

# Effect of a Majors-only Section of a Common Course and a Rabbit Trail of Other Factors

Laura P. Ford  
*University of Tulsa*

## Abstract

The University of Tulsa recently changed the freshman and sophomore classes for chemical engineering majors. Part of that change was a move from an all-majors Engineering Science (ES) 3053 Introductory Thermodynamics course with multiple sections to a section for only chemical engineering (ChE) majors. This ChE-only section would allow us to work on forming a cohort of students more strongly attached to and identifying with the major than the all-majors sections. This paper compares the ChE majors who took this section of ES 3053 to the ChE majors in other sections in performance in ES 3053, performance in the next course, and persistence in the major. The ChE-only section did not improve performance or retention. Further analysis of a larger dataset found lower performance by international students and by those taking the ES 3053 course late. Lower retention was seen in students taking ES 3053 late and in women.

## Keywords

Retention, International, Gender, Ethnicity, Chemical Engineering

## Introduction

The Russell School of Chemical Engineering decided in Fall 2014 to use a new computer science programming class (ES 2513) instead of the one we had been teaching in our department (ChE 1013). This decision affected the direct teaching contact we would have with our students, as seen in Figure 1. With ChE 1013, we taught our majors in a ChE-specific course in the 1st, 2nd, and 4th semesters. We also had contact with our majors in ES 3053, but we teach it to all majors in multiple sections. With recent high enrollments, we hired adjunct faculty to help teach this course. Our course rosters do not list majors, so those teaching ES 3053 often do not know who the chemical engineering majors are. While we do have contact with our majors in ES 3053, it is very different from the contact we have with them in ChE courses. We also teach the ES 3003 that the students should take in the 4th semester, and it is taught in multiple sections by tenured, tenure-track, and adjunct faculty to all majors. In changing from ChE 1013 to ES 2513, we would teach our majors in a ChE-specific course in the 1st and 4th semesters and in all-majors sections of ES 3053 in the 3rd semester and in all-majors sections of ES 3003 in the 4th semester. We would essentially lose teaching contact with our majors for an entire year in the freshman and sophomore years. To provide better contact with our students, we made a ChE-only section of ES 3053 to be taught in the fall, when students are supposed to take the course. These changes became effective quickly, with majors taking ES 2513 as freshmen in Spring 2015 and ChE-only ES 3053 as sophomores in Fall 2015.

