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Does it matter who teaches a core mathematics course to engineering undergraduates?

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Introduction

As part of getting the country into an economic recovery,[1,2] the nation is seeking to graduate 100,000 engineering students per year to meet the demand of high skill engineering jobs. At the same time, engineering majors are changing their minds[3] and switching majors. Most of this switching takes place in the first year. The number of undergraduates who begin with a major in engineering and then drop out or change majors ranges from 40% to 70% [4,5,6]. It is a misconception that the dropout rate in engineering is higher than it is in other majors. The truth is that many do not start as engineering majors.

In an article by Dan Reich[3] in Forbes magazine, he lists the reasons for dropping out of engineering majors and these include:

1. "cramsorption learning", where students listen to professors lecturing and then regurgitate the formulas to solve problems in a test,
2. concepts that are not learned through experience but by sitting in a lecture hall,
3. lower grades because of hard courses and hence not qualifying to enter the engineering major,
4. entry level salaries in engineering being lower than other majors such as business, and
5. coursework has a higher difficultly level compared to other majors.

So, coupled with the above reasons for dropping out or switching majors and having a small pool of potential students to begin with, it is imperative that state universities increase their retention rate for greater use of public funds and for better economic conditions for the USA.

Failure rates as high as 50% in entry-level calculus are found to be a barrier for students continuing into an engineering path[7,8,9]. One of the suggestions has been to give the mathematics series of courses an "engineering slant"[10]. These courses include Differential Calculus, Integral Calculus, Multivariate Calculus, Ordinary Differential Equations and Statistics & Probability. It is even suggested that engineering professors should teach these mathematics courses so that students can relate better to their major[11]. Several large efforts such as the WSU model have concentrated on increasing "student retention, motivation and success in engineering" by teaching courses that are application driven with a hands-on approach and only addressing those mathematics topics that are used in teaching engineering courses[12,13]. Their initial study shows 80% of the students passing the revised mathematics course.

Study

At the University of South Florida, our efforts of the above-mentioned reform of bringing mathematics courses to engineering have been limited to offering one section of the Ordinary Differential Equations (ODE) course in the College of Engineering. Students can also take the course in the Department of Mathematics for credit, and more than 75% of the students do so. The three-course sequence of Calculus is strictly taught by the Department of Mathematics.

The ODE course is a pre-requisite to the Numerical Methods course, which is a required core course for all mechanical engineering students at the University of South Florida. During the data collection phase of evaluating the effect of an open courseware[14] for Numerical Methods, we observed that some students had taken the course in the Department of Mathematics while others in the College of Engineering.

The two courses cover the same fundamental topics, but the College of Engineering takes a systems modeling approach to teaching the course. The course description for the mathematics course is "First order linear and nonlinear differential equations, higher order linear equations, applications: http://math.usf.edu/ug/syllabi/map2302/", while that of the engineering course is "Dynamic analysis of electrical, mechanical, hydraulic and thermal systems; Laplace transforms; numerical methods; use of computers in dynamic systems; analytical solution to first and second order ODEs: http://www.eng.usf.edu/~kaw/download/EGN3433.pdf".

The instructors of the engineering course are tenured faculty members and an adjunct faculty (a retired tenured faculty member in the College of Engineering), while the instructors of the mathematics course are mostly tenure-track faculty or full-time instructors.

Only by serendipity, we thought about posing some research questions such as

1. What type (age, gender, transfer status, GPA) of students take the ODE course in engineering (entitled Modeling & Analysis of Engineering Systems, and henceforth called ENG) over the ODE course in the Mathematics department (henceforth called MATH)?
2. Is there a difference in the knowledge they gain from ENG and MATH course as far as their preparation for the Numerical Methods course is concerned?
3. Is the performance in the Numerical Methods course different for students taking the ENG and MATH courses?

Since the design of the study was not set up front, the question one may ask is what student performance measures were used to answer these research questions retrospectively.

1. First, in the Numerical Methods course, we give 16-question multiple-choice pre-concept and post-concept tests. The tests include 2 questions based on ordinary differential equations.
2. Second, we give a 32-question multiple-choice final examination based on Bloom's taxonomy in the Numerical Methods course. Four of the questions are on the topic of numerical methods of ordinary differential equations, which is one of the 8 topics taught in the course.

Basing the analysis on just 2 questions on the pre- and post-concept tests and 4 questions on the final examination may not be adequate to compare the student preparation, but as we mentioned we are doing this study by serendipity. We will hence use only these performance measures to draw the conclusions of this study.

Methodology

The first step required in performing a comparative analysis was to separate those students who took the ENG course from those who took the MATH course. Once separated, the raw data was organized and discretized to ease future analysis.

