

Pre-quiz

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
control	106	494	4.6603774	1.9026056
exp	110	542	4.9272727	2.6185154

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3.8452703	1	3.8452703	1.6960054	**0.1942111**	3.8852794
Within Groups	485.19177	214	2.2672512			
Total	489.03704	215				

Course Grade

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
control	106	9230.92	87.08415	45.41996
exp	110	9826.7	89.33364	30.40189

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	273.1563	1	273.1563	7.231987	**0.007726**	3.885276
Within Groups	8082.901	214	37.77057			
Total	8356.058	215				

Spring 2004 TA1 Results

Pre-quiz

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
TA1-control	20	92	4.6	1.936842
TA1-exp	21	103	4.904762	3.190476

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.951452	1	0.951452	0.368818	**0.547169**	4.091277
Within Groups	100.6095	39	2.579731			
Total	101.561	40				

Course Grade

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
TA1-control	20	1782.82	89.141	32.62309
TA1-exp	21	1853.3	88.25238	56.71462

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	8.089034	1	8.089034	0.179845	**0.673836**	4.091277
Within Groups	1754.131	39	44.97772			
Total	1762.22	40				

Spring 2004 TA2 Results

Pre-quiz

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
TA2-control	20	96	4.8	1.852632
TA2-exp	22	112	5.090909	2.181818

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.88658	1	0.88658	0.437719	**0.512019**	4.08474
Within Groups	81.01818	40	2.025455			
Total	81.90476	41				

Course Grade

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
TA2-control	20	1750.9	87.545	34.17734
TA2-exp	22	1940.1	88.18636	29.75361

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	4.309353	1	4.309353	0.135281	**0.714958**	4.08474
Within Groups	1274.195	40	31.85489			
Total	1278.505	41				

Spring 2004 TA3 Results

Pre-quiz

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
TA3-control	21	96	4.571429	2.457143
TA3-exp	21	107	5.095238	3.490476

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2.880952	1	2.880952	0.968775	**0.330902**	4.08474
Within Groups	118.9524	40	2.97381			
Total	121.8333	41				

Course Grade

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
TA3-control	21	1780.5	84.78571	59.07829
TA3-exp	22	1933	87.86364	31.16814

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	101.7862	1	101.7862	2.272883	**0.139322**	4.078544
Within Groups	1836.097	41	44.78284			
Total	1937.883	42				

Spring 2004 TA4 Results

Pre-quiz

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
TA4-control	21	86	4.095238	1.290476
TA4-exp	23	104	4.521739	1.26087

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.9968	1	1.9968	1.566157	**0.217692**	4.07266
Within Groups	53.54865	42	1.274968			
Total	55.54545	43				

Course Grade

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
TA4-control	21	1805.4	85.97143	35.20214
TA4-exp	23	2095.7	91.11739	11.54423

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	290.6884	1	290.6884	12.74396	**0.000911**	4.07266
Within Groups	958.0159	42	22.8099			
Total	1248.704	43				

Spring 2004 TA5 Results

Pre-quiz

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
TA5-control	24	124	5.166667	1.710145
TA5-exp	22	112	5.090909	3.419913

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.065876	1	0.065876	0.026077	**0.87245**	4.061704
Within Groups	111.1515	44	2.526171			
Total	111.2174	45				

Course Grade

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
TA5-control	24	2111.3	87.97083	59.54824
TA5-exp	22	2004.6	91.11818	19.13775

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	113.7014	1	113.7014	2.824078	**0.099947**	4.061704
Within Groups	1771.502	44	40.26142			
Total	1885.204	45				

Fall 2004 Results (overall)

Pre-quiz

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
control	98	525	5.357143	3.551546
exp	88	430	4.886364	3.04441

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	10.27615	1	10.27615	3.102928	**0.079812**	3.892495
Within Groups	609.3636	184	3.311759			
Total	619.6398	185				

Course Grade

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
control	98	8235.9	84.0398	60.90572
exp	88	7448.8	84.64545	67.21676

