120th ASEE Annual Conference & Exposition
FRANKLY, WE DO GIVE A D*MN
June 23-26, 2013

Paper ID #6583

Fostering Diversity and Educational Learning among Minority Engineering Students through Group-Study: A Case Study

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Fostering Diversity and Educational Learning among Engineering Students through Selectively Random Study Group Approach

Abstract

Peer tutoring is established as one of the most efficient methods in learning. The same approach blended with diversity is used in this study through in-class-study-group formation. The effectiveness of group study in enhancing student performance is investigated in this paper. The study is done in fundamental engineering classes in two US regional universities over the last two years. One institution is a traditional mainstream university and other is a Hispanic Serving Institution (HSI) with a diverse student population. In general, engineering has very few students from underrepresented minority backgrounds. Low performance rate of minority students becoming a challenge for engineering programs in HSIs since minority students are the majority of the student body. Success of the entire engineering program will largely depend on the success rate of the minority students.

Selectively random study groups were formed by including students of different performance levels as well as ethnicity and gender. They are encouraged to study in a group inside and outside the class room. Each group is asked to do their in-class and home work problems as a team and learn from each other. For the purpose of grading, peer evaluations as well as individual exams were administered in addition to group work. Descriptive Statistics and ANOVA are used for data analysis. The results showed an enhancement in students learning in both the universities. However, performance rate appeared relatively higher among white students.

1. Diversity in Engineering Education

Students with different backgrounds, skill levels, and educational and motivational levels have complicated the traditional engineering class room. A wide spectrum of teaching and learning methodologies are required to guide and serve them equally to fulfill their dream. Ethnicity, gender and age differences are commonly used to define the diversity of human population. Currently, white students represent the majority of the student population and Latino and other minority groups are underrepresented in higher education in the United States. With the national population demographics shift, the Latino community continues to outpace other racial/ethnic groups[1]. This change in demographics will have an impact in higher education. In a report published by the National Science Foundation(NSF), engineering is the second most popular destination among the sciences for Latino students[2] . This suggests a strong likelihood of greater diversity with the increase in the numbers of Latinos in engineering. This might change the classroom environment and may impact the dynamics of the instruction.

Several efforts are undergoing to attract minority students to engineering from K-20. STEM Fellows in K-12 Education Program[3], providing exposure, stimulating enthusiasm, training, promoting the value of engineering, and mentoring minority K-12 students[4], are some of the approaches that help to bring minority students into the engineering program. This effort might not be fruitful unless the minority students with the interest and preparation feel a part of the engineering class.

1.1 Hispanic Serving Institutions (HSI)

Hispanic serving institutions (HSIs) are a group of minority-serving institutions established by recognizing the fact that the Latino community and the students have unique problems and are underserved by the mainstream universities. To be designated as an HSI, an institution should have at least 25% Hispanic students out of their total student enrollment. In 2007 HSI-STEM was established to promote science and technology among Hispanic serving institutions, since then HSI are among the fastest growing institutions that serve traditionally underserved populations[5]. Studies showed that HSIs are doing well in the enrollment of the Latino students. However, the graduation rate of minority students in HSIs are not higher than the predominantly white institutions[1].

1.2 Academic Performance of Minority Students

A study done by Ohland, et al, 2011, indicated that student success and persistence is related largely to ethnicity and gender with some variations by institution. Racial differences are more pronounced even if institutions were to treat all students equally; the outcomes will not necessarily be the same because various populations respond differently to the same stimulant[6]. Causes of lower success among Latino students might be many, including academic difficulties, dissatisfaction with the faculty's instruction, financial burden, etc. However, low motivation and inadequate math and science preparation as well as dry and hard content of engineering courses are commonly identified as the reasons for quitting engineering by the students. The reality seemed different, a study done by Seymour and Hewitt showed that grade distributions of students who leave technical curricula are essentially the same as the distributions of those who stay in[7]. That means students who leave engineering may not be poor performers but they might have lost their interest in engineering by the teaching methods that educators use to teach the courses. Time series plot of enrollment and degree awarded in an Engineering and Technology undergraduate program is presented in Figure 1 to demonstrate the scenario of engineering education in an HSI.

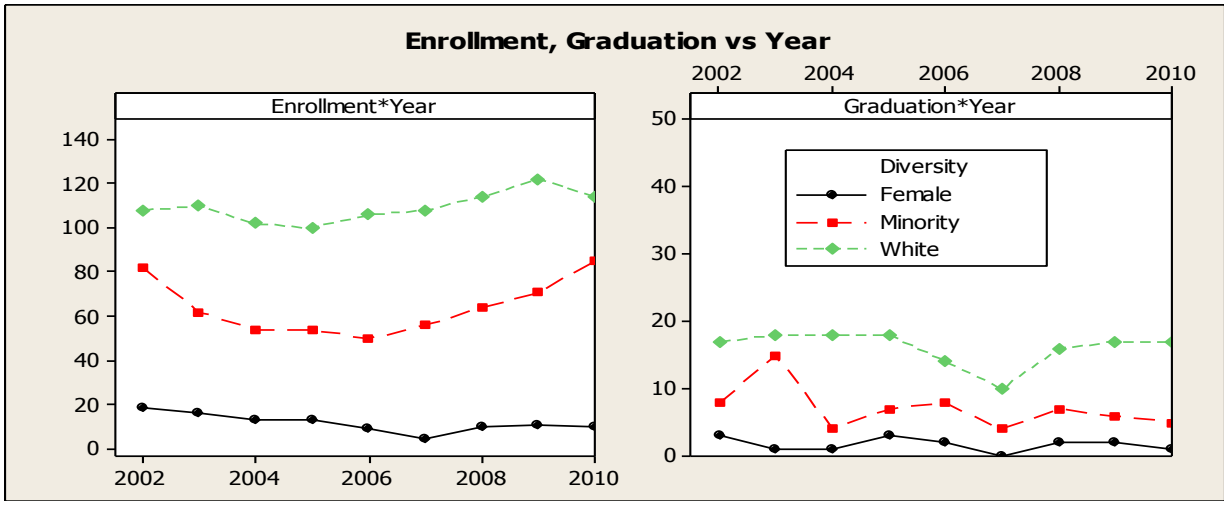

Figure 1. Enrollment and Graduation Rate in an HSI's Engineering Program

As shown in Figure 1, the chart displayed the number of students enrolled in engineering and engineering technology program in an HSI, and their graduation rate. Students are grouped under white and minority category according to their ethnicity. The female gender is considered underrepresented in engineering and is also considered in this study as a separate category. The minority category includes all those traditionally considered as underrepresented ethnicities: African American, Hispanics and Asian American. However, the number of students with Hispanic background is the largest in HSIs, and Hispanic is used instead of minority student in the later sections of this paper. Although white student's enrollment is the largest in the period of 2002-2011, the trend showed a higher enrollment rate of minority students. Women's enrollment is very low and no sign of increment is evident.

As displayed in second pan of the chart in Figure 1, the number of graduation is highest among white students, followed by the number of minority and female students. The trend of the white students' graduation rate appeared almost uniform throughout the years. Minority students' graduation rate appeared to be decreasing. Despite the increased enrollment of the minority students, the graduation rate was decreasing. This could be an indication of a lower success rate of minority students. That might be due to the time difference between the enrollment and graduation. After careful examination, the student enrollment of minority students was increasing after 2007, and these students might still be on campus and yet to graduate or taking more time to graduate. The overall graduation rate is around 15%, which is lower than the mainstream universities. The lower overall graduation rate was contributed by the graduation rate of minority students.

Traditional engineering educational strategies consisting of lecture, lab experiences, and homework have been criticized as inadequate to prepare engineering students to engage in the collaborative partnerships that are essential for the practicing engineer[8]. The January 2011 issue of Journal of Engineering Education also highlighted that engineering educators will need to change some of their existing perspectives and behaviors for the advancement of either instructional practices or engineering education research[9]. A need of fundamental change in university policies is pointed out to better support and create a better interface with students as part of our everyday operations[10] .

As suggested by the data and consensus of engineering educators HSIs also need to formulate a new strategy and approach to instruction to address these issues. Incorporating collaboration in the instruction process might be one of the methods to enhance the teaching and learning process.

Lack of inclusiveness and sense of belonging are some of the factors for the lower success rate of minority students. Jordan et al proposed an intervention to improve sense of belonging[11].Various approaches and strategies are used to increase the performance of minority students in engineering: Spanish language in instruction[12] might be a possible way but that may not serve the purpose of preparing internationally competitive engineers. Besides, most of the minority students in US are fluent in English.

