Increasing Success in a Dynamics Course through Multi-Intelligence Methods and Peer Facilitation

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1.0 Abstract

The University of Texas El Paso (UTEP) located in a multicultural region of far west Texas has a student population which is more than 70% Hispanic. UTEP is one of the largest producers of Hispanic engineers in the United States and prides itself in providing access to an exceptional quality undergraduate engineering program. Many UTEP undergraduates become graduates of the nation's top graduate programs and *they can often be found in the top levels of corporate America*. Clearly UTEP has a tradition for producing quality graduates.

In the spirit of continuous quality improvement, the authors with support from the National Science Foundation[*], have begun a program to produce **MORE** graduates with **BETTER** credentials **FASTER** than ever before. This paper discusses what these three concepts mean, the plan we have implemented to accomplish the objective, and preliminary assessments.

Our work consists of four steps: (1) adapting exemplary materials[†] for use in the classroom, (2) encouraging students to help each other learn material, (3) implementing and developing assessment instruments to guide our development and assess our results, and (4) disseminating our results to institutions similar to UTEP. The exemplary materials consist of problem based learning modules designed to present material in several modalities in an effort to present the subject matter to students in the form they prefer. Students are encouraged to help each other using the problem based modules that are designed for collaborative experiences. Peer facilitators are used in the classroom to demonstrate the student behaviors that are expected.

2.0 Introduction

Ultimately the goal of our work is to produce <u>more</u>, <u>better</u> graduates <u>faster</u> than we are currently doing. The concept of more graduates appears self-explanatory and can be achieved by

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[†] The materials are adapted from materials developed by New Mexico State University (NMSU) with support from the National Science Foundation (CCLI-EMD DUE-0089051). The NMSU materials were developed for an undergraduate hydraulics course. We are adapting these materials, and the concept behind them, for use in an undergraduate dynamics class.

successful recruitment and greater retention. Our immediate goal is to increase retention; however we ultimately desire to create an educational environment that values a more diverse skill set.

A number of studies over the past decade describe an expanded engineering skill set. One of the most recent studies has been reported by the National Academy of Engineering. [1] Our hypothesis is that by expanding the required skill set, the educational system will value people who are more diverse. If students feel they are valued, we believe they will have a greater endurance. Take as an example two hypothetical students. Suppose both students have acceptable mathematical skills but one is clearly better at mathematics but is a terrible communicator while the second clearly excels in communication. If an engineering program values mathematical analysis exclusively, the first student will most likely feel valued whereas the second may feel slightly inadequate. When the going gets tough, the communicator may choose a course of study that values communication. This is one possible explanation why females who leave engineering often have a much higher GPA in engineering than do their male counterparts. Perhaps they sense something de-valuing.

The immediate impact of our work will increase retention by using a problem oriented, collaborative environment to create more classroom excitement while making the material more relevant and understandable.

The idea of producing better students is also ultimately addressed by changing the value system at the university so students have the “extra” abilities as described by the National Academy of Engineering in [1]. In the short term, our work will produce students who are more inquisitive and creative. Throughout our labor, we are careful to assess student abilities in the traditional sense to be sure we are not diminishing the existing quality.

The idea of producing graduates faster means producing students in fewer attempted credit hours. We want students to learn material quickly and correctly.

Our intervention begins with an undergraduate Dynamics course that was chosen because of its low success rate and, thus, difficulty for students. To guarantee we achieve our goals we have centered our development on several assessment instruments. Since many UTEP graduates must pass the first licensing exam before graduation, we intend to use this exam to demonstrate that our graduates remain as exceptional in the traditional areas of engineering. Essentially this means that the students must be able to solve textbook-like problems quickly. We expect that they will remain excellent analysts. We expect that our intervention will help them further develop skills in identifying assumptions and principles to apply to analysis problems.

To assess our students' ability in understanding concepts, we intend to implement the dynamic concept inventory (DCI) developed with support from the National Science Foundation by the Foundation Coalition[2]. Similar to the Force Concepts Inventory developed for Physics, the DCI is expected to address student understanding of the concepts behind Dynamics.

To assess whether our students increase their appreciation for collaborative study, we will also be assessing their attitudes using locally developed survey instruments. The paper will provide survey results from the Fall 2004 semester.