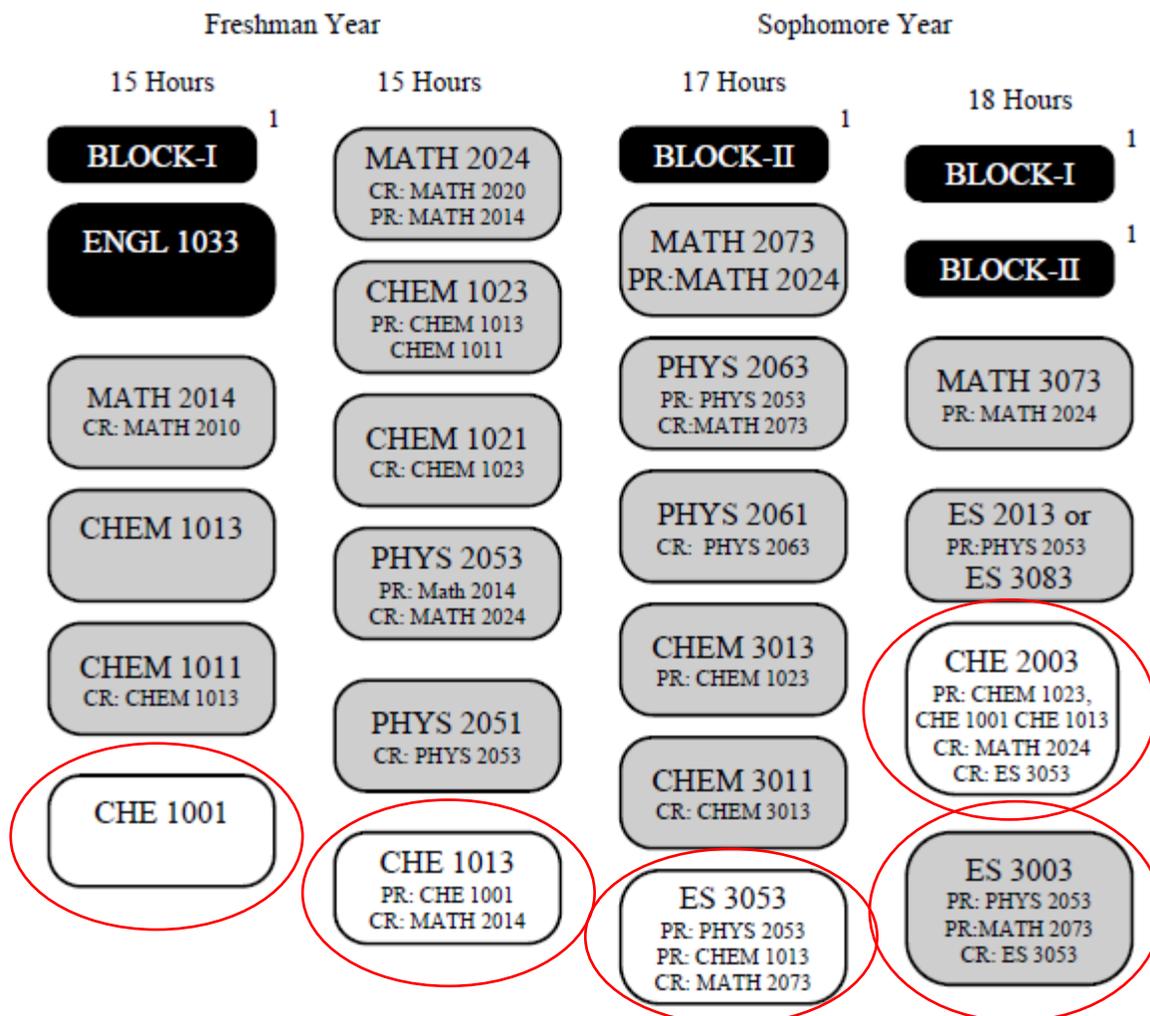


Figure 1. A portion of the courses required for chemical engineering majors starting before Fall 2014. The circled courses are taught by chemical engineering faculty members.

The new ChE-only section of ES 3053 covered fewer cycle variations but added several topics useful in subsequent chemical engineering courses. The faculty teaching the follow-up courses specifically requested the Clausius-Claperyon equation, heat capacities of mixtures, and heats of combustion, which were added to ES 3053. Two mechanical engineers took the first ChE-only section and thought the ChE-only material would be useful to them, too.

There are several ways that the students enrolled in the new ChE-only section should have understood that they were a cohort of majors. The ChE-only section was listed on the schedule of courses as being for chemical engineering majors only. The course objectives listed on the syllabus and emphasized on the first day of class included the regular section course objectives and additional objectives for the ChE-majors-only section. On that first day, they were told the course included teamwork so that they would get to know their chemical engineering classmates of the next three years. Nearly every day they did an exercise in a team of 2 – 4 students. I forced them to change around their teammates and explicitly stated a reason of getting to know the entire class. I called them chemical engineers several times in class over the semester.

Other efforts were made to make the students in the ChE-only ES 3053 feel a part of the department. Students were encouraged by extra credit offerings to attend student chapter meetings of the American Institute of Chemical Engineers. Announcements were made about summer internships, summer research opportunities for undergraduates, career fairs, and the departmental Industrial Advisory Board student lunch. Each student interviewed a TU ChE alumnus and prepared a one-page poster on what that alumnus does. As enrollment time approached, we went over the courses and talked about what they should be taking in the spring. Advice and guidance were offered throughout the semester on being a chemical engineer.

Unfortunately, not all of the majors took the ChE-only ES 3053. A few took a different section in the fall, possibly because of time conflicts with other classes they were taking. Others were off-schedule in some way and took ES 3053 in either the spring or summer semester. This raises questions about the importance of taking the ChE-only section of ES 3053. Considering that we added ChE material to the ChE-only ES 3053 course, did the students who took ChE-only ES 3053 do better in the follow-up ChE 2003 course than those who took a regular ES 3053? Considering the efforts to make the majors in ChE-only ES 3053 feel connected to the major, did they stay in chemical engineering at a higher rate than those who took the regular section?