A selectively random approach is proposed to provide a small controlled intervention to encourage minority students to mix and collaborate with other students. This might be a better way to train our students for tomorrow's diverse workforce.

1.3. Classroom Dynamics

With the change in demographics, the student body in higher education is changing from all white homogeneous groups to a heterogeneous one. This might challenge the traditional dynamics of an engineering classroom. The nature of the teaching and learning process, mode of instruction, advising and their pedagogical implications might need a review. A student may adopt one or a combination of more than one learning styles, which in a particular situation depends on a complex array of intrinsic and extrinsic factors. Constructive alignment of intrinsic and extrinsic elements is crucial in achieving desired learning outcomes[13]. No single learning style is predominantly identified and attached to a specific ethnicity. The Myers-Briggs Type Indicator (MBTI)[14] is commonly used to classify personality types and often used to select the most relevant teaching strategy to accommodate and reinforce the learning styles[15]. Various frameworks are proposed to understand the experiences of minority students and develop strategies to overcome the barriers for academic success of underrepresented minorities in engineering programs[16].

1.3.1 Collaboration versus Competition

Collaboration is generally described as an approach involving joint intellectual efforts that provides opportunities for interaction among students and between students and the instructor[17]. Research has shown that collaborative learning positively influences student achievement[18]. When explaining concepts to a peer, the more prepared gains a clear, deeper understanding of concepts to be committed to long-term memory. In the mean time, the less prepared will have an opportunity to assimilate new information as well as construct a solid understanding by clarifying confusions into his or her knowledge structures.

Understanding each other's culture and background to create an inclusive environment that fosters constructive interaction is more imminent for our students. From the cognitive perspective, interactions among students result in an increase in their achievement due to the intense information processing during discussion. From this viewpoint, the opportunity for students to discuss, debate, and present their own ideas and receive others' perspectives is the critical element of group study. Students learn from one another actively because, in discussions of content, cognitive conflicts will arise, inadequate reasoning will be exposed, and enriched understanding will emerge. Revisiting an existing information help students to retain longer in memory and increases the effectiveness of elaboration[19].

In a traditional competitive environment, students have a mindset that there is a limited number of A's available in a class and that they need to compete with each other to stay on top. Using collaborative approach instead might induce some confusion and generate reluctance among high performing students who think proudly of themselves; and others who prefer to study by themselves. In the other side, poorly performing students may think that high achievement in

technical classes is out of reach, and lacks social appeal. In such situations, it is understandable to have some resistance to collaborate. Some students might thing collaboration as an opportunity to receive higher score in somebody else's effort and treat as a free ride. It is important to draw the distinction between competitiveness and collaboration from philosophical perspectives to practical implications.

The degree and extent of collaboration expected in a class should be well explained. The difference between collaboration and its benefits, and the act of copying from others' work (plagiarism) and its consequences were clearly explained beforehand in reference to the academic behavior as well as professional practice.

In a fundamental engineering class most of the problems are well defined and have unique answers but variations might be possible in the solution approaches the studies of which provide an opportunity to collaborate. Examples from daily life and professional practices would be effective in conveying the importance of collaboration as well as in encouraging students to share ideas that might ignite collaboration.

Since personal thought process is different among individuals, communication and interactions among students from different backgrounds are critical to formalize a constructive collaboration. Personal values and differing beliefs might compound the thought process and if not addressed properly might be a hindrance in the collaboration effort. Students should be instructed to take precaution while commenting about religion and other ethnic issues.
Special attention might need to avoid any kind of domination, which threatens the natural interaction incur due to a student's behavior or personality type. Humanist theory suggests a nonthreatening environment in group work to lead a natural learning. In well balanced team integrations, particularly women and members of underrepresented groups will have greater opportunities to be heard, and also be able to learn by participating in more collaborative and democratic teaching and learning processes[20]. The concept of this paper and the preliminary study results comparing the performance improvement by selectively random study group in a mainstream university and HSI was presented at the 2012 American Society of Engineering Education-Rocky mountain Section conference (ASEE-RMS)[21].

1.3.2 Accountability, Performance Evaluation and Facilitation

To ensure individual accountability, and avoid a tendency of free ride, an evaluation structure consisting of individual performance measures in addition to group work and peer evaluation should be established. The role of the instructor (or tutor) was to facilitate more frequent and less constrained interaction among the peer students, rather than to serve as an unquestioned authority or allowing free flowing gossip.

2. Scope of the Work and Objectives

Interaction among students with different backgrounds could be made possible by forming a *selectively random study group.* This type of grouping helps to break the cohort of students with a similar background and eliminate a virtual fence created around the cohort to create a diverse group consisting of individuals with different backgrounds.

In a society, the purpose of advocating diversity is to educate people about each others' faith, tradition, culture and values, and provide them an environment to understand each other by interaction, which will bring them closer and reduce the differences between them and enhance the harmony. A similar approach could be used to enhance the performance of the students by constructing the selectively random study groups with diverse members. In summary this research was planned to include the following elements:

- Developing a frame work for collaboration
- Formulating a selectively random study group to enhance the interaction between students of different backgrounds and educational performances
- Breaking the cohort of like minded students or students of similar performance level
- Engaging and managing a big class in a small university context
- Improving the performance of minority students and fostering sense of belonging among the students of all kinds
- Investigating quantitatively as well as qualitatively the effectiveness of selectively random study group

3. Selectively Random Study Group

After developing an understanding on collaborative study approach and weighing its benefits and challenges, the authors proposed a classroom setting with selectively random study groups to address the deficiencies of a traditional classroom. The selectively random groups transformed the classroom setting and made it more inviting to minority students with a sense of belonging and engagement. In the HSI, each group consisted members representing different ethnicity, educational level and gender. Specifically, each group included:

- A white student
- A Hispanic student
- A female student, and
- One student from any background

At least one student with high performance level was included in each group. This student takes the overall ownership of functioning of the group although the group leader for individual assignment is rotating. The high performer might be from any ethnicity and gender although most of the groups have a white male student as the high performer. We also have groups with female and Hispanics as a high performer. Effort was made to distribute the students evenly in each group to lower the variation on average performance of the groups. This suggests each group consists of a good, medium and poor student and one more member from any performance level that allowed flexibility in group formulation. The randomization is within each category of the set. The ideal selectively random study group would include members from different ethnicity, gender and academic performance level. In a traditional mainstream institution the number of the minority students is very small forcing to form some groups of all white students although the performance level is considered.

Each team was encouraged to study in a group inside and outside the class room and allowed to do a portion of their in-class and homework problems as a team. Each team member was asked to introduce and share their contact information in the first meeting, and encouraged to find a

common time outside the class to study in a group to foster a team involvement and time management skills.

For the purpose of grading, peer evaluations (10% of group grade), individual exams and quizzes (80% of total grade), and individual home work and quizzes (7.5% of total grade each) were administered in addition to group work (group grade is 5% of the total grade). If a member is absent during a class group activity, he or she will receive a zero on that activity. Peer evaluation helps to assess the contribution of each individual to the team, and individual exams evaluate their individual understanding and level of competency on the subject. Student achievement based on exam grade is used to measure the effectiveness of this approach. Grade inflation is another factor commonly raised by the critics of group study. In the selectively random group, the average group performance may not be always higher than the average of the individual performance. In addition, group study grades are weighted at less than half of the individual homework and quizzes, which comprise 10-20 percent of the total grade. It is expected that the student sense of belonging, engagement and the overall improvement of class performance will be acceptable trade-off for any real or perceived grade inflation.

4. Methodology

This study was conducted in three phases. Phase 1 was performed at a regional comprehensive university in Southwestern Wisconsin and Phases 2 and 3 were completed at a Southeastern Colorado institution. The university in Southwestern Wisconsin is a typical traditional mainstream university whereas the one in Southeastern Colorado is a Hispanic serving institution (HSI) consisting of a diverse student population. Both universities focus on undergraduate teaching with normal class sizes of 20-25 students. A survey was taken to gather the information about the background of the students and their learning styles. The methodology of this research involves the following steps:

- Pre-surveying about the students background, ethnicity, their learning styles and their interest in participating in a selectively random study group
- Creating the baseline of the performance level and formation of the group
- Assigning home work, quizzes and performance evaluation (individual as well as group)
- Evaluating the effectiveness of the study qualitatively on a continuous basis
- Performing quantitative statistical analysis of the performance improvement

The pre-survey identified the composition of the diversity in the class, and students' interest in selectively random study group. The students' previous and current performance (SAT score, grade from the previous class or first midterm test in the course), was considered to set up a group, in addition to ethnicity and gender as explained in Section 3 above. Numbers of study groups were 6, 7 and 15 in the first, second and third year of study, respectively.