The following raw data pertaining to each student was used in the analysis:

- Pre-Requisite GPA (Average grade of Calculus I, II, and III)
- Modeling & Analysis of Engineering Systems (ENG) and Ordinary Differential Equations (MATH) Letter Grade
- Gender
- Age
- Transfer Status (First Time in College [FTIC], Community College [CC], Other Transfer [OT]). FTIC are students who started their college at University of South Florida, CC are students who transferred to University of South Florida after finishing their AA degree, and OT are students who transferred from other institutions.
- Numerical Methods Final Examination Performance
- Pre-Concept Test Performance
- Post-Concept Test Performance

The data was collected over six semesters – Spring 2008, Summer 2008, Spring 2009, Summer 2009, Spring 2010, and Summer 2010. Because of the shorter length of the summer semesters (contact hours remain the same for spring and summer semesters. The summer class meets for two 110-minute sessions per week for 10 weeks. The spring class meets for three 50-minute sessions per week for 15 weeks), the pre-concept and post-concept tests were only given in the spring semesters. A summary of the data is given in Table 1.

Table 1: Overall raw data for the two groups – ENG and MATH course takers

Attribute	**ENG Group**	**MATH Group**
Total Students	82	369
Pre-Requisite GPA		
<2	1 (1%)	3 (1%)
[2.0-2.5)	18 (22%)	63 (17%)
[2.5-3.0)	21 (26%)	80 (22%)
[3.0-3.5)	29 (35%)	120 (33%)
[3.5-4.0]	13 (16%)	103 (28%)
ODE Letter Grade		
A	21 (26%)	143 (39%)
B	34 (41%)	130 (35%)
C	26 (32%)	88 (24%)
D	1 (1%)	7 (2%)
F	0 (0%)	1 (0%)
Age Distribution		
<22	32 (39%)	109 (30%)
[22-26]	44 (54%)	205 (56%)
>26	6 (7%)	55 (15%)
Gender		
Male	75 (91%)	330 (89%)
Female	7 (9%)	39 (11%)
Transfer		

FTIC	58 (71%)	157 (43%)
CC	12 (15%)	141 (38%)
OT	12 (15%)	71 (19%)
Pre-Concept Test (Maximum Score is 2)		
Average	0.548 (27%)	0.526 (26%
Standard Deviation	0.504 (25%)	0.500 (25%)
Post-Concept Test (Maximum Score is 2)		
Average	0.714 (36%)	0.728 (36%)
Standard Deviation	0.457 (23%)	0.446 (22%)
Final Examination ODE Questions (Maximum Score is 4)		
Average	2.41 (60%)	2.56 (64%)
Standard Deviation	0.98 (25%)	1.07 (27%)
Final Examination (Maximum Score is 32)		
Average	22.21 (69%)	21.98 (69%)
Standard Deviation	4.17 (13%)	3.82 (12%)

Research Question 1: What type of students took ENG over MATH course?
The data was discretized as follows.

- Pre-Requisite GPA (<2.0, 2.0-2.5, 2.5-3.0, 3.0-3.5, 3.5-4.0)
- Grade in ENG and MATH courses (A, B, C, D, F)
- Age (<22, 22-26, >26)

Once the data was properly organized, initial statistical metrics were retrieved such as the average (mean), standard deviation and variance of the Pre-Requisite GPA, and the ENG and MATH grade (non-binned data).

To determine if students with a different pre-requisite GPA took the ENG or the MATH course, a two-sided (H_0: $\mu1 = \mu2$, H_1: $\mu1 \neq \mu2$) t-Test was utilized. The tests were conducted assuming an alpha value of 0.05.

The following graphical representations (Figures 1 and 2) were established regarding the pre-requisite GPAs and the letter grade in the ODE course of the two student groups.

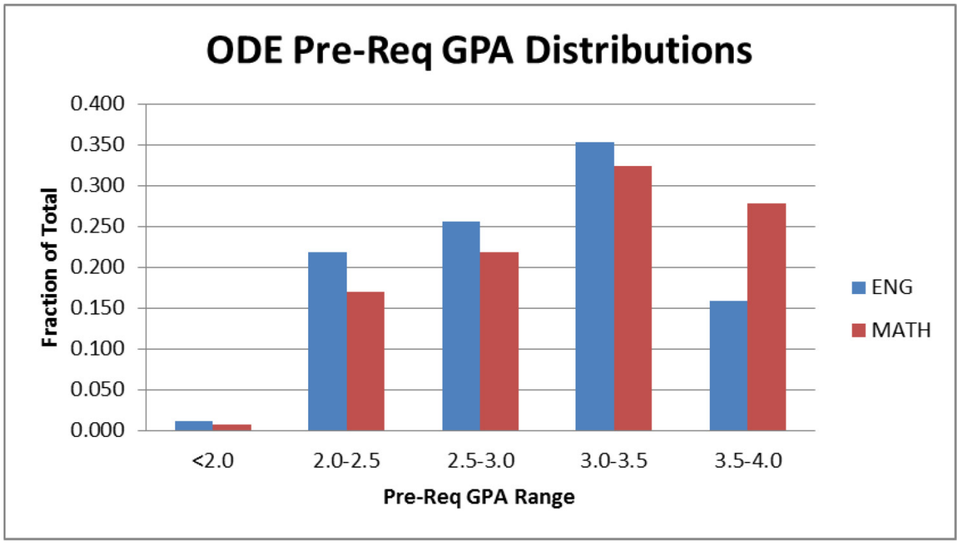


Figure 1: Pre-requisite GPA of students in ENG and MATH courses (n=82 for ENG; n=370 for MATH).

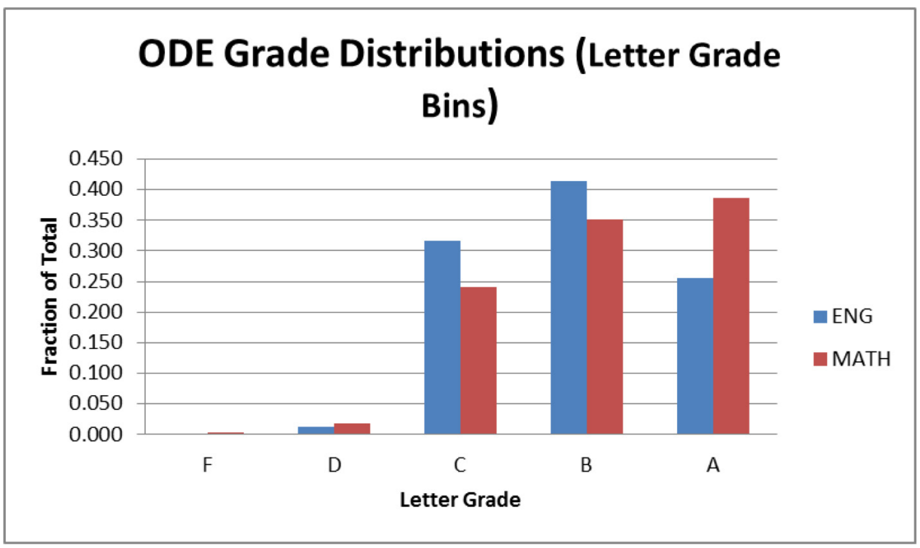
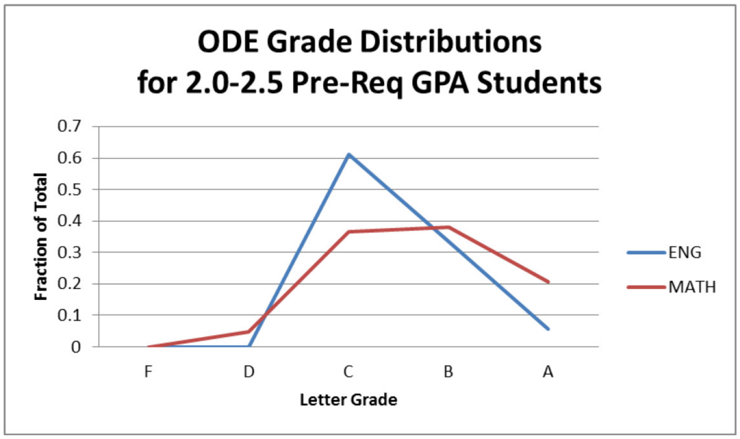


Figure 2: Letter grade distributions in ENG and MATH courses (n=82 for ENG; n=370 for MATH).

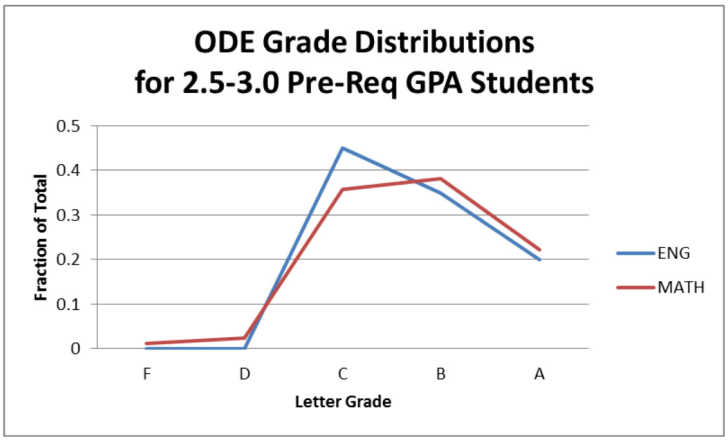
In addition to providing a graphical representation of the letter grade distributions as given in Figure 2, an ANOVA test was utilized to provide a statistical conclusion. The null hypothesis was not rejected (p=0.054). The ANOVA test results are given in the appendix in Table A-1. Following this, comparative analysis was performed on those students from similar pre-requisite GPA bins. Figure 3 and the ANOVA results illustrate the four pre-requisite GPA bins analyzed with respect to the letter grade earned in the ENG and MATH courses. There is statistically no significant difference in the grades earned in ENG and MATH courses.



ANOVA Results
ENG Average: 2.444 (n=18)
MATH Average: 2.741 (n=63)

F-statistic value: 1.974
F-critical value: 3.962

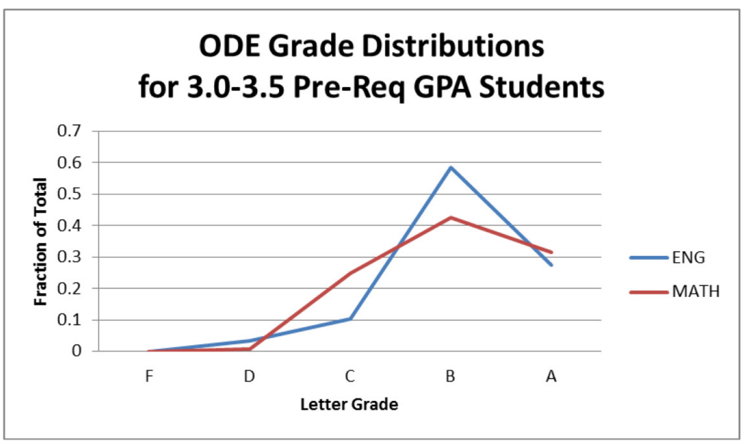
p-value: 0.164



ANOVA Results
ENG Average: 2.750 (n=20)
MATH Average: 2.808 (n=80)

F-statistic value: 0.085
F-critical value: 3.938

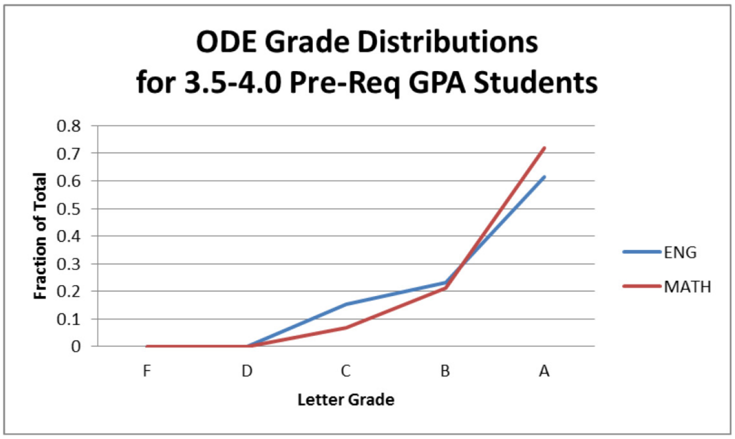
p-value: 0.771



ANOVA Results
ENG Average: 3.103 (n=29)
MATH Average: 3.034 (n=120)

F-statistic value: 0.198
F-critical value: 3.905

p-value: 0.657



ANOVA Results
ENG Average: 3.462 (n=13)
MATH Average: 3.667 (n=103)

F-statistic value: 1.377
F-critical value: 3.924

p-value: 0.243

Figure 3: Grade distributions in the ODE for ENG and MATH courses

The topic of demographic makeup of the ENG and MATH courses is discussed next. Figures 4-6 illustrate the demographic makeup of the ENG and MATH courses with respect to age, transfer status, and gender. A higher percentage of FTIC students take the ENG course because they are more prone to receive the advice to take the ENG course, while the CC students may have already taken the ODE course during their AA degree, as it is one of the recommended courses in Florida community colleges. A slightly higher proportion of students less than 22 years of age enroll in the ENG course while a slightly higher proportion of students greater than 26 years of age enroll in the MATH course. This may again be because the CC students tend to be older as many of them are working and starting a new career.

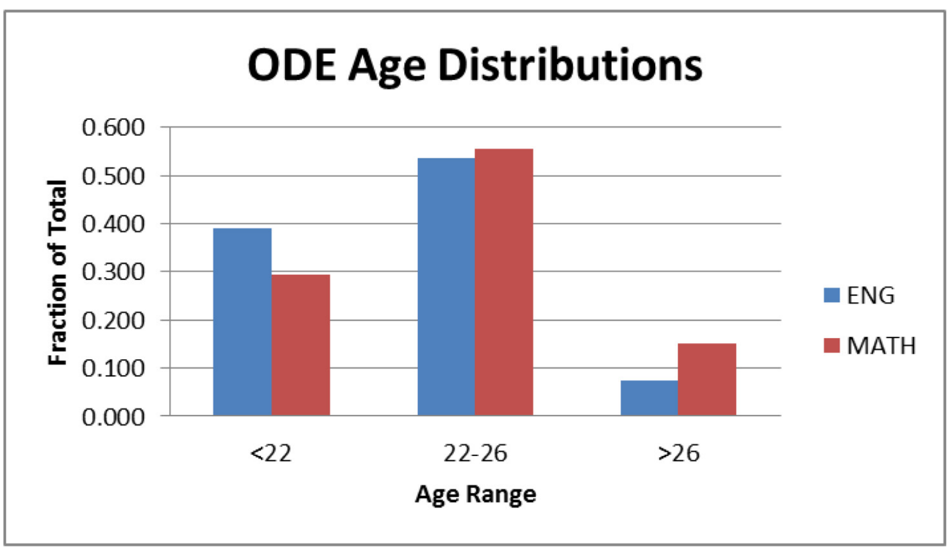


Figure 4: Age distributions in the ODE for ENG and MATH courses (n=82 for ENG; n=370 for MATH).

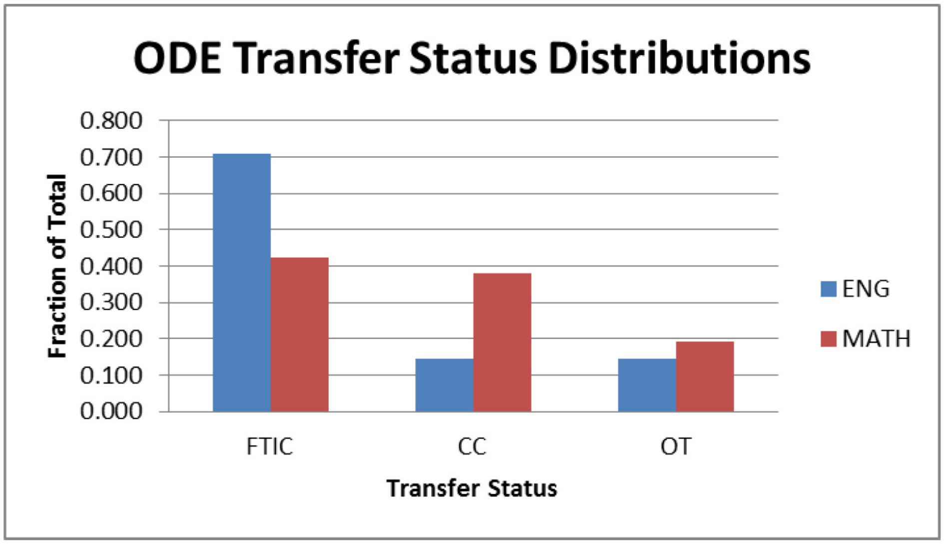


Figure 5: Transfer status distributions in the ODE for ENG and MATH courses (n=82 for ENG; n=370 for MATH).

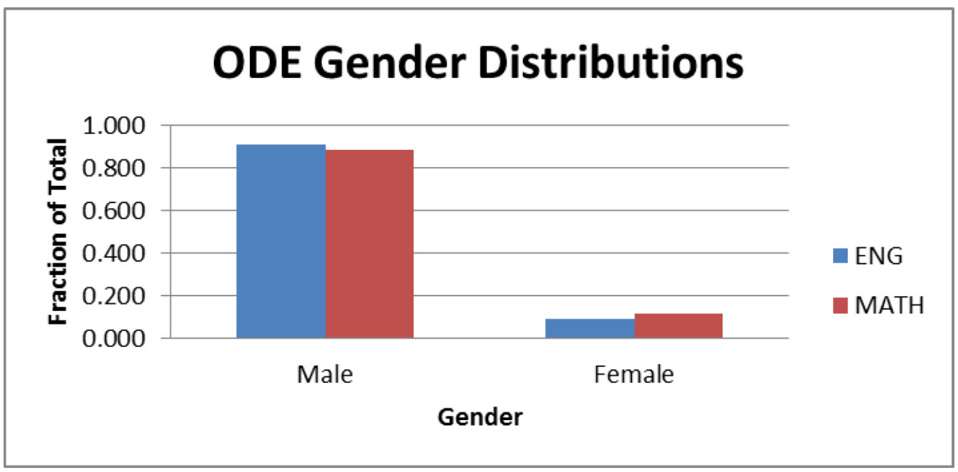


Figure 6: Gender distributions in the ODE for ENG and MATH courses (n=82 for ENG; n=370 for MATH).