3.0 Justification of Our Hypotheses

Our principal hypothesis is that students who are presented with authentic real world problems will be better equipped to solve traditional textbook problems. Our justification is derived from results published by New Mexico State University (NMSU). The NMSU work implemented several problem based modules in an undergraduate hydraulics course. Each module consisted of five components designed to address a particular learning style. A more complete discussion of learning styles can be found in [3] and [4].

Before NMSU's intervention, their students were performing below national average on the fluids component of the FE exam. Since the intervention, the performance of NMSU students in fluid mechanics, *for the first time ever*, has exceeded that of peers in the Carnegie Research Doctoral-Extensive institutions; their performance in all other topic areas remains around national average. For the following reasons we believe the improved performance in the fluid mechanics section in the FE Exam is due primarily to the intervention:

1. NMSU admission standards have not changed since 1990, and thus the quality of the student populations are presumed to be the same.
2. Typically, 90-95 percent of NMSU students take fluids only in the impacted courses.
3. NMSU student performance in topics other than fluid mechanics is practically the same over this time period.

There are a number of potential reasons why this performance increase occurred. We believe that confronting real problems enhances learning because it provides a context for the information making it easier for students to learn and retain the information; and student interest is enhanced.

A secondary hypothesis is that real problems will assist students in becoming more creative and therefore better designers. It is our belief that a thorough understanding of fundamental principles allows a person to perform "mind experiments" and thereby recognize unique ways to tackle problems. Intuition is a valuable asset for a designer but like any skill, it must be cultivated. By explaining real phenomena using fundamental principles, students will develop better intuitive skills. Because many students trust their intuition more than lecture materials [5] it becomes important to present the students with something they believe is true that contradicts their intuition. Once our modules demonstrate the conflict, materials help students reconstruct their understanding of the physical world. The objective is to help students rely on intuition yet show them that intuition must be developed using their knowledge of fundamental principles. We plan to assess student growth in this area using the dynamic concept inventory as a pre-and post-test and through locally defined attitude surveys.

Our third and final hypothesis is that if students begin to value collaborative study, they will develop many of the extra skills required by engineers in the future. Some of the skills we expect our students to develop are: better communication skills which are important in a multilingual environment such as UTEP, a better appreciation for multicultural issues, and leadership.

4.0 Creating an Active, Collaborative Environment

We have decided to use peer facilitators (PF) to help set a good example of student interaction. The peer facilitator is an undergraduate student who helps students work in teams and is one or two semesters beyond the completion of the course they assist. They are not used as content experts although they have provided technical assistance to students; their main purpose is to show by example how students can effectively work together to solve problems.

To encourage collaboration, students are put in small groups or teams and are given challenge problems during class time. As a further encouragement for students to work together, extra credit points are provided on examinations when everyone in a small study group improves their exam scores. For example, suppose the official study group size is three members. Refer to the students as Student A, Student B and student C. After grading the first exam, add the scores earned by students A, B and C. Call this sum X. After grading the second exam, add the scores earned by students A, B and C and call the sum Y. If Y is a predetermined amount larger than X, all three students A, B and C earn extra credit on the second exam.

Preliminary survey results presented later in the paper show the effect of our intervention and student attitudes towards collaborative study groups.

5.0 Example of the Multi-Intelligence Modules for Dynamics

This section will give one example of the modules that will be developed for the dynamics course. As originally conceived, each completed module will consist of the following five components: (1) a physical model that students can touch, (2) a computer model that will enable students to modify parameters, (3) computer tutorials that emphasize the principles behind the model, (4) computerized tests, and (5) textbook homework problems. The objective is to produce one module per month. As the modules are developed they will be posted to: https://mspace.utep.edu/leverett/NSF/MultiIntel/.

5.1 Automobile Stability

The concepts that are covered in this module include free body diagrams, dynamic stability, moments and angular momentum, and friction forces on rolling bodies. The demonstration consists of two wooden blocks each with two rubber wheels that can rotate freely about a dead axle[‡]. The two wooden blocks are set on an incline plane as shown in Figure 1. The students are told that the two blocks will be released from rest and they must predict which block will have the least rotation about it center of gravity. After making their prediction, the students were also asked to explain how they came to their prediction.