5. Results

Grade score of each student were recorded before and after the program implementation. Although both the institutions were student centered learning based, the level of diversity was different. The HSI is more diverse. The institution that represented the mainstream university has a selective enrollment policy whereas the other representing HSI has an open enrollment policy.

Teaching style, content of the course and academic infra-structure and facilities were similar in both the institutions. The quantitative analysis student exam paper was graded with a maximum possible score of 100. The following table shows the summary of the composition and number of students during each phase of the study.

Table 1 Number of Students Participated in the Study

	Phase 1	Phase 2	Phase 3	Total	Total Students
White	18	14	36	68	113
Hispanic	2	10	19	31	
Female	4	4	6	14	
No of Groups	6	7	15	28	

Since as shown in Table 1 the number of students was increasing during the three phases, and number of study groups was also increased to maintain the group size of four students per group. Total numbers of white students involved were 68 followed by 31 Hispanic students. Female students are presented as a separate category if combined into their respective ethnicity, total number of White and Hispanic students will be 77 and 36, respectively. This data suggests that almost 25% of the student's population is minority. Numbers of students from other minority groups' were very small and lumped into the Hispanic category. The total number of students participated in this study was 113, forming 28 groups altogether. To study the student learning style and behavior, a set of questions were developed and a pre survey was conducted. The survey questions and frequency of the students' response to the questions is presented in Table 2.

Table 2 Pre-study Survey and Students Responses

Questions	Response	Frequency
If you could not solve the problems what you do?	Close the book and do something else	10
	Look for class notes and books and try to solve by myself even if it takes more time	70
	Seek help	27
If you need help, who do you prefer most to ask?	Faculty	31
	Tutor	15
	Friends	45
	Senior students	8
How you prefer to study?	Individually by myself	14
	In a group with friends if possible	95
If you study in a group, who is your group member?	Close friends	79
	Classmates	23
Are you willing to work in a group assigned by the faculty	Yes	98
	No	7

As shown in Table 2, the pre-survey result showed that currently, majority of students (65%) are trying to figure out the solution of the assignment by themselves, whereas fewer students (25%) seek help from others if they struggle in their assignment. Peers are the first preference of help seekers. More than (87%) students prefer to study in a group if possible and mentioned that many of them study with their close friends. It was also observed that like-minded students were

studying together in such a voluntarily determined team. With this a tendency of low-performing students staying together in isolation of others and high-performing students clustering together creating two different levels of cohorts was surfaced. Moreover, the students' cohort appeared to be influenced by the ethnicity: White students staying with White students and Hispanic students staying together with Hispanic students. When investigating the grade distribution, Hispanic students were not performing well in comparison to the white students. The author then realized that, students of different ethnicity and performance levels needed to be mixed; motivation to break such cohort and rebuild a new set of groups spark the idea of the selectively random study group.

The pre-test and post test score was collected and presented in a histogram plot as shown in Figure 2. The first pan with conventional heading is pre-test score distribution.

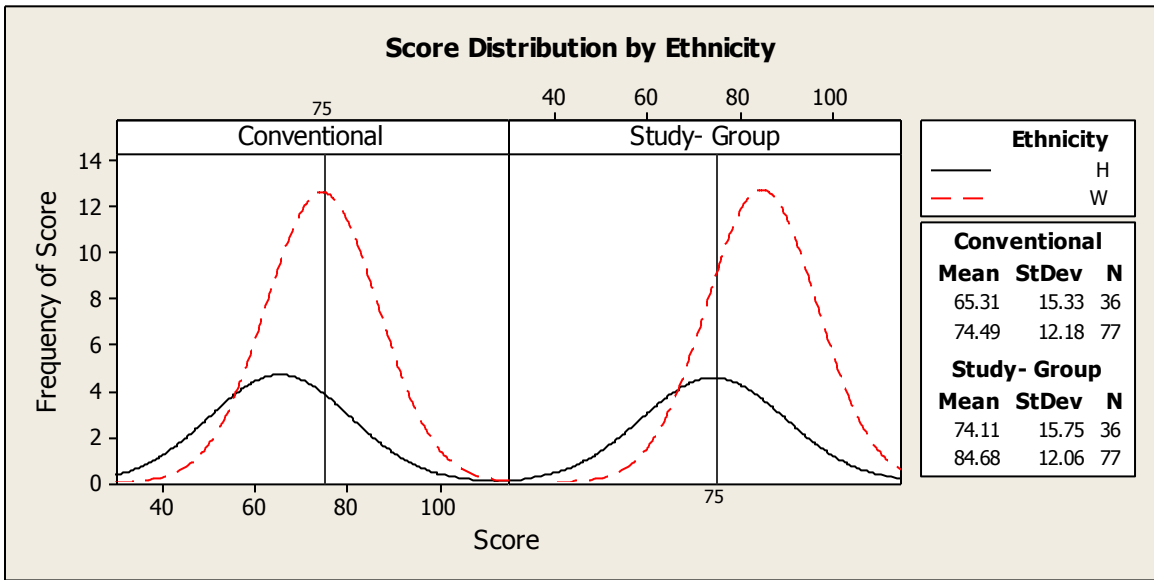

Figure 2 Test Score Distribution of the Students by Ethnicity

As shown in Figure 2, students' score histogram plot has a bimodal distribution in both the instruction methods. Initially, Hispanic students' mean score was 65.31 and white students' mean score was 74.49 with a slightly larger standard distribution among Hispanic students' score. After the group study mean of the both students' group was increased. Hispanic students' had 74.11, and white students had 84.68. Although the average score of the Hispanic students was still lower than the white students' average, a performance improvement was witnessed, the displayed an improvement in student performance after including the group study approach. Score below 60 suggested the grade below D, and left skewed distribution in the Hispanic students' score had suggested higher numbers of Hispanic students are still struggling. This implied not all students passed the class although they improved their performance after the study-group inclusion. The test score distribution by gender is presented in Figure 3.

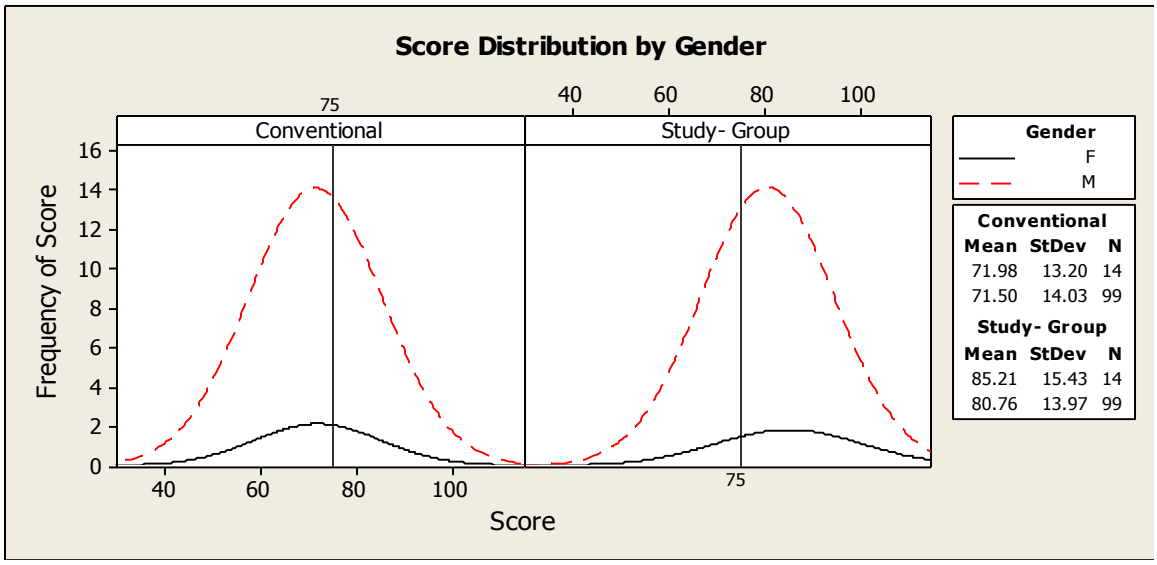

Figure 3 Test Score Distribution by Gender

As shown in Figure 3, mean score of both male and female students is almost same (~72) in the conventional window. After the selectively random group study, both male and female students had increased their grade. However, female students' average score increases is higher than male students.