Research Question 2: Is there a difference in the knowledge they gain from the ENG and MATH courses as far as preparation for the Numerical Methods course?

This research question involved a comparative analysis of students' performance on the ODE-related questions featured in the pre-concept and post-concept tests administered at the commencement and conclusion of the Numerical Methods course, respectively.

Figure 7 illustrates the performance on the pre-concept test relative to the two ODE-related questions on the examination.

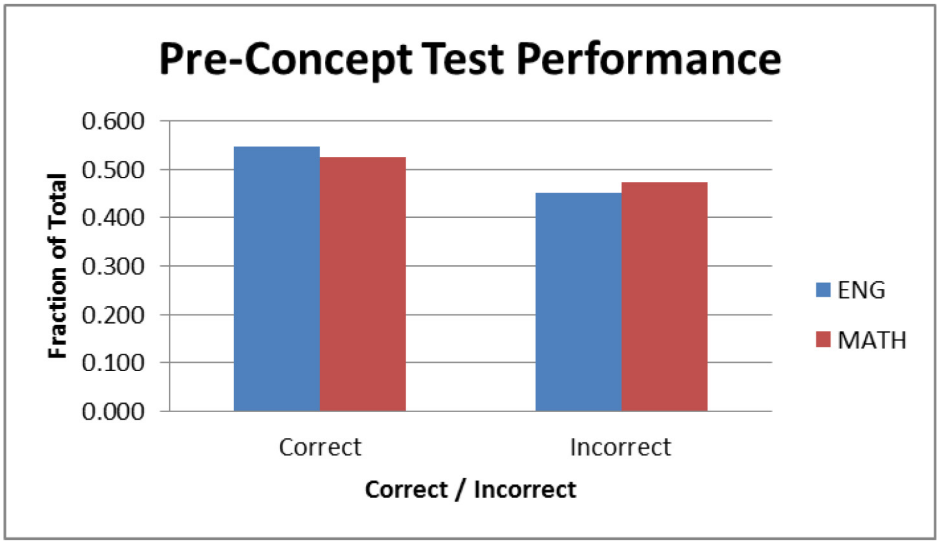


Figure 7: Pre-concept test performance in Numerical Methods course for 2 questions on ordinary differential equations (n=42 for ENG; n=232 for MATH).

In addition, ANOVA results (Appendix Table A-2) were generated for the above comparison. Note that the number of students taking the pre-concept test is less than the students taking the final examination in the Numerical Methods course as the concept tests were only given in the spring semesters. Again, no statistical significant difference (p=0.7958) was found in the pre-concept scores between the students taking the MATH and the ENG course.

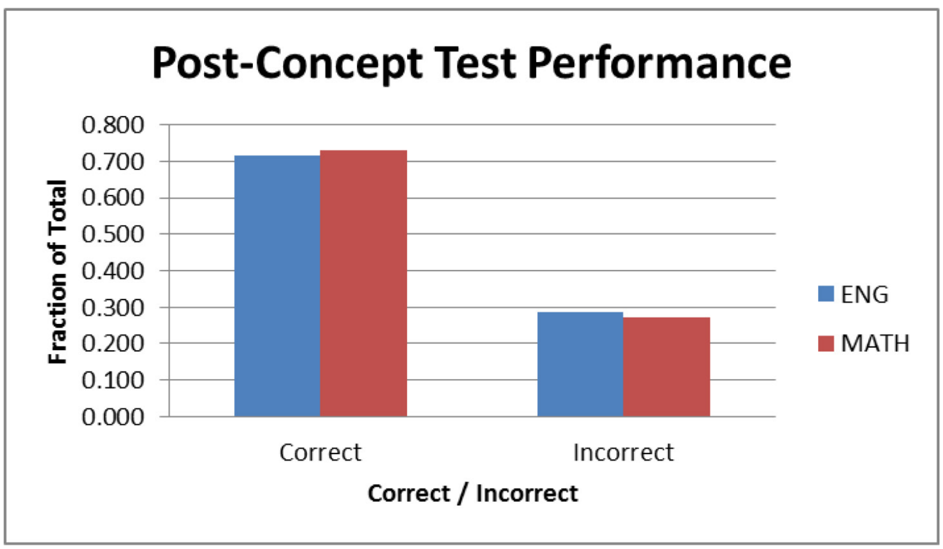


Figure 8: Post-concept test performance in Numerical Methods course for 2 questions on ordinary differential equations (n=42 for ENG; n=232 for MATH).

