Exploring the Relationship Between Communication Skills and Performance in First-Year Engineering

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Abstract - **This Complete Research paper attempts to uncover the links between incoming student ACT (math and English language arts (ELA) scores) and performance in first year engineering and composition courses to determine if a remedial path was needed for students with low ELA skills. Statistically significant differences were found between ACT math and ELA scores, with incoming engineering students possessing greater math than ELA abilities. However, even students with ELA scores 7-points lower than the mean ACT composite score performed adequately in first year engineering courses, indicating no need for a communication focused remedial path in first year engineering.**

Background

First year engineering programs focus on retention of students within engineering programs, development of essential skills for engineering, and the selection of engineering majors. Incoming students' math abilities as measured by ACT/SAT are often used as a threshold of acceptance into engineering programs and are seen by some as a predictor of performance in engineering programs. To aid in the retention and success of all students, many first year programs have special classes for students who many need additional math skill development. Math skills are recognized as essential to the success of future engineers. However, other skills are integral to the engineering career path.

Within industry, it is communication skills that often make or break careers. Technically capable engineers will find their careers stagnating without well-developed communication skills, which are an essential part of engineering work. In fact, it has been shown that engineers spend *over half* their working days (55-60%) communicating both orally and in writing [1]. When engineers were surveyed about the most important competencies for engineers, communication was in the top three responses (after planning & time management and problem solving) [2]. Yet communication remains one of the skills engineering students struggle with the most, often failing "to appreciate that written words, not just calculations, express engineering content" [2]. Engineers often confuse equations and accurate technical content with good communication.

The importance of communication as a skill is recognized by ABET, and is included in their program as Criteria 3, Student Outcomes 3, "ability to communicate effectively with a range of audiences" [3]. ABET accredited programs are required to assess program outcomes. During this assessment, programs focus on final student capabilities. Communication is often assessed within the context of a final report or senior design project, at the end of a student's experience. These end-of-experience assessments do not address incoming students' verbal or written communication abilities.

This project was undertaken to examine the relationship between incoming student reading/writing/English skills (as measured by English Language Arts (ELA) ACT scores and performance in first year composition courses) and performance in first-year engineering courses. Our ultimate purpose was to determine whether or not a remedial path in first year engineering programs might be necessary for those who enter engineering programs with low communication abilities. This paper is a continuation of a work-in-progress paper presented at ASEE's First Year Engineering Experience conference in 2018 [4].

This investigation of the role of communication in first-year engineering was in part motivated by a recent change to the flipped classroom format in the first year engineering program at the study site. The

first year engineering flipped class requires communication daily with teammates in an active learning environment. Multimodal communication is embedded into the class assignments through several audio/visual presentations, memos, and a final design project portfolio including engineering graphics, a drawing package, computational modeling, and a written report. Thus, communication skills come into play not only in their own right, but also as a vehicle for learning. ACT ELA scores are a combination of the ACT English, Reading, and Writing scores. The first two ask questions relating to knowledge of Standard English and reading comprehension, and the last requires the writing of an essay. The composition course at the study site follows several national trends: stressing multimodal composition (combining aural, visual, and/or written modes of communication) and including a portfolio incorporating reflection as well as requiring more traditional analytic and research essays.

Methods

Students who enter this university calculus-ready are enrolled in ENG1101 in the fall semester, followed by ENG1102 in the spring. These two courses make up the common first year engineering experience across all engineering majors. They focus on engineering design and problem solving while developing programming and solid modeling skills. Students who are not ready to take calculus do not take ENG1101. Instead, they take a two-course sequence designed to cover all of the same material as ENG1101 over the whole of their first year. These students will then take ENG1102 in the fall of their second year. The two pathways into ENG1102 are shown in Figure 1. Thus, our data has two primary cohorts: those who completed ENG1102 their first year in college (who came to the university calculus ready) and those who completed ENG1102 their second year (those who needed some remedial math courses).