### **Dataset and Analysis**

Two university employees provided a de-identified dataset to the author. Summaries of the results from grouping the students in this dataset are presented in this paper. The dataset included

- Student identifier (not the university student ID),
- Last major,
- Date of last major change or when the student left the University, if any,
- ES 3053: Semester taken, section taken, grade, semester GPA, and cumulative GPA at the end of that semester,
- ChE 2003: Semester, section, grade, semester GPA, and cumulative GPA at the end of that semester,
- Matriculation semester at TU, and
- Gender, citizenship, and ethnicity.

The letter grades were converted to numbers for statistical analysis: A = 4, B = 3, and so on. These number grades were averaged to calculate a course GPA for various groupings of students, and the number grades for the groupings were compared using a 1-tailed, heteroscedastic t-test. The semester GPAs were not used as they may have been too heavily influenced by the ES 3053 and ChE 2003 course grades that were already being analyzed (3 out of the 12 to 18 credit hours likely taken that semester). The cumulative GPAs were also averaged and compared using a 1-tailed, heteroscedastic t-test.

In one case, the number of students who stayed in the major versus those who left the major or TU was compared using a chi-squared test. The chi-squared test could not be used in most cases because some “expecteds” were less than 5, even when reasonable groupings of students were made. For all of the other cases, the number of students staying in the major was compared to those not staying with a t-test. A code of 0 was assigned if the student was still a ChE major, and

a code of 1 was assigned if the student had changed majors from ChE or had left the University. A 1-tailed, heteroscedastic t-test was then used to compare the codes for different groups.

**Results and Discussion**

The first comparison was between two groups in the 2015/2016 sophomore ChE cohort: those in the ChE-only section of ES 3053 and those who took all-majors sections of ES 3053 in Fall 2015, Spring 2016, and Summer 2016. Students may take both ES 3053 and ChE 2003 in the summer to complete the required sophomore courses for the major and move on to the junior-year major courses, so they are included as sophomores. Students who took ChE 2003 during the 2015/2016 academic year but did not take ES 3053 during that academic year could also be considered sophomores, but they were not since this analysis was focusing on the effect of ES 3053. The course GPAs, averaged cumulative GPAs, and how many changed major or left TU are given in Table 1. It might seem that the students in the ChE-only ES 3053 section performed better than the other students, but none of the differences are statistically significant at a 5% confidence level. It might also seem that more students in the ChE-only ES 3053 changed majors or left TU, but this difference was not statistically significant at the 5% confidence level using a chi-squared test.

Table 1. Performance comparison for all ChE majors in ChE-only ES 3053 and all other ES 3053 sections in the 2015/2016 academic year. Individual grades in ES 3053 and ChE 2003 were combined into a course GPA, and the cumulative GPAs for students were averaged.

Category	#	ES 3053		ChE 2003		Changed Major or Left TU (%)
		GPA	Cumulative GPA Average	GPA	Cumulative GPA Average	
ChE-only ES 3053	24	3.125	3.308	3.000	3.338	5 (21)
Other ES 3053	32	2.813	3.272	2.815	3.299	4 (13)

These results are disappointing. The extra ChE material in the ChE-only ES 3053 section did not appear to help the students in the follow-up course, and attempting to connect them with the department did not seem to discourage them from changing majors or leaving TU.

The ChE-only ES 3053 section included 22 students who were on-track for graduation: they started TU in the fall semester and were taking ES 3053 in their 3rd semesters. One student had started in the spring semester and took ES 3053 in his 4th semester, so he was both off-track and late in taking ES 3053. The other student did not have a starting semester listed, so it is unknown if he was off-track or on-track.

Of the majors who took other sections of ES 3053 during the 2015/2016 academic year, only 4 were on-track. Table 2 repeats the comparison of Table 1 with only the students who were on-track. In this comparison, the on-track majors in the ChE-only section appeared to perform worse than the on-track majors in other sections! With only 4 students in the other sections, though, only the number who changed major or left TU is statistically different at the 5% confidence level (t-test).