Finally, Figure 8 illustrates the performance on the post-concept test relative to the two ODE-related questions. The ANOVA results (Appendix Table A-3) showed no statistical significant difference (p=0.8504) in the post-concept scores between the students taking the MATH and the ENG course.

Research Question 3: Does a significant difference exist in student performance on the final examination of the Numerical Methods course?

The next research question was to determine if a significant difference existed for students' performance on the four ODE questions on the Numerical Methods final examination as well as the entire examination. This was accomplished by determining the number of correct and incorrect responses from both ENG and MATH students on the specified Numerical Methods final examination questions as shown in Figure 9. The ANOVA test (Appendix Table A-4) shows no statistical difference (p=0.2541) between the performance of the two groups of students.

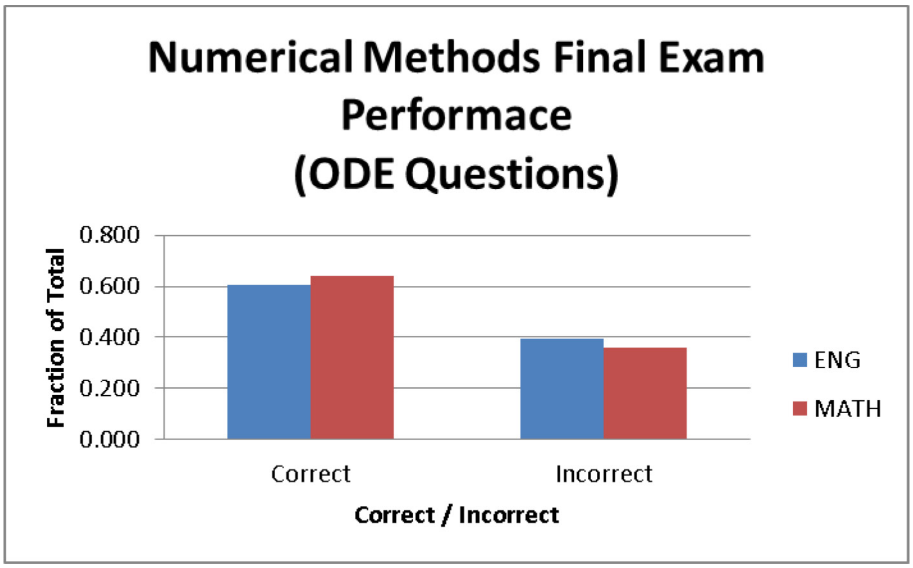


Figure 9: Final examination performance in Numerical Methods course for 4 questions on ordinary differential equations for students having taken the ENG and ODE course (n=42 for ENG; n=232 for MATH).

The above analysis techniques were again utilized to determine if a significant difference existed in regards to students' performance on the entire Numerical Methods final examination. This examination consisted of 32 questions, four of which were related to ODE content, while the other 28 were related to various other mathematical topics. Figure 10 shows the performance of two groups of students in the final examination. No statistically significant difference in the performance of the two groups were detected (p=0.6257) as shown in Appendix Table A-4.

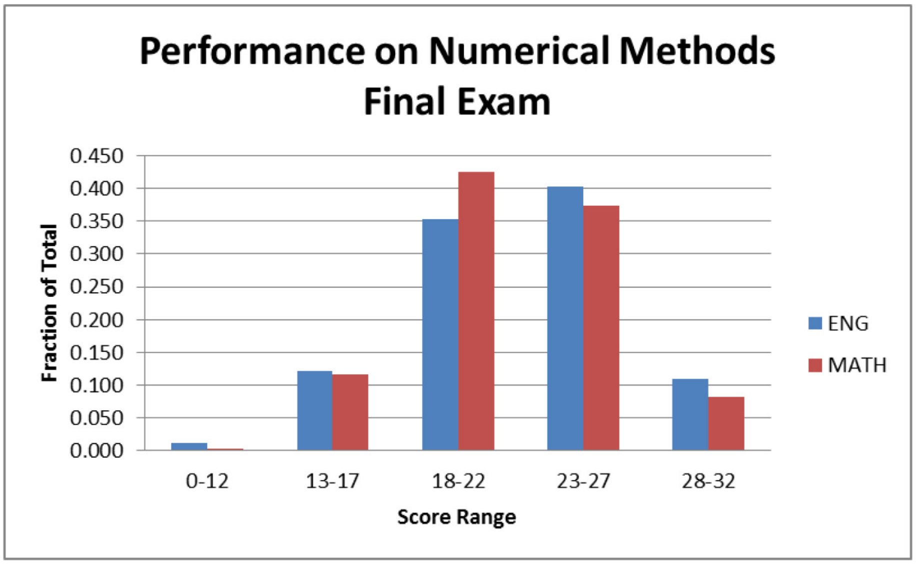


Figure 10: Final examination performance in Numerical Methods course for students having taken the ENG and ODE courses (n=42 for ENG; n=232 for MATH).

