Correlating Student Performance in Fundamental of Construction Science Course with Mathematics and Physics Grade Point Average

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It is believed that the performance of Construction Management (CM) students in their undergraduate study is dependent on their mathematics and physics performance. A Fundamental of Construction Science (FCS) course, offered for freshman, covers materials related to mathematics and physics. CM students must perform better in mathematics and physics to perform better in FCS course. This study aims at finding the correlation between the mathematics and physics Grade Point Average (GPA) with their performance in FCS course. This study also tests whether students improve their mathematics and physics knowledge by taking this course. The population for this study consists of the students enrolled in spring 2007 and 2008 courses. Relevant data related to this study were collected from office of Undergraduate Advising and from the test results conducted at the beginning and end of this course. The research hypotheses related to this study are: there is a significant correlation between mathematics and physics GPA with FCS course grade and the students significantly improve their mathematics and physics knowledge by taking this course. The statistical test results showed that there is a positive correlation between the mathematics GPA and FCS course grade and students significantly improve their mathematics and physics knowledge by taking this course.

Key Words: Mathematics, Physics, Construction Science, Undergraduate Study, Grade Point Average

Introduction

Statement of Research Problem

Construction management students frequently ask the question whether they have to do well in mathematics and physics to do well in coursework contained within the construction management curriculum. The American Council for Construction Education (ACCE) requires that students in accredited programs take a minimum of 15 semester credit hours of mathematics and science courses. Furthermore, ACCE requires these students take a minimum of 20 semester credit hours in construction science and a minimum of 20 semester hours in construction. ACCE also requires a minimum aggregate of both construction science and construction combined of 50 semester credit hours. In the Construction Management (CM) Program at the University of Nevada, Las Vegas (UNLV) the construction science courses require a significantly higher level of knowledge, skill, and ability in mathematics and physics than do the construction courses. Therefore, it is believed that students must perform well in mathematics and physics courses to perform satisfactorily in construction science courses. It is also believed that students must perform equally well in construction science and construction courses to develop the level of knowledge, skills and abilities that are critical to becoming a successful professional in the construction industry. Therefore, the UNLV CM program places an emphasis on ensuring that students take the necessary mathematics and physics courses and understand and are able to apply these courses' fundamental concepts in order to be successful in construction science and construction courses.

At UNLV, students pursuing the Bachelor of Science in Construction Management may select from two options; the management option or the engineering science option. Both options require the same courses in construction and business. The difference in the options arises from the courses satisfying the mathematics, science, and construction science requirements. The management option's courses in construction science are taught by construction management faculty and are based on an applied analysis approach which is less theoretical. All full-time and adjunct faculty teaching the construction science courses have advance degrees in engineering and 67 percent of the full-time faculty hold a doctorate in engineering. Eighty percent of the full- and part-time faculty are licensed professional engineers, that teach the construction science courses that have significant design and analysis content. Construction science courses in the engineering science option are traditional engineering courses taught by the Department of Civil and Environmental Engineering and the Department of Mechanical Engineering. In the management option, the construction science courses limit their use of calculus to the material presented in the required 4 credit calculus course.

In 2005, the Bachelor of Science curriculum underwent a significant strategic review resulting in major revisions. During the previous 17 years, curriculum changes were evolutionary in nature. The curriculum developed in 2005 and implemented in 2006, requires management option students take 7 credit semester hours in mathematics and statistics, and 8 credit semester hours in physics. The required mathematics and statistic courses are: MATH 181 Calculus I (4 credits), and STAT 152 Introduction to Statistics (3 credits). The required physics courses are PHYS 151, General Physics I (4 credits), and PHYS 152 General Physics II (4 credits). The prerequisite for PHYS 151 is 5 to 6 semester credit hours of precalculus. A comparison of the pre 2006 and post 2006 mathematics and science requirements for the management and engineering science options are provide in Table 1.