Table 2. Performance comparison for on-track ChE majors in ChE-only ES 3053 and all other ES 3053 sections in the 2015-2016 academic year. Individual grades in ES 3053 and ChE 2003 were combined into a course GPA, and the cumulative GPAs for students were averaged.

Category	#	ES 3053		ChE 2003		Changed Major or Left TU (%)
		GPA	Cumulative GPA Average	GPA	Cumulative GPA Average	
ChE-only ES 3053	22	3.227	3.371	3.056	3.388	5 (23)
Other ES 3053	4	3.500	3.540	3.250	3.489	0 (0)

These results led to more questions. How did on-track versus off-track majors compare over other years? Does it matter when the student starts classes at TU? The *requested* dataset included ChE majors who took ES 3053 (any section) during Fall 2013 to Summer 2016. The *provided* dataset includes ChE majors who took ES 3053 back to Fall 2010. These students were divided into groups based on whether they started at TU in the fall or spring semester and when they took ES 3053 relative to when they started. When counting semesters, the summer semester was considered the same semester as the spring semester. Students who transferred credit for ES 3053 were not included. No students starting in the spring semester took ES 3053 in the 1st or 2nd semesters. The groups were compared to students who started in the fall semester and took ES 3053 in the 3rd semester on campus – those students who were on-track – using a 1-tailed, heteroscedastic t-test. Keep in mind that multiple comparisons that have been done with this dataset, and the confidence level should probably be lower than 5% as no adjustment for multiple comparisons has been made. Results are presented in Table 3.

Table 3. Performance comparison for ChE majors in all ES 3053 sections by semester taken and semester started at TU. Individual grades in ES 3053 and ChE 2003 were combined into a course GPA, and the cumulative GPAs for students were averaged.

Semester		#	ES 3053		ChE 2003		Changed Major or Left TU (%)
ES 3053 taken	Starting		GPA	Cumulative GPA	GPA	Cumulative GPA	
1 <sup>st</sup>	Fall	6	3.167	3.407	3.333	3.477	0 (0)**
2 <sup>nd</sup>	Fall	37	3.405	3.636**	3.531**	3.729***	6 (16)
3 <sup>rd</sup> (On-track)	Fall	105	3.238	3.393	3.121	3.415	9 (9)
3 <sup>rd</sup>	Spring	20	2.550**	3.104*	2.211**	3.101*	6 (30)*
4 <sup>th</sup>	Fall	42	2.952*	3.062***	2.421**	3.034***	12 (29)**
4 <sup>th</sup>	Spring	5	1.800**	2.785	2.333	3.016	3 (60)
5 <sup>th</sup>	All	7	2.714	3.104	3.250	3.055	3 (43)
6 <sup>th</sup> or more	All	2	1.000	3.028***			2 (100)***
Repeated	All	7	3.143	2.744***	2.286*	2.933*	1 (14)

\* means  $p < 0.05$ , \*\* means  $p < 0.01$ , and \*\*\* means  $p < 0.001$  when compared with the 3<sup>rd</sup> semester, fall start, on-track row.

Students who took ES 3053 during the first semester at TU either brought in a considerable amount of Advanced Placement credit or were transfer students. Students with Advanced Placement credit may be better students than the rest of the cohort. Transfer students are often viewed as weaker students, particularly if they transferred from an open-admission community college to most-selective TU. In the provided dataset there were only 6 majors who took ES 3053 in their first semester at TU. Their performance was not statistically different from the on-track students, except that they changed majors or left TU at a lower rate, as seen in the first row of Table 3.

Students who start in the fall semester and take the ES 3053 course in the 2nd semester at TU are often bright students who are ahead in the curriculum. They are considering double majors or study abroad and need to make room or flexibility in their schedules for other courses. These students do not perform statistically differently in the ES 3053 class from the on-track students or leave the major at a different rate, as seen in the second row of Table 3. They do have higher GPAs at the end of the ES 3053 and ChE 2003 semesters and they perform better in ChE 2003. The higher cumulative GPAs are taken as an indication that the majors starting in the fall and taking ES 3053 in the 2nd semester are higher performing students.