Conclusions

In this paper, we have attempted to answer the question: Does it matters which college (engineering or mathematics) teaches a mathematics course in ordinary differential equations for improved student performance?

When determining if a statistical difference was present in the pre-requisite GPAs of the two student groups, it was concluded that *there is no significant difference in the student pre-requisite GPA enrolling in the ENG course versus the MATH course.*

The demographic makeup of the separate ENG and MATH courses presented a couple of intriguing observations. First, a slightly higher proportion of students less than 22 years of age enroll in the ENG course while a slightly higher proportion of students greater than 26 years of age enroll in the MATH course. In regards to transfer status, a significantly larger proportion of FTIC (first time in college) students enroll in the ENG course compared to the MATH course. Comparatively, students who have transferred from a community college or other institutions more commonly enroll in the MATH course compared to the ENG course. This difference may be due to FTIC students being more aware of the existence of the ENG course whereas those students who have transferred are less likely to have been informed about the ENG course and instead enroll in the MATH course, which is more common to educational institutions in general. Also, many of the community college students may have already taken the ODE course during their completion of the AA degree.

When comparing the pre-concept and post-concept test performance, there was not a significant difference in students' performance on either the pre-concept or the post-concept test in regards to their enrollment in the ENG and MATH course. Therefore, it can be concluded that the *students' enrollment in the ENG and MATH course is not a factor in regards to their performance on the pre-concept or post-concept tests*. Another conclusion invoked by these findings is that students are not less prepared for ODE-related content based on their enrollment in either the ENG or the MATH course.

The ODE questions on the Numerical Methods final examination provided results concluding that the *students' enrollment in the ENG and MATH course is not a factor in regards to their performance on the four ODE-related questions or the entire Numerical Methods final examination*.

Based on the results of this study, we find no differences in student conceptual understanding and examination performance between the two groups - one that took the ODE course in the College of Engineering and the other that took it in the Department of Mathematics.

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Appendix: ANOVA test results

Table A-1: ANOVA test results for performance in the ODE courses

	ANOVA: Single Factor (Performance in ODE)						
	SUMMARY						
	Groups	*Count*	*Sum*	*Average*	*Variance*		
	ENG	82	239	2.915	0.622		
	MATH	369	1146.340	3.107	0.674		
	ANOVA						
Source of Variation		*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups		2.473	1	2.473	3.718	0.054	3.862
Within Groups		298.618	449	0.665			
	Total	301.091	450				

Table A-2: ANOVA test results for performance in pre-concept test questions on ordinary differential equations

	ANOVA: Single Factor			*Pre-Test Concept Data*			
	SUMMARY						
	Groups	*Count*	*Sum*	*Average*	*Variance*		
	ENG	42	23	0.5476	0.2538		
	MATH	232	122	0.5259	0.2504		
	ANOVA						
Source of Variation		*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups		0.0168	1	0.0168	0.0671	0.7958	3.8759
Within Groups		68.2496	272	0.2509			
	Total	68.2664	273				

Table A-3: ANOVA test results for performance in post-concept test questions on ordinary differential equations

	ANOVA: Single Factor			***Post-Test Concept Data***			
	SUMMARY						
	Groups	*Count*	*Sum*	*Average*	*Variance*		
	ENG	42	30	0.7143	0.2091		
	MATH	232	169	0.7284	0.1987		
	ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*	
Between Groups	0.0071	1	0.0071	0.0356	0.8504	3.8759	
Within Groups	54.4637	272	0.2002				
	Total	54.4708	273				

Table A-4: ANOVA test results for performance in the four questions on ordinary differential equations in the Numerical Methods course final examination.

	Anova: Single Factor (ODE Questions on Final Exam)						
	SUMMARY						
	Groups	*Count*	*Sum*	*Average*	*Variance*		
	Column 1	82	198	2.4146341	0.961759		
	Column 2	369	945	2.5609756	1.132821		
	ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*	
Between Groups	1.436807	1	1.4368071	1.303864	0.254117	3.862253	
Within Groups	494.7805	449	1.101961				
	Total	496.2173	450				