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	17.00794	1	17.00794	0.266208	**0.606507**	3.892495
Within Groups	11755.71	184	63.88974			
Total	11772.72	185				

Fall 2004 TA1 Results

Pre-quiz

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
TA1-control	18	83	4.611111	3.428105
TA1-exp	13	69	5.307692	2.730769

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3.662669	1	3.662669	1.166621	**0.288998**	4.182965
Within Groups	91.04701	29	3.139552			
Total	94.70968	30				

Course Grade

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
TA1-control	18	1468.5	81.58333	71.11206
TA1-exp	13	1047.1	80.54615	92.59269

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	8.120112	1	8.120112	0.101501	**0.752319**	4.182965
Within Groups	2320.017	29	80.0006			
Total	2328.137	30				

Fall 2004 TA2 Results

Pre-quiz

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
TA2-control	21	127	6.047619	3.247619
TA2-exp	23	116	5.043478	3.86166

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	11.06837	1	11.06837	3.101027	**0.085523**	4.07266
Within Groups	149.9089	42	3.56926			
Total	160.9773	43				

Course Grade

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
TA2-control	21	1795.6	85.50476	27.88848
TA2-exp	23	1957.4	85.10435	80.44316

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.760002	1	1.760002	0.031759	**0.859414**	4.07266
Within Groups	2327.519	42	55.41712			
Total	2329.279	43				

Fall 2004 TA3 Results

Pre-quiz

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
TA3-control	20	104	5.2	1.957895
TA3-exp	19	84	4.421053	3.035088

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	5.912011	1	5.912011	2.382017	**0.13125**	4.105459
Within Groups	91.83158	37	2.481935			
Total	97.74359	38				

Course Grade

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
TA3-control	20	1699.1	84.955	71.85629
TA3-exp	19	1633.7	85.98421	42.95696

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	10.32113	1	10.32113	0.178575	**0.675046**	4.105459
Within Groups	2138.495	37	57.79716			
Total	2148.816	38				

Fall 2004 TA4 Results

Pre-quiz

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
TA4-control	18	106	5.888889	3.751634
TA4-exp	14	71	5.071429	3.60989

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	5.262401	1	5.262401	1.426043	**0.241768**	4.170886
Within Groups	110.7063	30	3.690212			
Total	115.9688	31				

Course Grade

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
TA4-control	18	1521.7	84.53889	54.5731
TA4-exp	14	1223.4	87.38571	53.9167

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	63.82227	1	63.82227	1.175609	**0.286889**	4.170886
Within Groups	1628.66	30	54.28866			
Total	1692.482	31				

Fall 2004 TA5 Results

Pre-quiz

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
TA5-control	21	105	5	4.6
TA5-exp	19	90	4.736842	2.093567

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.690789	1	0.690789	0.202415	**0.655335**	4.098169
Within Groups	129.6842	38	3.412742			
Total	130.375	39				

Course Grade

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
TA5-control	21	1751	83.38095	83.20662
TA5-exp	19	1587.2	83.53684	61.50135

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.242409	1	0.242409	0.003324	**0.954326**	4.098169
Within Groups	2771.157	38	72.92517			
Total	2771.399	39				

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Vita

Justin David Briggle was born in Fort Worth, Texas on February 18, 1979, the son of Patricia Davis and Joe David Briggle. After completing his work at Richland High School, North Richland Hills, Texas, in 1997, he entered The University of North Texas in Denton, Texas and received the degree of Bachelor of Science in Chemistry in May, 2001. In August, 2001, he entered The Graduate School at The University of Texas at Austin to later complete the degree of Master of Arts in Chemistry under the supervision of Dr. Joseph J. Lagowski in August, 2003. His thesis was titled “On the Existence of Naturally Occurring Xenates”. On January 3, 2004, he married Rebecca Dawn Brown. Upon completion of his work at The University of Texas at Austin, Justin has accepted an offer for Assistant Professor of Chemistry at East Texas Baptist University in Marshall, Texas.

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