Table 1. Mathematics and Science courses in the UNLV CM Curriculum

Subjects	**Courses**	**ACCE Requi-rement**	**Prior to 2006**		**Beginning 2006**	
			Management (credit hours)	**Engineering Science (credit hours)**	**Management (credit hours)**	**Engineering Science (credit hours)**
Mathematics	MATH 132 Finite Mathematics		3			
	MATH 181 Calculus I		4	4	4	4
	MATH 182 Calculus II			4		4
	MATH 183 Calculus III			3		3
	MATH 431 Mathematics for Engineers and Scientists I					3
	STAT 152 Introduction Statistics				3	
	STAT 463 Applied Statistics for Engineers					3
	Subtotal	3	7	11	7	17
Science	CHEM 121 General Chemistry I			4		4
	GEOL 101 Introductory Geology: Exploring Planet Earth		4	4		
	PHYS 151 General Physics I		4		4	
	PHYS 151 General Physics I		4		4	
	PHYS 180 Physics for Scientists and Engineers I		4	4		4
	PHYS 182 Physics for Scientists and Engineers III			4		4
	Subtotal	8	16	16	8	12
Mathematics and Science Total			23	27	15	29

Students selecting the engineering science option, as of fall 2008, are required to complete 17 credit semester hours of mathematics and statistics courses, and 8 credit semester hours of physics courses. The 14 credit semester hours of mathematics courses are provided in Table 1.

In the CM program the outcomes of the American Institute of Constructors' (AIC) CQE-Level 1 examination are used as an element of assessment. This examination provides an excellent metric to benchmark students' performance on a national scale. As it is an objective and quantitative metric it is one of the most useful. Each year, since 2003, UNLV CM students have taken the examination offered in the spring. It was observed that these students' average score in the engineering category for 2003-2005 time period were at or slightly below the national average for other students taking the examination. This was of particular concern since the UNLV CM program always had a strong emphasis on an applied engineering content in our construction science course offerings that dealt with design and analysis. Additionally, requirements in mathematics and science have always exceeded ACCE requirements. The ACCE minimum requirement for mathematics are 3 semester credit hours and may only be satisfied with course work beyond college algebra and trigonometry. Table 1 shows that the CM program meets and exceeds the ACCE minimums.

In addition to the concerns raised by the AIC CQE-Level 1 examination results, faculty had observed that the management option students had greater difficulty in applying mathematics and physics concepts from previous courses in their construction science courses. Poor mathematics skills are a university wide problem at UNLV with entering freshman and transfers. The Howard R. Hughes College of Engineering has decided to apply greater emphasis to improved learning in mathematics and physics. In 2007 all entering students in the College of Engineering who are not qualified to take MATH 181 Calculus I are required to enroll in EGG 101Introduction to Engineering and Computer Science (2 credits) and EGG 101L Engineering Problem Solving Tutorial (1 credit, which may be repeated up to four times). This should be beneficial to CM students. The College of Engineering in partnership with the College of Science's Department of Mathematical Sciences have created special sections for College of Engineering students for MATH 128 Precalculus (5 credits), MATH 181, MATH 182, and MATH 283 to which they assigned faculty with demonstrated exceptional mathematics teaching abilities. The College of Engineering is presently engaged in negotiations to create similar courses with the Department of Physics.

Prior to the College of Engineering's increased emphasis in mathematics and physics learning, the CM program created CEM 101 Fundamentals of Construction Science in 2006. CEM 101 is now renumbered as CEM 150 Fundamentals of Construction Science. It covers introduction to engineering problem solving applied to construction science. It includes units, engineering analysis, early preliminaries of statics, and the built environment from a mechanics perspective emphasizing construction science. The purpose of CEM 150 was to reinforce and enhance the student's the application of mathematics and physics knowledge from previous courses. It covers broad based higher-level mathematics and physics applications to construction science problems and their ability to apply them to construction science courses (hopefully resulting in an improvement in performance on the engineering section of the ACI examination). This course was first taught in spring 2007, again in spring 2008 and beginning in fall 2008 in both fall and spring semesters. The authors, who are also instructors of this course, found that students need a solid knowledge base in mathematics and physics to perform well in this class. Most of the students who have a good background in math and science perform well in this course. Therefore, the authors have hypothesized that students' performance in the course CEM 150 Fundamentals of Construction Science (FCS) is affected by their undergraduate mathematics and physics GPA.

Variables and Hypothesis

The main variables in this research are: mathematics GPA, physics GPA, and the FCS grade. The major objectives of this research are to determine whether there is a significant correlation between mathematics and physics GPA with the FCS course grade and whether CM students significantly improve their mathematics and physics knowledge by taking this course. There are three main research hypotheses.

Research Hypothesis 1: There is a significant correlation between mathematics GPA and the FCS course performance.