[‡] A dead axle is one in which the tires rotate but the axle does not. Non-driven tires on an automobile are typically installed on dead axles. The driven tires on an automobile are usually on a live axle.

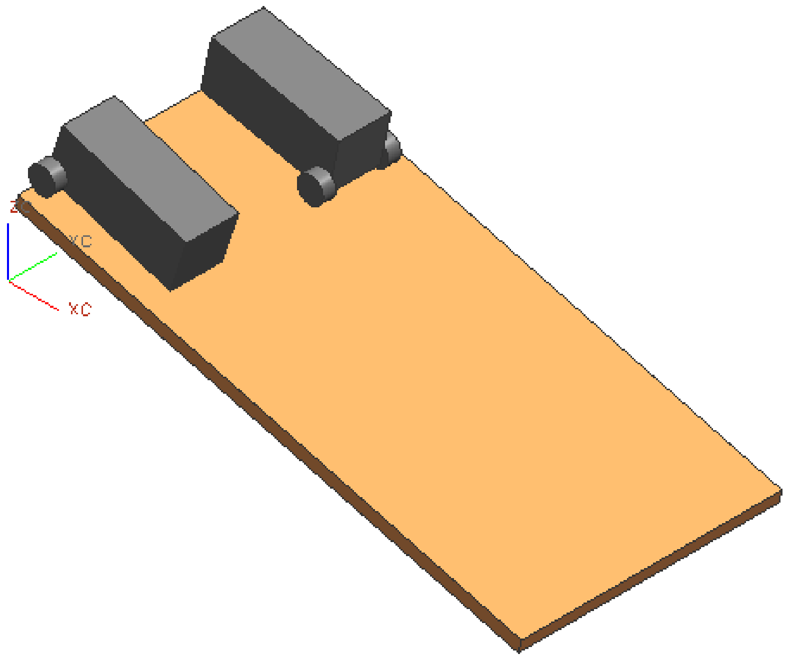

Figure 1 - Two Wooden Blocks, Each with Two Wheels on an Inclined Plane

Most students and some professional engineers predict that the block with wheels in the front will have the least rotation. Anecdotal information suggests that the most common reason given for the prediction is that the friction force on the block drags behind the wheels and will attempt to keep the block straight. When the wheels are in the back, the argument goes, the friction force between the block in the incline plane is in front of the wheels; therefore, the force would have a tendency to rotate the block.

After the students make their predictions the blocks are released from rest and they roll down the incline. The block with wheels in front will rotate 180° until wheels are in the rear. Once the wheels are in the rear, large rotation stops. A video of this demonstration can be downloaded from: https://mspace.utep.edu/leverett/NSF/MultiIntel/. The behavior is opposite to what students expect and they are now asked to explain the phenomenon using basic principles covered in class. The students need to be directed so that at some point they understand that the friction forces on the wheels are predominately parallel to the axle and therefore produce a significant moment about the center of mass.

When the wheels are in the rear and the car deviates slightly from a straight trajectory (which it will) the friction force from the wheels is as shown in Figure 2. The block in the figure shows an exaggerated rotation for clarity only. The friction from the dragging edge produces an insignificant moment when the rotation is small at the beginning. As a result the tires produce a stabilizing moment that tends to drive the block back to a straight trajectory.

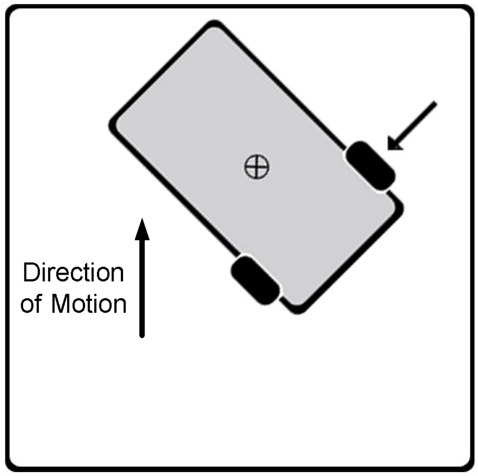

Figure 2 - Wheels in the Back Produce a Stable Motion.