To further examine the statistical validity of the study results, t-tests and confidence interval were investigated at 95% of Confidence interval. The null hypothesis was the score difference (after-before) equal to zero in all categories (white, Hispanic and female); the test results are presented in Table 3.

Table 3 Result of Statistical Significance Test

Paired T-Test and CI of Minority Students' Score before and after N Mean StDev SE Mean Difference 36 8.80 15.75 2.63 95% CI for mean difference: (3.47, 14.13) T-Test of mean difference = 0 (vs not = 0): T-Value = 3.35 P-Value = 0.002
Paired T-Test and CI of White Students' Score before and after N Mean StDev SE Mean Difference 77 10.19 12.18 1.39 95% CI for mean difference: (7.43, 12.95) T-Test of mean difference = 0 (vs not = 0): T-Value = 7.34 P-Value = 0.000
Paired T-Test and CI of Female Students' Score before and after N Mean StDev SE Mean Difference 14 13.23 15.43 4.12 95% CI for mean difference: (4.32, 22.14) T-Test of mean difference = 0 (vs not = 0): T-Value = 3.21 P-Value = 0.007

As shown in Table 3, p-value of the t-test was: minority students 0.002, White students 0.000 and female students 0.007. P-value below 0.05 (with 95% of CI) rejected the null hypothesis of equal mean (or no difference) and suggested a significant difference in the respective categories of students' performance score before and after study. All positive confidence interval (CI) implied that the difference (After-before) was greater than zero ensuring a statistical increment in score.

6. Discussion

The purpose of a selectively random study group was to increase interactions among the students and supplement the instruction. Selectively random provided an opportunity to spur a direct interaction among the students and helped them to understand each other's culture, values and thoughts, which will be instrumental to manage the challenges of the socially demanding engineering profession in future. Although a significant improvement in performance was resulted, numbers of minority students are still struggling. Tardiness, commitment to other activities or work in conflict with class schedule, and other intrinsic as well as extrinsic factors of minority students yet to be considered and addressed.

Diversity education and practices is expected to expand the students' horizon and to encourage them to think out of the box. Well educated person with the exposures of different cultures and values could perceive multiple ways to perform the same task and motivates them to evaluate a task from different perspectives, and evaluations with the multiple perspectives will deliver the better solution.

7. Conclusion and Significance

As a conclusion, the approach of forming diversified study groups has enhanced the interaction among the students with different backgrounds and helped them to escape the trap of a poor performing cohort. All categories of students (white, minority and females) improved their performance and were able have benefits of selectively random study group. Minority students especially got an opportunity for interaction and engagement, which Interaction with other students and faculty leads to engagements that sprout sense of belonging and develop a continuing motivation to pursue an engineering degree. This approach was praised by students in the course evaluation at the end of the semester. Diversified study groups would be suitable for the student body consisting of different levels of preparation and experience. In addition to the learning improvements for the students this framework also provided some flexibility to instructors and can be extended to other universities by forming a customized diversified team suitable for the specific environment.

In addition to educational benefits, students working in a diverse team can share their experiences, and they will be able to identify and address their shortfalls with the constructive feedback from the peers, which will help to hone their social skills. If implemented properly, diversity could be a resource rather than a constraint. Interactions may identify the hidden talents of the students, which can be tapped by the faculty to serve a broader. With all these benefits, collaboration is the best tool to foster learning. In summary, diversity group brings different mindsets to the table, facilitating multidimensional evaluation of a problem, and offers a well-rounded approach to a solution. This type of collaboration could provide some insights to the faculty's professional development.

8. Limitations of This Work and Future Study

This work was conducted in only two universities and with a small class sizes producing limited data. The minority category consisted of Hispanics, African American, Asian, and Pacific Islanders as well as students of mixed race. The study did not account for the heterogeneity of

students within each ethnic group. One of the challenges during this study was to find a way to incorporate a student with a disability who could not focus and work in a team and was deprived from realizing a productive learning experience. Group study approach might be more effective in higher level engineering classes having open ended problems (i.e. design courses)

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