The null hypothesis is: The correlation coefficient between mathematics GPA and FCS course test grade is not significantly different from zero.

$$\beta = 0$$

Research Hypothesis 2: There is a significant correlation between the physics GPA and the FCS course performance.

The null hypothesis is: The correlation coefficient between physics GPA and the FCS course test grade is not significantly different from zero.

$$\beta = 0$$

Research Hypothesis 3: The mean initial score of the FCS course test is significantly different from the mean final score of the FCS course test.

The null hypothesis is: The mean initial score of FCS course test is not significantly different from the mean final score of the FCS course test.

$$\mu_{initial\ score} = \mu_{final\ score}$$

Literature Review

The performance of students in any course does not only depend on their performance in prerequisite courses, but also depends on other factors like student characteristics, teaching effectiveness, gender, academic classification, and overall academic ability (Choudhury, 1999; Coleman and Gotch, 1998; Seymour et al., 1994; Rose et al., 1996) . Choudhury (1999) conducted research at Texas A&M University to determine the correlation between a student's grade in an environmental system course and the factors mentioned above. The factors considered in this research were: class size, semester in which they were enrolled, gender, academic class level of students, general feelings towards the course, perceived understanding of the material being taught, overall course satisfaction, and academic ability. Students from summer 1997 to summer 1998 were sampled. The total sample size was 225. A correlation coefficient was measured to show the strength of relationship between performance in the environmental system course and other factors. The author conducted a multiple regression analysis and the model developed by author is shown below:

$$\begin{aligned} Grade = {} & 62.4 + 0.05 \times classsize + 0.95 \times semester - 2.04 \times gender - 2.30 \times level + \\ & 0.64 \times \text{interest\&enthusiasm} + 0.24 \times feeling - 0.93 \times contribution + \\ & 0.21 \times understanding + 0.50 \times satisfy + 5.36 \times GPA \end{aligned}$$

The variables included in this study are described here. The grade is the student's percentage of total numerical grade obtained in the course. Semester is the academic term during which the student attended the course. It is categorized as regular (fall and spring) and summer semesters. Gender is the sex identification of a student. Level indicates the academic classification of a student. Interest and enthusiasm for class work, feeling toward the course, understanding of the materials taught, and overall course satisfaction are the variables used to measure teaching effectiveness. Contribution is the variable that measures the students' participation in class discussion. Grade Point Average (GPA) is the reported overall grade point average of the student.

The correlation analysis showed that the correlation between overall academic ability, which is indicated by overall GPA of the students, and grade in this course, was significant. The p value was found to be less than 0.001. The finding also showed that the grade in this course was negatively correlated with gender and level of students. For level there were two types of students enrolled in this class, junior and senior. The coefficient of determination, R^2, of this model was 0.34.

Orth (2004) performed research to identify variables that could serve as predictors of student retention and success in an undergraduate construction management program. The independent variables considered for this analysis were: high school rank, high school GPA, high school class size, number of high school science courses, number of high school mathematics courses, SAT composite score, matriculation age, gender, race, and residence. The samples were taken from students enrolled from fall 1992 to fall 1997 in the Building Science Department at Purdue University. The total sample size was 343.

The author analyzed the data by using a logistic regression model and the relationship was tested at the 0.05 significance level. The results showed that the Wild Chi-Square test for high school GPA and the number of high school mathematics subjects with graduation in the CM program were found to be statistically significant at $\alpha = 0.05$. The high school mathematics subjects considered in this study were academic high school mathematics courses such as algebra, geometry, calculus, statistics, and finite mathematics. The author recommended analyzing the correlation between semesters of high school mathematics and graduation to determine if different types and levels of academic mathematics courses have significant correlation with graduation. The study showed that the students who had taken significant mathematics courses in high school have a high graduation rate. This is one of the significant findings to show that mathematics education is vital for CM students to graduate from this program.

Various research on correlation between CM students' academic achievement and other influencing factors have been conducted. One study found that there was a strong correlation between performance in a construction graphic course and students previous work experience (Williamson, 1992). Another study found no statistically significant correlation between engineering technology students' performance and supervised industrial work experiences (Eze, 1985). Two other studies also showed that there is no significant correlation between work experience and construction student's achievement (Berryman and Scheinder, 1982 and Desy et al., 1984). Another study conducted by Wirtz in 1987 found that there was a strong negative correlation between intense work and grade point average achieved by the construction students. These studies investigated the input factors that might have significant correlation with the academic achievement of the construction students.