When the wheels are in front as shown in Figure 3, the opposite occurs. The wheel forces produce a moment that will drive the vehicle further clockwise and is therefore unstable.

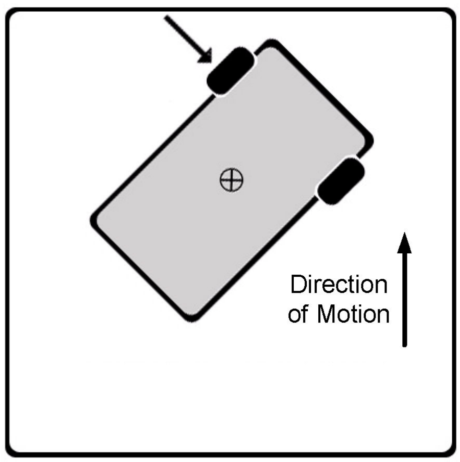

Figure 3 - Wheels in the Front Produce an Unstable Motion.

After the students are able to articulate why the blocks behave the way they do, the instructor asks whether a front wheel drive vehicle is more stable than a rear wheel drive. During the discussion, students who have rear wheel drive “muscle” cars are asked to describe the feeling when the car accelerates to the point that the driving wheels spin. Essentially when the rear driving wheels spin, the car is behaving like the wooden block with tires up front; it is unstable. Students should then be asked why muscle cars typically have rear wheel drive; the answer of course is because the acceleration of the automobile creates more normal force under the rear wheels which creates for friction and more forward acceleration. The concept involved is still moment and angular momentum.

Again the objective is to use the concept of freebody diagrams, moment and angular momentum to "explain" observed phenomena. The more similar phenomena packed into a single module the better.

As a conclusion to the module demonstration, students are asked to explain how the phenomenon is useful in other applications. Some answers include a shopping cart in which the non-steering wheels are placed in the rear so it is stable when pushed forward[§]. Rocket stability also typically requires the rocket to be "nose heavy" which is counter to most student intuition. A third application is in aviation landing gear. Two common types of landing gear are the "tricycle" gear and the "tail dragger" shown in Figure 4. The advantages of the tail-dragger are predominately involved with the aerodynamics of flight (such as angle of attack at take off) but the gear is inherently unstable.

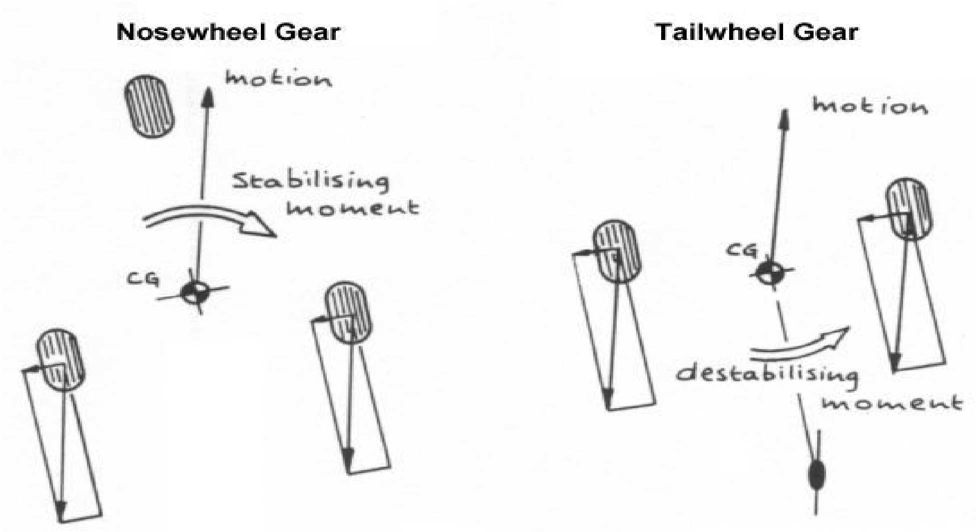

Figure 4 - The Tricycle (Nosewheel) and Tail Dragger (Tailwheel) Landing Gear Configurations (taken with permission from http://www.aerospaceweb.org/about/).