The majors who started in the spring semester and took ES 3053 in the 3rd semester (fourth row of Table 3) performed worse in ES 3053 and ChE 2003, had lower GPAs at the end of the ES 3053 and ChE 2003 semesters, and changed majors or left TU at a higher rate than the majors who were on-track. 100% of the students who started in the spring semester were international students, but only 11% of the 105 on-track students (12) were international students. International students often have language and cultural barriers which can negatively affect classroom performance. International students who started in the spring semester may have been completing remedial English work in the fall semester before starting at TU. When the spring-starting majors who took ES 3053 in the 3rd semester (all international) are compared with the international students who started in the fall and took ES 3053 in the 3rd semester, there are no statistical differences, as seen in Table 4. The factor associated with lower performance seems to be international student status rather than fall or spring semester start date.

Table 4. Performance comparison for international ChE majors who took ES 3053 in the third semester. Individual grades in ES 3053 and ChE 2003 were combined into a course GPA, and the cumulative GPAs for students were averaged.

Category	#	ES 3053		ChE 2003		Changed Major or Left TU (%)
		GPA	Cumulative GPA Average	GPA	Cumulative GPA Average	
Fall-starting (on-track)	12	2.833	3.226	2.667	3.178	1 (8)
Spring-starting	20	2.550	3.104	2.211	3.101	6 (30)

The fifth row in Table 3 is fall-starting majors who took ES 3053 in the 4th semester. This group is 55% international students. Any student who takes the course in the 4th semester or later likely either needed remedial math coursework or failed a prerequisite. The prerequisites for ES 3053 are shown in Figure 1 and include PHYS 2053 (General Physics I), which has a prerequisite of MATH 2014 (Calculus I). The co-requisite for ES 3053 is MATH 3073

(Calculus III), which requires Calculus II, which requires Calculus I. Any student who is not ready to take Calculus I in the first semester will not be able to take ES 3053 on-track without summer school. Similarly, a student who fails Calculus I or II or Physics I will not be able to take ES 3053 on-track without summer school. The dataset does not have information to determine if the students needed remedial work or repeated a prerequisite course. Fall-starting students who take ES 3053 in the 4th semester get lower grades in ES 3053 and ChE 2003, have lower GPAs, and change majors or leave TU at higher rates than the students who are on-track. The overall lower cumulative GPAs indicate that these students are indeed struggling.

Spring-starting students who took ES 3053 in the 4th semester are the sixth row in Table 3. These students, who are 100% international, also probably needed remedial math coursework or failed a prerequisite, similarly to the fall-starting students who took the course in the 4<sup>th</sup> semester. There are only 5 spring-starting students who took ES 3053 in the 4<sup>th</sup> semester, so most differences with the on-track group are not statistically significant. They do perform worse in ES 3053.

There are not enough students who took ES 3053 in their 5th semester for any differences with the on-track students to be statistically significant (seventh row of Table 3).

The two students who took ES 3053 in their 6th or later semester had lower cumulative GPAs in the ES 3053 semester than the on-track group (eighth row of Table 3). One student changed his major from ChE and the other withdrew from TU, which is a higher rate of changing major or leaving TU than the on-track group. Neither student took ChE 2003. These students must have needed remedial math courses and/or failed multiple classes to get this far behind.

The last row in Table 3 is majors who obviously repeated ES 3053. They took ES 3053 after ChE 2003, even though ES 3053 is a co-requisite for ChE 2003. When they took ES 3053 the first time and the grades earned are unknown. Other students included in other groups may have repeated ES 3053 as well, but it was not obvious from the provided dataset. The majors who repeated ES 3053 did statistically as well in ES 3053 as the on-track students, but they had lower GPAs at the end of the ES 3053 and ChE 2003 semesters. The majors who repeated ES 3053 did not perform as well in ChE 2003, possibly because they did not understand the co-requisite ES 3053 material sufficiently well when they were taking ChE 2003.

Since the spring-starting majors who took ES 3053 in the 3rd semester were lower-performing than the on-track group and a higher percentage international, the entire on-track group was compared on the basis of international/domestic, male/female, and ethnicity. International students did have slightly lower performances in ES 3053 and ChE 2003 and lower cumulative GPA at the end of the ChE 2003 semester, as seen in Table 5. Men and women did not perform differently or have different cumulative GPAs, but women did leave the major or TU at higher rates than the men did, as has been reported elsewhere<sup>1</sup>.

All but one of the international students had “International” as the ethnicity, so only the on-track domestic students were grouped by ethnicity. There were 2 African American/Black students, 1 Native American student, and 6 Hispanic students, so they were grouped together as Under-represented Minorities for analysis purposes. Two students did not specify an ethnicity, and one

Table 5. Performance comparison for on-track ChE majors by nationality, gender, and ethnicity. Individual grades in ES 3053 and ChE 2003 were combined into a course GPA, and the cumulative GPAs for students were averaged.

Category	#	ES 3053		ChE 2003		Changed Major or Left TU (%)
		GPA	Cumulative GPA Average	GPA	Cumulative GPA Average	
International	12	2.833*	3.226	2.667*	3.178*	1 (8)
Domestic	93	3.154	3.415	3.184	3.447	8 (9)
Female	37	3.162	3.380	3.188	3.475	9 (22)**
Male	68	3.279	3.401	3.090	3.386	1 (1)
Asian/Pacific Islander	14	3.286	3.356	3.231	3.441	1 (7)
Under-represented Minorities	9	3.111	3.290	3.111	3.315*	0 (0)**
White, Non-Hispanic	68	3.326	3.460	3.175	3.486	7 (10)

\* means  $p < 0.05$ , \*\* means  $p < 0.01$ , and \*\*\* means  $p < 0.001$  when compared with domestic, male, or white, non-Hispanic students.

student listed “Two or more races”. These three were left out of the analysis. Only two differences appeared with ethnicity: the under-represented minorities had a slightly lower cumulative GPA at the end of the ChE 2003 semester, and they left the major or TU at lower rates.

### Summary

The ChE-only section of ES 3053 did not improve performance in the follow-up ChE 2003 course or affect student retention.

When a student takes ES 3053 relative to starting TU appears to make a difference, but other factors may be more important than semester the course is taken. Students who start in the fall and take ES 3053 in the 2nd semester do better in ChE 2003 and in cumulative GPA for both semesters than on-track students. These bright students are taking the course early. Spring-starting majors who take ES 3053 in the 3rd semester do worse overall, but they are all international students, who perform lower than domestic students in some categories even when on-track. Similarly, fall-starting students who take ES 3053 in the 4th semester also perform lower across the board. These students have probably taken remedial math courses or repeated a prerequisite course. There aren't enough students taking ES 3053 in later semesters to make many supportable comparisons, but they do not perform as well as the on-track students. Students who repeat ES 3053, while having lower cumulative GPAs, do as well in ES 3053 as the on-track students.

On-track international students performed lower than on-track domestic students in ES 3053, ChE 2003, and ChE-semester GPA. On-track women left the major or TU at higher rates than

men, even though they didn't perform any worse in ES 3053 or ChE 2003. On-track under-represented minorities stayed in the major at a higher rate than white, non-Hispanic students.

There are definitely areas for possible improvement with international students, students who take ES 3053 after the 3rd semester, and with retaining women in the major. There are many strategies to improve retention<sup>2,3</sup>, but some of them require departmental, college, and university action, which are out of the control of this author. Others are classroom and advising interventions, and the author will attempt to include some of these in Fall 2016.

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## Laura P. Ford

Dr. Laura P. Ford earned a B.S. in Chemical Engineering from Oklahoma State University and a M.S. and Ph.D. in Chemical Engineering from the University of Illinois at Urbana-Champaign. She is an Associate Professor of Chemical Engineering at the University of Tulsa. She was awarded the Kermit E. Brown Award for Teaching Excellence by the College of Engineering and Natural Sciences in 2016. Dr. Ford works with Engineers Without Borders – USA and teaches engineering science thermodynamics, mass transfer and separations, and senior labs. She is Chair of ASEE's Chemical Engineering Division for 2016/2017.