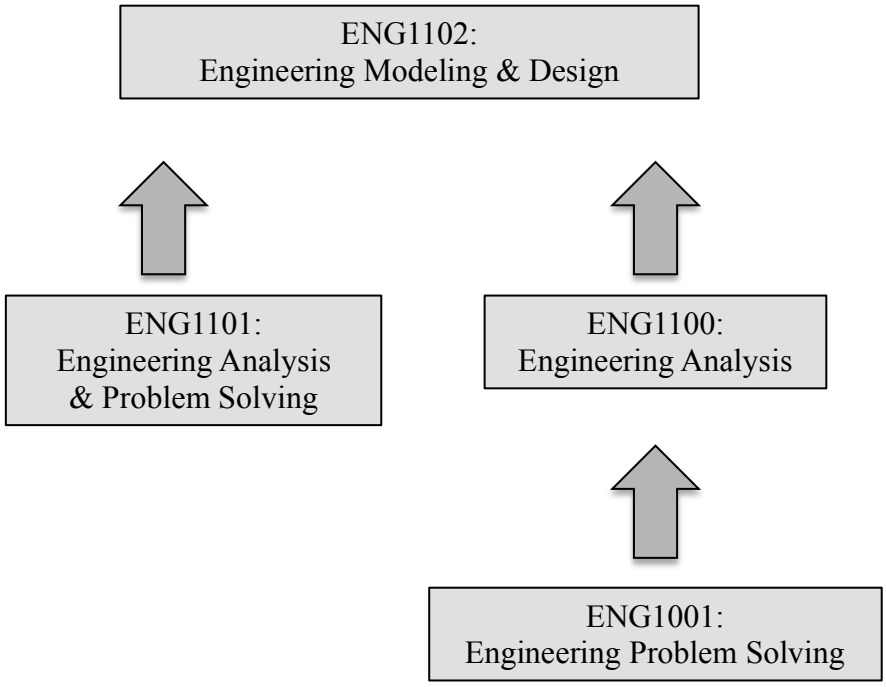

Figure 1. Pathways Through the First Year Engineering Program

Data from 829 engineering students who began their studies in the fall of 2016 was collected from a STEM-oriented university in the US Midwest. Information collected included each student's incoming math and ELA ACT scores, as well as final grades in first year composition (UN1015) and in the second class of a two-class introduction to engineering thinking and design series common to all engineering

majors (ENG1102). Unfortunately, not all incoming students submit ELA ACT scores to the university. Only 433 students with both math and ELA ACT scores were examined in this study.

Mean math and ELA ACT scores were compared using a paired two-tailed t-test to determine if there was a statistically significant difference in the students' incoming math and verbal performance. For students who earned a numerical grade (not receiving transfer credit, placement credit, or withdrawing from the course), mean final course grades (on a 4 point scale) were compared using a paired two-tailed t-test to determine if there was a statistically significant difference in the students' performance in UN1015 and ENG1102. For both of these comparisons, a significance level α of 0.01 was chosen prior to data comparison to test the null hypothesis of no difference in the means. This analysis was performed for the total of 433 students, including 363 students who completed ENG1102 in their first year and 70 students who completed ENG1102 in their second year.

Results

Results from this work are presented in three sections. The first is the overall performance results for the 433 students who began their engineering studies at the university in the fall of 2016. The second section presents the results from the 363 students who entered the university calculus ready and completed ENG1102 in their first year. The third section presents the results from the 70 students who required some math remediation and completed ENG1102 in the fall of 2017, in their second year at the university.

Overall Results

Overall, students' ACT math scores were statistically significantly higher than their ACT ELA scores, regardless of whether they entered the university calculus ready or not. For the 433 students who began their engineering studies at the university in the fall of 2016, the mean ACT math score was 28, with a range of 16 to 36 and a standard deviation of 3.3. The mean ELA score was 25 with a range of 8 to 35 and a standard deviation of 3.8. A paired, two-tailed t-test showed a p value of 1.06×10^{-52}, which is far less than the selected alpha. The difference in the means is statistically significant. The mean grade in ENG1102 by cluster of ACT ELA scores is shown in Figure 2. In general, grades in ENG1102 decreased with a decrease in ELA ACT scores, although even the lowest scores were adequate to continue on within engineering programs.

ACT ELA score range	average grade in ENG 1102	# in cohort
36-33	3.83	3
32-29	3.39	87
28-25	3.27	146
24-21	3.21	151
20-17	2.77	40
16-	2.92	6

Figure 2. Table of Grade in ENG1102 by ACT ELA Score for all Students

Despite higher math than ELA skills, the students earned statistically significantly higher grades in their composition courses than in their engineering courses.