In addition to the physical demo, computer simulations will be available so students will be able to explore the factors that increase or decrease the instability. Through simulation, students will be able to see the effect of center of mass location, moment of inertia, friction coefficients and live versus dead axles. The computer simulations will be presented in the form of a design requirement to enable students to understand how a deep understanding of fundamental principles can help them be creative

Finally the textbook assignments would include exercises in drawing freebody diagrams, computing moments and angular momentum. The exercises reinforce the expected mastery of the manipulative skills required for doing analysis.

[§] You can easily demonstrate this by grabbing a shopping cart with steering wheels in front. Hold the front of the cart and shove it backward. The cart will rotate violently half a revolution and proceed with steering wheels in front.

The modules we develop will not dictate the instructor's behavior in the classroom, they will provide content only. The modules will (1) explain the phenomena that are demonstrated, (2) list "prerequisite" information, (3) provide expected student responses and explanations, (4) provide a "correct" explanation, and (5) give materials that show related applications.

Currently funding from NSF provides stipends to be paid to individuals who submit module ideas. Details can be found at: https://mspace.utep.edu/leverett/NSF/MultiIntel/.

6.0 Assessments

Because there are three components to this work, our assessments are divided into three categories.

1. Textbook Style Analysis

First we would like to see if our interventions improve student performance on typical textbook type problems. We plan to track this performance using three measures. First we intend to compare student passing rates compared to historic data. Admittedly this can be a biased measure due to a possible conflict of interest. Second, before entering the junior year, most students must pass an FE-styled exam which is administered by the College of Engineering and we intend to monitor student performance compared to historic data on this exam. Third, most students at UTEP must pass the FE exam before graduation and we intend to compare performance with historic data on the exam sections related to the interventions we perform.

2. Conceptual Understanding

Conceptual understanding is the ability to reason about how objects perform and is distinct from analytical thinking and the mathematical manipulations required in analysis problems. Conceptual understanding is necessary for creativity and good design. Being able to think about fundamentals without being bogged down by complex mathematical analysis enables an engineer to perform "mind experiments," one requirement in creativity. A person with good conceptual understanding would be able to explain phenomena in simplified terms which will enable finding the critical parameters governing a behavior. Once an engineer knows what governs, analysis can be used to compute how much is required for the exact response needed. To measure conceptual understanding we intend to use the Dynamics Concept Inventory developed by the Foundation Coalition [2] as a pre- and post-test.

3. Student Attitudes About Study Groups

Students taking responsibility for their education and the education of other students is an important lesson. Students often can be available to each other at times convenient to them whereas professors and teaching assistants tend to work conventional hours

Often the better students seldom want to help weaker students because (according to confessions made to the authors) they fear they will (1) ruin the curve[**], (2) pull down the good students, (3) distract from what should be studied, and countless other fears. Of course most experienced educators will confess that they really understood principles when they began to teach so teaching in a study group is possibly the best thing to happen to a good student. One disconnect

[**] This is actually a strange fear because the authors tell students that there are no curves.

between this reality and student perception comes from the fact that many students do not study principles, they tend to study examples. Answering questions however can force a person to compare one "example" to another and begin to see the underlying relationships between them; they begin to see the principles.

The weaker students sometimes resist working in study groups because (again according to student confessions) (1) students "look down their nose" at them and (2) they simply want to be told the correct answer. When working properly, study groups work out the answers together.

To assess success in changing student attitudes about study groups, attitude surveys are administered immediately after returning graded exams to the students.

6.1 Preliminary Results

At the writing of this paper, the project has completed one semester. None of the modules had been designed in time to implement so the only results available are the student attitude assessments and class grades.

Figure 5 shows the grade point distribution in the class. All grades were assigned based on individual work on in-class exams. No homework grades or group grades were assigned.