Little research has been conducted to investigate the correlation between mathematics and physics GPA and student performance in construction courses. This study is a fresh start to investigate the possible correlation between construction course performance and physics and mathematics performance.

Study Methodology

This study investigates the correlation between the FCS course grade and physics and mathematics GPA of CM students. The data of 27 students enrolled in spring 2007 and spring 2008 in the FCS course were analyzed. The test questionnaires were distributed to the students on the first day of class to evaluate their mathematics and physics knowledge prior to taking this course. The questionnaire consists of basic mathematics and physics problems that CM students do in their university mathematics and physics courses. The questionnaires are not returned to the students nor are the results discussed with the students. At the conclusion of the course the same questionnaire is administered to determine student improvement.

Sample Description

The data sample consists of students who have already taken their calculus course and have taken or are currently enrolled in the first physic course. Most of the students had taken their mathematics courses at the university level but some had taken them at the community college level. Similarly, most of the students had taken their physics course at the university and a few had taken them at the community college. In the data analysis, only the students who had taken mathematics and physics courses at the university level were considered. In the correlation tests, the sample size is less than 27, because some students did not take their mathematics or physics courses at the university level. Therefore, the total sample for correlation analysis was 20. The sample for correlation analysis between physics GPA and FCS course grade was 17. The multiple regression analysis was conducted with a sample size of 15. Figure 1 shows the histograms for these four variables.