Of the 433 students who began their engineering studies at the university in the fall of 2016, 121 did not take composition at the university due to possessing transfer or advanced placement credits. These show up on student transcripts as TR/CR and do not have a grade attached to them. A few other students transferred credit for their engineering course or earned a W, indicating a withdrawal from the course, in either. Thus, analysis of performance in the final first year engineering class versus composition was for a reduced pool of 301 students. Measured on a 4-point grading scale , the overall average grade in ENG1102 (the second class in the common first year engineering program) was 3.16, with a range of 0-4 and a standard deviation of 0.85, and the average grade in UN1015 (composition) was 3.43, with a range of 0-4 and a standard deviation of 0.81. A paired, two-tailed t-test shows a p value of 9.11×10^{-8}, less than the selected alpha. The difference in the means of 0.27 is thus statistically significant. However, this difference is also small, particularly considering that this institution's grading scale operates in increments of 0.5 (A=4.0, AB=3.5, etc.).

Tracing the relationship between all students' grades in UN1015 and ENG1102 revealed a surprising result (see Figure 3). In general, students with higher grades in UN1015 earned higher grades in ENG1102. However, students who placed out of the composition requirement, earning a CR (credit) or TR (transfer) in UN1015, had the second-highest mean score in ENG1102: 3.43, only slightly less than the A cohort's mean of 3.48. This cohort warrants further attention.

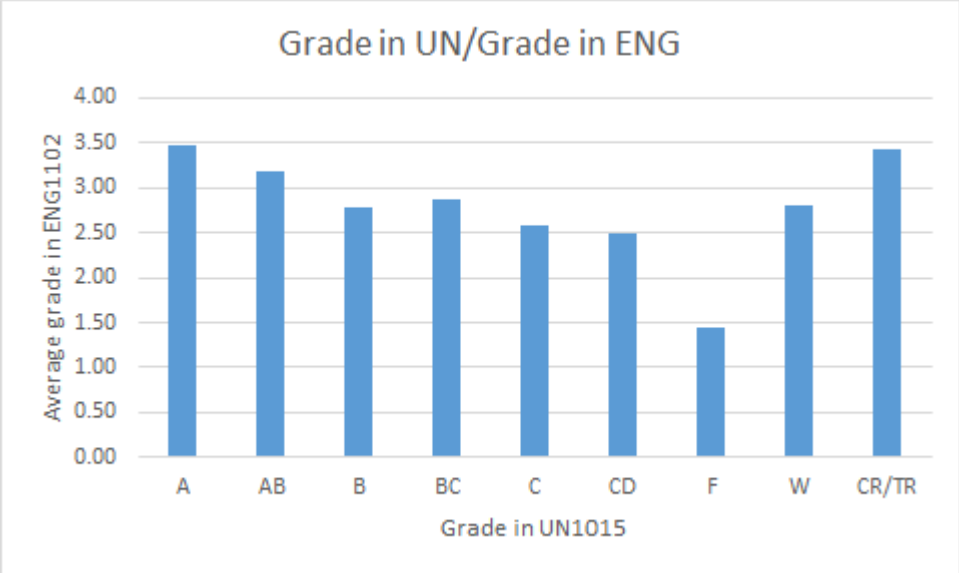

Figure 3. Grade in ENG1102 According to Grade in UN1015 for all Students

Results from Calculus-Ready Students

The results presented in this section (of calculus-ready students) were originally presented in a work-in-progress paper presented at ASEE's First Year Engineering Experience conference in 2018 [4]. It includes the results from 363 students who entered the university calculus ready and completed 1102.

Statistical analysis showed a mean math ACT score of 28, with a minimum of 16 and a maximum of 35, and a standard deviation of 3.08. The mean ELA ACT score was 25, ranging from 15 to 35, with a standard deviation of 3.41. A paired, two-tailed t-test revealed a p value of 2.28×10^{-38}. Since the p

value is less than the selected alpha, the null hypothesis is rejected and the 3 ACT point difference in the means is significant.

The mean grade in ENG1102 by cluster of ACT ELA scores is shown in Figure 4. This figure includes numbers in the cohort to give additional context to the numbers. This cohort also shows a general downward trend of grade in ENG1102 with decreasing ACT ELA score.

ACT ELA score range	average grade in ENG 1102	# in cohort
36-33	3.83	3
32-29	3.38	82
28-25	3.34	133
24-21	3.25	116
20-17	3.4	24
16-	3.00	5

Figure 4. Table of Grade in ENG1102 by ACT ELA Score for Calculus-Ready Students

Of the 363 students who entered the university calculus ready and completed 1102 in their first year, 105 did not take composition at the university due to possessing transfer or advanced placement credits. A few others earned other non-numerical grades in one or both courses. Thus, analysis of performance in the ENG1102 versus UN1015 was for a reduced pool of 248 students. Grades in both classes ranged from a 0 (F) to a 4.0 (A). The average grade in Engineering Fundamentals was 3.24 (standard deviation of .78) and the average grade in Composition was 3.44 (standard deviation of .82). The average difference (as calculated for individual students) was 0.20. A paired, two tailed t-test revealed a p value of 2.52×10^{-5}, indicating that the difference in the means is significant.

The relationship between grades in UN1015 and ENG1102 for calculus-ready students can be seen in Figure 5. In general, students with higher grades in UN1015 earned higher grades in ENG1102. When combined, the entire cohort of 364 students earned a mean grade of 3.30 in ENG1102. The 105 first-year students who placed out of UN1015, either through AP credit or transfer credit achieved a greater mean score in ENG1102 (3.45) than all but the A students in UN1015.

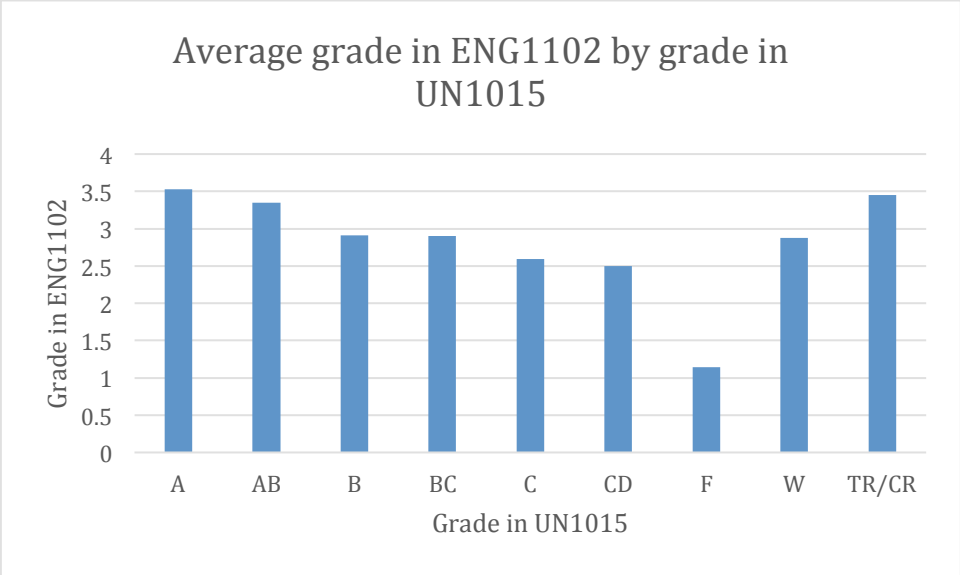

Figure 5. Grade in ENG1102 According to Grade in UN1015 for Calculus-Ready Students

Results from Non-Calculus-Ready Students

The 70 students who took the slower path to the same ENG1102 course because they arrived at university non-calculus-ready display a similar trend. The mean ACT math score was 25.5 with a range of 19 to 35 and a standard deviation of 3.0. The mean ACT ELA score was 22.7 with a range of 16 to 30 and a standard deviation of 3.1. A paired, two-tailed t-test comparing the means of the ACT math and ELA scores for this population revealed a p value of 9.3×10^{-7}, lower than the selected alpha. The difference in the means of 2.8 points is thus statistically significant.

We compared the mean grade in ENG1102 by cluster of ACT ELA scores (see Figure 6). This figure includes numbers in the cohort to give additional context to the numbers. This cohort also shows a general decrease of grade in ENG1102 with decreasing ACT ELA score.

ACT ELA score range	average grade in ENG 1102	# in cohort
36-33	n/a	0
32-29	3.5	5
28-25	2.54	13
24-21	3.09	35
20-17	2.29	16
16-	2.5	1

Figure 6. Table of Grade in ENG1102 by ACT ELA Score for Non-Calculus-Ready Students

Of the 70 students who completed 1102 in year two of their studies, 12 did not take composition at the university due to transfer or advanced placement credits. The comparison of grades in ENG1102 and UN1015 was performed for the 58 students with grades in both classes.

The mean grade in ENG1102 was 2.8, with a range of 0 to 4 and a standard deviation of 1.0. The mean grade in UN1015 was 3.3 with a range of 0 to 4 and a standard deviation of 0.7. The differences in individual students' grades in the two classes, with UN1015 subtracted from ENG1102, was -0.6, with a range of -4 to 4 and a standard deviation of 1.2. A paired, two-tailed t-test comparing the means of the grades in the two classes revealed a p value of 0.0009, which is lower than the selected alpha. The difference between the means of 0.5 is significant.

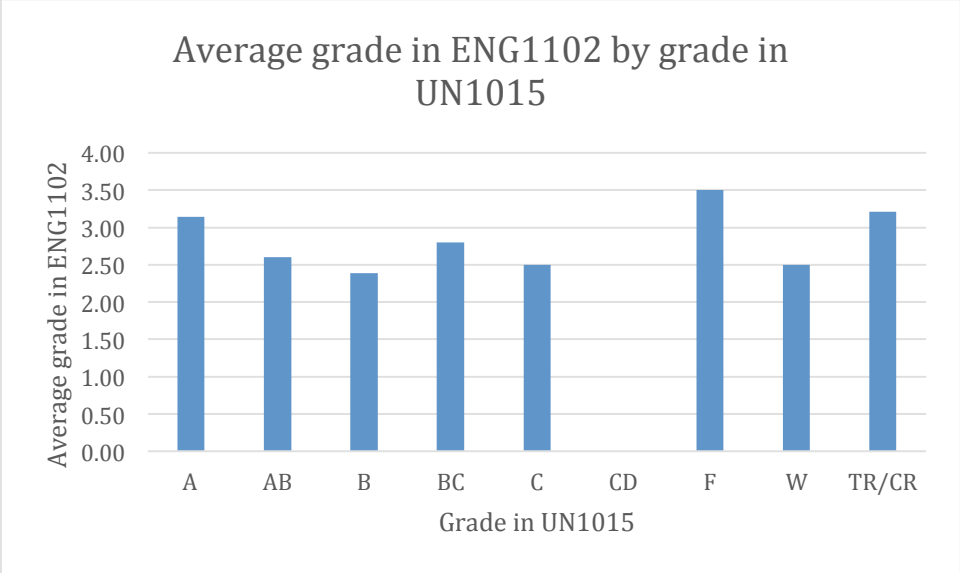

Figure 7. Grade in ENG1102 According to Grade in UN1015 for Non-Calculus-Ready Students

In this group, the students who placed out of their composition requirement actually earned a higher average grade in ENG1102 than the students who earned an A in UN1015 at the university: the TR/CR students averaged a 3.21 and the A students averaged a 3.14. This sample also had a small number in some cohorts: only one in the F and W categories each (see Figure 8).

GRADE IN UN1015	AVERAGE GRADE IN ENG1102	# IN COHORT
A	3.14	18
AB	2.60	15
B	2.38	15
BC	2.80	5
C	2.50	2
CD	n/a	0
F	3.50	1
W	2.50	1
TR/CR	3.21	12

Figure 8. Table of Grade in ENG1102 According to Grade in UN1015 for Non-Calculus-Ready Students

Summary of Results

A final summary table of the results across all cohorts is presented in the table below. It should be noted that those students with TR/CR instead of UN1015 had higher mean ACT scores than their peers in all cohorts. Additionally, the Math-ELA ACT mean score gap was lower among those students who placed out of composition than their peers.

Cohort	# in cohort	Mean ACT Math	Mean ACT ELA	Mean ACT Math Minus ELA	UN % CR/TR	Mean ENG1102 Grade	Mean UN1015 grade	Mean ENG1102 Minus Mean UN1015 grade
All in study	433	28.1	25.1	3.0	27.71	3.23	3.42	-0.19
ENG1102 in 1st yr	363	28.6	25.5	3.1	13.77	3.30	3.45	-0.15
ENG1102 in 2nd yr	70	25.8	23.0	2.9	12.86	2.84	3.32	-0.52
All TR/CR*	121	29	27	2	100.00	3.43	N/A	N/A
ENG1102 in 1st year TR/CR*	105	29.1	26.9	2.2	100.00	3.45	N/A	N/A
ENG1102 in 2nd yr TR/CR*	12	27.3	24.8	2.5	100.00	3.21	N/A	N/A

*TR/CR refers to students who did not take UN1015 at the university, but instead transferred composition credits or tested out of first-year composition.
Figure 9. Summary Table of Results Across Cohorts

Discussion

In all the cohorts, a statistically significant difference was found between the students' mean ACT math and mean ACT ELA scores. These results indicate that students entering the university are more highly functioning in their math abilities than in their reading/writing abilities. As such, higher performance was anticipated by the students in engineering classes than in composition classes.

This relationship does not display as expected when examining performance in Engineering and Composition 1000-level classes. The students' mean grades in UN10105 were statistically significantly higher in all cohorts than their grades in ENG1102. This grade difference was greatest in the non-math-ready cohort, resulting in a half point on the 4-point GPA scale, equivalent to a difference in grades according to the institution's grading scale. The average difference in course grades was 0.20 (about 5% of the available 4 point scale), with average grades in ENG1102 (3.23) being lower than the average grade in UN1015 (3.44). In essence, engineering students performed better on average in their first-year composition courses than first year engineering courses, despite a lower average ELA score.

The results of this study do not justify a remedial track for communication among engineering students. Although students with higher ELA scores seem to perform better in first-year engineering courses, the differences are slight. Only the lowest-performing 46 students earned below a B (3.0) in the engineering course. These students on average would still be considered within the range of the grade of B/C. These B/C students possessed a 20 or lower ELA score on the ACT. Considering that the average ACT composite score of students entering the university is 27.2, [5], these students overall could be considered below the average of those admitted. But most importantly, they still performed adequately in first year engineering classes, indicating no need for a remedial path for communication abilities within the first-year program.

However, students who placed out of UN1015 indicate some correlation between skills in reading and writing and performance in ENG1102. These students had higher mean ACT scores in both math and ELA (29 and 27 respectively), with less of a difference in the mean scores as well as less of a mean individual difference. They also performed better in ENG1102 than their cohorts. The mean grade of students completing ENG1102 in their first year was 3.3, but for those who did not take composition at the university, it was 3.45. The mean grade of students completing ENG1102 in their second year was 2.84, but for those who did not take composition at the university, it was 3.21.

Several routes to placing out of the composition requirement exist, including advanced placement exams and transfer credits, hence the use of the abbreviation CR/TR. These students, whose aggregate ACT scores and grades in engineering indicate high performance, may be encouraged to transfer in composition credits to ease time to degree. One avenue for further work is a continued study of these students to determine the effect of these paths on their continuing development of communication skills during their undergraduate experience. It may be that higher performing ELA students are not advancing their communication abilities as much as they could if they are placing out of UN1015. A developing trend among first year programs is to offer classes in entrepreneurship and rapid prototyping. Yet, not all incoming first year students are ready for this content. Those students in the highest ELA performance category may be among the potential candidates for these advanced first year classes.

Conclusion

Results indicated a statistically significant difference in first year engineering students' math and ELA ACT scores, with math scores being higher. However, these same students displayed a statistically significant difference in their mean performance in first year composition and engineering courses, with composition grades being higher than engineering. On the other hand, students who placed out of their composition requirement earned higher grades in their engineering courses. This trend holds true when examining students who did not enter the university calculus ready. A remedial path for communication skills within the engineering program does not seem justified by this study. Instead, consideration should be given to the further development of communication skills for those high performing students who enter the university. These students should also be considered in the pool of potential candidates for possible advanced sections of the first-year program.

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