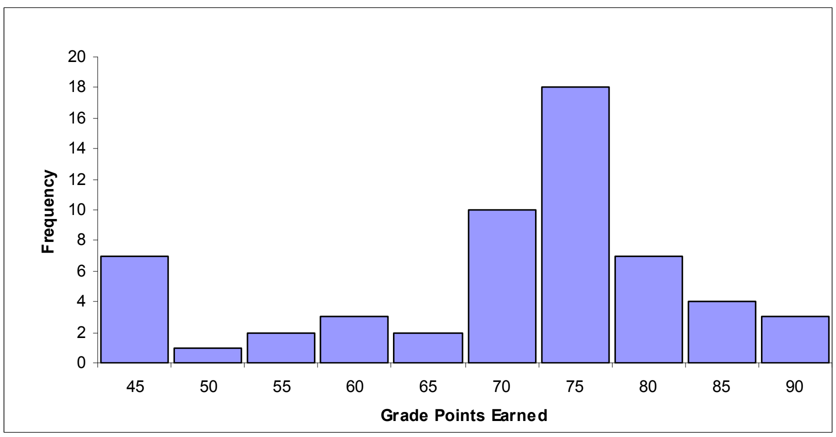

Figure 5 - Final Grade Points Earned.

The only intervention used in the class was to have peer facilitators present at all times who help students work together to solve textbook questions in class. The students were also placed in study groups and monitored. At first, students were assigned to groups but after the first exam, they were allowed to reform study groups. The groups had the incentive of earning "extra points" on an exam if the group's exam score sum increased over the previous exam sum by a threshold amount. This incentive caused the very weak students to become valuable to the stronger students because they had a tremendous margin for improvement. An example of the surveys administered can be found in the Appendix

There were five exams in the class and four opportunities to earn extra credit. An attitude survey was administered after exams 2, 3 and 4. The results follow.

6.1.1 Survey 1 Results and Discussion

The attitude survey given between the second and third exam had the following results:

- 77 % of the students earned higher marks on Exam 2 compared with Exam1 and 57% of them received the extra credit.
- Only 40% of the students said the study group influenced their performance. Of those who said the group did NOT help, a lack of communication within the group was given as the main cause of problems.
- There was a reasonably strong correlation between students who earned the extra credit and those who said the study group was effective. We believe this indicates the students are relating study group effectiveness to earning the bonus and not necessarily to whether the group helped their understanding.

To prepare for the third exam, 80% of the students said they will continue to solve problems from the book and do all the homework problems. Since homework problems were not collected for a grade, the students are admitting they understand the importance of doing problems. Most of the students felt they needed to start studying early for their exams as opposed to last minute preparations. Acknowledging a truth is the first step to creating a change in behavior; these results are encouraging.

6.1.2 Survey 2 Results and Discussion

The survey given between the third and fourth exams had the results shown in Table 1 and are summarized as follows:

- 38% of the students performed better on the third exam compared to the second but none of them earned the extra credit. Essentially the first exam grades were so low it was easy for the students to earn the extra credit on the second exam. To be able to increase a second time would require serious work and the students were probably not prepared for this.
- 20% reported that the study group helped.
- On the average groups met outside of class 1.45 times with an average study time of 3.86 hours.
- More students felt that group worked well both in and outside of class and they felt that their groups encouraged them to study more and vice versa.
- The most common reason for poor group performance reported by the students was a lack of time to meet outside of class.
- The majority of the students claim they value group study and they felt confident while taking the exams. These results appear conflicting since the majority of the students say encouraging things about the study group yet only 20% claim the group helped them. This is another indication that students relate group effectiveness to the bonus points. Did the group directly impact an immediate reward or not?

To better understand the student's thinking we looked for a correlation between the first and fourth questions and between the second and fourth. Results show a correlation coefficient of 0.63 between the first and fourth. This indicates a moderately strong relationship between students who said "I did NOT earn the extra credit and my group was NOT effective." In other words, if the students did not earn the extra credit, you could reasonably predict they would also say the group was ineffective. The correlation coefficient between the second and fourth question was 0.43, a relatively weak relationship indicating that students who earned better grades could be weakly predicted to say the group was effective.

Table 1 - Results of Questions 7 Through 14 of the Second Questionnaire.