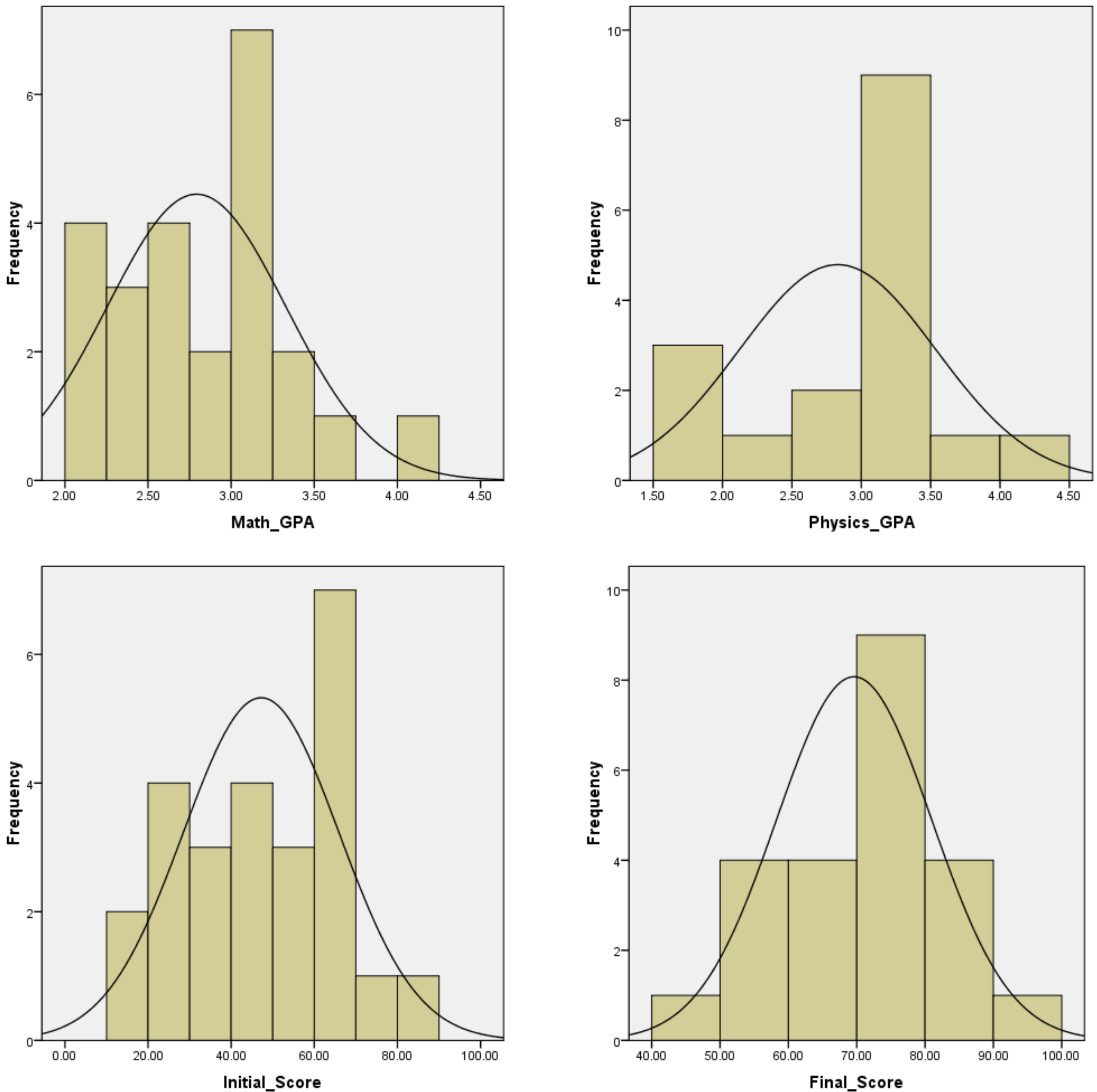

Figure 1. Histogram for Mathematics GPA, Physics GPA, initial, and final test score.

Instrumentation

The FCS course students were given two tests: one at the beginning of the course and another at the conclusion of the course. The students were not allowed to use any books or notes during the test. The students were allowed to use hand calculators. The questionnaire for both of these tests was identical. The instructor did not tell the students that they would be tested again with the same questions at the end of the semester. The graded initial test was not returned to the students, so that they could not prepare for the final test by reviewing their previous test. The objective of conducting the initial test was to determine the level of knowledge students possessed in mathematics and physics at the beginning of the course. The final test was administered to determine whether the students had improved their mathematics and physics knowledge as a result of taking this course. The mathematics and physics GPA were measured on 4.0 scale where 4.0 is equal to an A, 3.0 is equal to a B, etc. The scores for both tests were calculated in percentage.

Results

Analysis of Data

The data were analyzed using various statistical tests. The descriptive statistics (e.g. mean, median, and standard deviation) were calculated to show data variability. Analysis of Variance (ANOVA) was conducted to determine whether the mean score of the initial test was significantly different from mean score of the final test. The linear correlation tests between mathematics GPA with the initial test score and the final test score were conducted separately. The linear correlation tests between physics GPA with the initial test and the final test score were also conducted. Two multiple regression tests were conducted. Physics and mathematics GPA were regressed with the initial test score to determine the regression model to predict the initial test score based on mathematics and physics GPAs. A multiple-regression test between mathematics and physics GPA with final test score was also conducted. The findings of these descriptive and inferential statistics are explained below.

Descriptive Statistics

The descriptive statistics of mathematics GPA, physics GPA, initial, and final test score were calculated using the data analysis tool package of Excel. Table 2 shows the descriptive statistics for these variables. The mean mathematics GPA is 2.7. The mean and median are very close to each other. The low standard deviation shows that there is less variation in scores. The mean physics GPA is also very close to the mean mathematics GPA. The mean and median physics GPA are close to each other. The mean initial test score was found to be 46.5 where as the mean final test score was 69.6. The standard deviation for both of these variables shows that there is a lot of variation in the initial and final test scores. The mean value for initial and final test scores shows that the test scores improved significantly at the end of the coursework. It should be noted that students were not allowed to use any books or notes during the test. This data indicates that this course assisted students in reinforcing their mathematics and physics knowledge.

Table 2. Descriptive statistics of Mathematics, Physics, Initial and Final Score.

Variables	No. of Samples	Mean	Median	Standard Deviation
Mathematics (GPA)	27	2.7	2.8	0.64
Physics (GPA)	20	2.9	3.0	0.71
Initial Score (%)	27	46.5	45.8	18.6
Final Score (%)	23	69.6	73.5	11.4

Inferential Statistics. The first inferential statistical test conducted was ANOVA. This test was conducted in Statistical Package for the Social Sciences (SPSS) to determine whether the difference in means for initial and final test scores were statistically significant. Table 3 shows the result of the one-way ANOVA test. The result shows that the mean of the final test scores is significantly different from the mean of the initial test scores at significance level .05 for this sample. The significance value was found to be less than 0.001. This shows that the students performed well on the final test compared to the initial test. The average initial test score course was about 47, whereas the final test score increased to about 70. This indicates that CM students significantly improved their mathematics and physics knowledge by taking the FCS course for this sample.

Table 3. ANOVA results of initial and final test scores.

Description	Mean Score	Standard Deviation	F Value	Significance
Initial Test Score	46.5	19.05	25.72	< 0.001
Final Test Score	69.6	11.60		

A simple linear correlation test was conducted to determine the correlation between these variables. The correlation test was conducted separately for mathematics and physics GPAs with the initial and the final test scores. Table 4 shows the result of the simple regression tests. The tests show that the mathematics GPA was linearly correlated with the final test score for this sample. The correlation coefficient was found to be 0.53. The $\mathbf{R^2}$ value for this regression model was 0.28. This correlation coefficient is statistically significant at level 0.05. This value shows that, for this sample, the test rejects the null hypothesis that states the correlation coefficient is equal to zero. Other correlation coefficient values were not found to be statistically significant. It can be concluded that the mathematics GPA is significantly correlated to the final test scores for this sample. The students who earned higher GPAs in their university mathematic course scored higher in their final test. It also shows that these students with high mathematic GPAs tend to learn FCS course material more effectively than other students.

Table 4. Simple regression analysis of initial and final test scores.

Variables	**R**	**Intercept**	**Regression Coefficient**	**R^2**	**Significance**
Correlation with Initial Test Scores					
Mathematics	0.14	36.67	3.88	0.02	0.52
Physics	0.24	28.83	7.25	0.06	0.34
Correlation with Final Test Scores					
Mathematics	0.53	39.06	11.29	0.28	0.02
Physics	0.35	55.30	5.75	0.12	0.16

A multiple regression test was conducted to determine the combined effect of the mathematics and physics GPAs on the initial and the final test scores. Table 5 shows the multiple regression analysis test results. It shows that both models were not statistically significant at level 0.05. The most reliable regression model was the final test score model which has a significance value of 0.15 and is shown below.

$$Final - Test - Score = 7.94 \times Math(GPA) + 3.87 \times Physics(GPA) + 38.05$$

Table 5. Multiple regression analysis of initial and final test scores.

Variables	**Regression Coefficient**	**Constant**	**R^2**	**F Value**	**Significance**
Correlation with Initial Test Scores					
Mathematics	7.02	8.49	0.11	0.77	0.48
Physics	7.76				
Correlation with Final Test Scores					
Mathematics	7.94	38.05	0.25	2.18	0.15
Physics	3.87				

Significance of Effect. The significance values of the ANOVA, simple, and multiple regression tests show that the differences in mean and correlation values are not by chance. It also shows that the result of these inferential statistics will be held true if these tests are conducted with different samples. These inferential tests show that CM students tend to improve their mathematics and physics knowledge by taking an introductory class in construction science. The $\alpha = 0.05$ denotes that these findings can be wrong one in 20 occasions.

Conclusions

For this sample, the study results indicate that CM students improved their mathematics and physics knowledge by taking this course. The ANOVA test shows that the mean score achieved after this class was significantly higher than the mean score achieved before this course for this sample. One of the objectives of FCS course was to improve students' mathematics and physics knowledge through the introduction of this course. This study result showed that this objective was fulfilled.

This study also shows that there was a simple correlation between the performance in the FCS course and the students' average mathematics GPA taken at the university level. For this sample, the correlation coefficient was found to be 0.53 and it was statistically significant at level 0.05. The students who achieved higher grades in mathematics perform better in this course. However, the correlation between performance in this course and the students' physics GPA was not statistically significant. Similarly, the multiple regression test shows that when the students' mathematics and physics GPA are combined together to predict the performance in this course, the regression model was not statistically significant.

Further study on this issue is recommended. This study was conducted with a small sample size due the fact that this course was only recently introduced into the present curriculum. However, the results thus far have been gratifying. The authors will continue to conduct the tests and collect data every semester. Results of additional data analysis will be presented at the conclusion of two additional years of data collection and might further validate these findings. Similarly, the authors are also conducting a study to find the correlation between undergraduate students' mathematics and physics performance with their overall GPA. Another study is underway to determine the predictor courses that improved their overall undergraduate GPA. The authors would also like to recommend further study on this topic considering class size, instructor ability, type of instruction, gender, teaching effectiveness etc.

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