	Q7	**Q8**	**Q9**	**Q10**	**Q11**	**Q12**	**Q13**	**Q14**
Strongly Agree %	25.00	21.43	25.00	28.57	35.71	42.86	25.00	21.43
Agree %	57.14	42.86	46.43	35.71	53.57	42.86	42.86	39.29
Disagree %	10.71	14.29	17.86	25.00	3.57	14.29	32.14	28.57
Strongly Disagree %	7.14	17.86	7.14	7.14	7.14	0.00	0.00	7.14

Q7	Group worked effectively in class
Q8	Group worked effectively outside of class
Q9	Encouraged group to study harder
Q10	Was encouraged by group to study harder
Q11	Needed more time to meet outside of class to study
Q12	Value group study
Q13	Value group study more than ever
Q14	Confident while taking exam

6.1.3 Survey 3 Results and Discussion

The survey given between the fourth and fifth exams had the results shown in Table 2.

- 59% of the students had higher grades on the fourth exam and 15% of them earned the bonus points.
- 28% felt the study group was effective slightly more than previous.
- Groups met on the average 1.18 times with an average study time of 2.39 hours, lower than previous values.
- Note also fewer students felt confident during the exam; perhaps they realized they had not prepared properly.
- Although the majority of the students report attitudes we want to encourage, their gradients are negative.

Note that compared to the previous survey, fewer students believe their groups are performing well in or out of class and they do not value group study as much as before. An interesting point is that although on the average it appears the value system of the "average" student appears to be headed away from group study, there are actually more individuals who "value group study more than ever before." Perhaps those who are becoming "believers" are strengthening their belief whereas the average person is beginning to "give up on" group study. About the same report their group encouraging them to study as previously but fewer of them report being the one who was the encourager. Fewer students than previous are saying they need more time out of class to meet. The average student met less and is not as concerned about it.

The two correlation coefficients between questions 1 and 4 and between questions 2 and 4 are respectively 0.69 and 0.39 which does not represent much change from the previous.

Table 2 - Results of Questions 7 Through 14 of the Third Questionnaire.

	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14
Strongly Agree %	21.88	12.50	15.63	25.00	25.00	40.63	31.25	18.75
Agree %	46.88	37.50	46.88	40.63	53.13	31.25	28.13	31.25
Disagree %	18.75	31.25	21.88	25.00	12.50	12.50	21.88	40.63
Strongly Disagree %	12.50	15.63	12.50	9.38	6.25	12.50	12.50	6.25

Q7	Group worked effectively in class
Q8	Group worked effectively outside of class
Q9	Encouraged group to study harder
Q10	Was encouraged by group to study harder
Q11	Needed more time to meet outside to study
Q12	Value group study
Q13	Value group study more than ever
Q14	Confident while taking exam

7.0 Conclusions

Since our interventions have not been fully implemented it is premature to draw conclusions. The paper has described planned intervention intended to increase student success. Preliminary results from attitude surveys suggest that many students can be brought to a point where they claim to value group study. It would be interesting to see if these attitudes persist over time. Unfortunately our study does not allow longitudinal tracking of the students.

8.0 Bibliography

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9.0 Author Biographies

LOUIS J. EVERETT is a professor of mechanical engineering at The University of Texas at El Paso. He holds degrees from The University of Texas at El Paso, Stanford University and Texas A&M. His interests are problem based learning, automation, and electrical machines.

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10.0 Appendix – A Sample of the Attitude Survey

Midterm Questionnaire
Do NOT Put Your Name on This.

Please answer the following:

1. Did you earn the extra points on Exam 4? YES NO
2. How much did your Exam 4 score differ from Exam 3?
   a. Exam 4 was higher by _________ points.
   b. Exam 3 was higher by _________ points.
3. What was your approximate score on Exam 4?
   a. Above 90
   b. Above 80
   c. Above 70
   d. Above 60
   e. Above 50
   f. Below 50
4. Did your triad (those in your "extra credit" group) affect your Exam 4 performance? YES NO
   Explain.

5. How many different times did your study triad meet?

6. How many TOTAL hours did your study triad meet?

	Strongly Agree	Agree	Disagree	Strongly Disagree
7. My group worked effectively together in the classroom/lab.				
8. My group worked effectively outside of the class/lab to prepare for the exam.				
9. I encouraged my study partners to work harder.				
10. I was encouraged to work harder by my study partners.				
11. I needed more time to meet outside of class with my study group.				
12. I value group study.				
13. I value group study more now than ever before.				
14. I felt confident while taking the exam.				

15. Comments: