Evaluation of One-Semester Freshman Chemistry Course for Civil and Environmental Engineers

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Introduction

At the University of Nebraska-Lincoln (UNL), the current required chemistry component for the Civil Engineering program is a four-credit hour, "Chemistry for Engineering and Technology" course (Chem 111). This course has three hours of lecture and a one-hour laboratory. Students in the Agricultural Engineering and Mechanical Engineering programs are also required to take Chem 111. This intensive course covers the most important chemistry topics, especially those related to environmental engineering and materials engineering. UNL is one of the few Universities in the United States to offer such a course. UNL's Civil Engineering program is one of the few programs in the United States that does not require two semesters of general chemistry. This course originated in 1995 as part of an effort by the UNL Engineering College reduce the number of credit hours for its B.S. degrees. Some engineering disciplines (e.g., Computer Engineering, Electrical Engineering and Industrial Engineering) require just the first semester of chemistry, allowing either Chem 109 (General Chemistry I) or Chem 111, whereas programs where some chemistry may be needed (Agricultural, Civil, and Mechanical Engineering) require this new course (Chem 111).

For the past five years, students in the Civil Engineering program have had the option of taking several different combinations of chemistry courses. Prior to 1998, Civil Engineering students were given the option of taking either Chem 111 or Chem 109 (first semester of general chemistry), and students who took Chem 109 were given the option of taking the second semester of general chemistry (Chem 110) instead of the second semester of physics. Since 1998, students can take the intensive one semester course (Chem 111), or take the slower-paced traditional two-semester general chemistry series (Chem 109 and Chem 110) but only receive credit for the second four-credit course toward their degree. In addition, a few students transfer to Civil Engineering from majors that require the two-semester chemistry series, Chem 113 and 114 (Fundamental Chemistry I and II), that is primarily targeted at Chemistry majors. Consequentially, the students in Civil Engineering have a wide range of chemistry backgrounds. The main goal of this paper is to examine the impact of these backgrounds.

This paper has two main objectives. The first is to examine differences in student performance on the chemistry components of the junior-level Introduction to Environmental Engineering course based on the students' chemistry course background. Specifically of interest is whether the intense single semester course (Chem 111) and the two-semester series (Chem

109 and 110) provide a background in chemistry that is sufficient for Civil/Environmental Engineering students. The second objective is to develop a set of advising heuristics to help incoming freshman select the appropriate program of study in chemistry based on their preparation and interests.

In order to meet these objectives, four years of data from CIVE 326 (Introduction to Environmental Engineering) were used to compare students' performance on the chemistry-related portions of CIVE 326. Also, four years of data from Chem 109 and Chem 111 were used to develop advising heuristics.

Description of Chemistry Courses

Chemistry 109, "General Chemistry I," serves as an introduction to principles of chemistry for students in technical and vocational areas that require some chemical training for their major field. Entering students are expected to have taken at least two units of high school math including algebra and geometry. No prerequisite of high school chemistry is mandatory, but many of the entering students have had such a course. As part of the general admission requirements to the University of Nebraska, incoming students are expected to have completed at least three units of natural sciences, including at least two units selected from biology, chemistry, physics, or earth sciences. The course is focused on the following topics: states of matter and kinetic molecular theory, atomic theory and structure, chemical bonding and molecular structure. The following topics are introduced, but are not covered in depth: kinetics and equilibria, acid-base reactions, and oxidation-reduction reactions.

In Chemistry 110, "General Chemistry II," chemical principles are applied to real systems. Topics introduced in Chemistry 109, which is a prerequisite for this course, are covered in more detail and in more quantitative fashion. These topics include: kinetics and equilibria, acid-base reactions, and oxidation-reduction reactions. The course also treats the chemistry of metal and nonmetals and nuclear chemistry. Introductions to organic chemistry, to biochemical reactions, and to metabolism are also provided. The Chemistry 109-110 sequence serves as the minimum chemistry requirement for a number of major fields of study. This sequence is also mandatory students for students wishing to take courses in quantitative chemical analysis or organic chemistry, both of which often follow in the sophomore year.

Chemistry for Engineering and Technology, Chemistry 111, is a one-semester introduction to fundamentals of chemistry. The course is designed for engineering majors other than majors in chemical engineering. The topics covered in this course are similar to those in Chemistry 109-110, but the topics are covered at a much faster rate. In recent years there has not been much emphasis on introductory organic chemistry or on biochemical reactions. The prerequisites for this class are more extensive than those for the109-110 sequence. In addition to three units of high school math including algebra and geometry, entering students are expected to have completed at least one unit of high school chemistry and one unit of high school physics. The expectation is that these prerequisites allow the students to handle the faster rate at which the course material is covered.

Chemistry 113 is the introductory chemistry course for students majoring in the physical sciences or in chemical engineering. Topics include atomic and molecular structure, chemical bonding, states of matter, solutions, and acid-base reactions. This course is recommend for students who plan to take upper-level courses in chemistry, such as physical chemistry, instrumental analysis, and advanced organic chemistry. The prerequisites for Chemistry 113 are the same as those for Chemistry 111. Chemistry 114 is the second semester of the freshman sequence (with Chemistry 113) for physical science and chemical engineering majors. The course is focused on chemical kinetics, electrochemistry, ionic solution equilibria, introductory thermodynamics, and the chemistry of selected elements. Chemistry 116, "Quantitative Chemistry Laboratory," is a two-credit course that is taken in parallel with Chemistry 114. The course serves as an introduction to quantitative analytical methods, especially acid-base and redox titimetry, gravimetry, use of pH meter, separations, and analytical spectrophotometry.

Description of CIVE/BSEN 326

All Civil Engineers are required to take the 3-credit hour Civil Engineering (CIVE) 326 (Introduction to Environmental Engineering) course. CIVE 326 is cross-listed as Biological Systems Engineering (BSEN) 326, hereafter referred to as CIVE 326. Its prerequisites are differential equations and chemistry. CIVE 326 is the first introduction the students receive to the principles of environmental engineering, including water quality, atmospheric quality, pollution prevention, and solids and hazardous waste engineering. This course is taught during the fall semester by Civil Engineering faculty and during the spring semester by Biological Systems Engineering faculty. Over 90% of Civil Engineering students take 326 during the fall. Only 3 or 4 students enrolled in 326 each fall are non-Civil Engineers (typically Biological Systems Engineers or Chemical Engineers). The same syllabus and book has been used for 326 for the past five years. The CIVE 326 data used in this study were taken from the past four fall semesters taught by Civil Engineering faculty members (Dr. Bruce Dvorak, 1997-1999 and Dr. Matt Morley, 2000).

Approximately 15% of course and exam content in CIVE 326 requires the direct use of chemistry concepts. For the past four years, each lecture on a topic that required the use of chemistry included review of the basic chemistry principles, because two or three years had elapsed since most students had taken their last chemistry course. There are four general types of chemistry applications used in CIVE 326. Stoichometry is used to balance chemical reactions and to calculate theoretical oxygen demands. Molar and normal units are used to make molar calculations, calculate equivalents, concentrations such as $CaCO_3$, and work simple hardness and alkalinity problems. Simple pK relationships for acid-base systems are introduced to the students to understand environmentally important systems such as the carbonate system and chlorine disinfection. Simple K_{so} relationships for precipitation chemistry are used to introduce students to solid solution chemistry applications. Table 1 lists the percent weighting of the chemistry topics on the chemistry portion of the exams. Table 1 also lists the chemistry courses that cover each of the concepts. Each fall, the chemistry component on exams was worth between 10 and 15% of the final grade.

Table 1. Chemistry Topics Covered in CIVE 326 Exams.

Chemistry Concept	Chemistry Class Topic Covered	% Distr. of Chemistry Topics '00	'99	'98	'97
Use of stoichiometry	109, 111, 113	35	25	20	20
Use of molar and normal units	109, 111, 113	40	40	35	35
Chemical equilbria: pK relationships for acid-base systems	110, 111, 113	25	25	20	25
Chemical equilbria: K_{so} relationships for precipitation chemistry	110, 111, 113	10	10	25	20

The chemistry background of the CIVE 326 students varied over the study period, as listed in Table 2. Students were categorized into five groups: Chem 109 only, Chem 109 and 110, Chem 111, Chem 113, and those who had taken their chemistry outside of UNL. Many of the students who had taken Chem 113 had also taken several additional advanced chemistry courses. A change in the chemistry courses taken by the CIVE 326 students occurred between 1997 and 1998, which represents a policy change (two years before) which effectively made most students take Chem 111 instead of Chem 109 (only).

Table 2. UNL Chemistry Background of CIVE 326 Students

Year	Chem 109 only	Chem 109/110	Chem 111	Chem 113+	Non-UNL chemistry
'00	6	5	17	1	10
'99	12	7	11	6	6
'98	4	7	17	4	4
'97	26	7	13	1	4
TOTAL:	48	26	58	12	24

Methods: Assessment of Chemistry Performance in CIVE 326

Four years of data (fall semesters 1997 through 2000) from CIVE 326 (Introduction to Environmental Engineering) were used to correlate students' performance on the chemistry-related portions of CIVE 326 with the freshman chemistry course(s) they completed. Information concerning the college chemistry course(s) taken by the CIVE 326 students came from a survey given to each class at the start of the semester. Each student's performance in different subject areas of CIVE 326 was recorded each semester in a spreadsheet; each student's performance on chemistry exam questions, overall exam performance, and overall course average were recorded. The data for each student concerning grading and chemistry background was combined for this study into a single spreadsheet. Data was not included in this study from students who completed their chemistry at a University other than UNL (14% of the CIVE 326 students).

In order to combine data from different semesters, the overall exam grade and chemistry question grades were standardized, since the averages for each of these varied each year as listed

in Table 3. To standardize the data for each semester, the overall and chemistry question average were determined. Then the overall exam grade and the chemistry exam question grade for each student were adjusted by the same percentage so the average grade for all the students in each semester course was 80%. In other words, after standardization, the chemistry exam average and the overall exam average for each year in Table 3 would be 80%. This standardization was necessary to account for differences in exam difficulty year to year.

Table 3. Exam Averages Before Standardization.

Year	Chemistry Exam Average	CIVE 326 Exam Average	Δ CIVE 326 Exam Ave. - Chem Exam Ave.
'00	75.5%	82.8%	9.3%
'99	78.6%	82.1%	3.5%
'98	78.1%	82.3%	4.2%
'97	80.9%	82.5%	1.6%

Results: Assessment of Chemistry Performance in CIVE 326

An overall analysis of the chemistry performance in CIVE 326 was performed and the combined data from 1997 through 2000 is shown in Table 4. Four types of observations can be made from this data. The first is that in general, the strongest students in CIVE 326 (represented by the overall exam average) were the students who had taken Chem 111, followed by students who had taken Chem 113 and those who had taken both Chem 109 and 110. The lowest achieving students were the students who had taken Chem 109 only. This trend is likely a reflection of freshman advising, where the least academically prepared CIVE students (low ACT, high school class rank, and high school chemistry background) have tended to be advised to take Chem 109 (only) and the best academically prepared CIVE students have been steered toward taking Chem 111.

Table 4. Assessment of Chemistry Performance in CIVE 326 (1997-2000). Each Semester's Exam Data Standardized to an 80% Course Average.

	Chem 109 only	Chem 109 & 110	Chem 111	Chem 113+
Number of Students	48	26	58	12
Overall Exam Average	77.4%	80.8%	82.3%	81.7%
Chemistry Exam Question Average[1]	77.0%	82.4%	79.6%	95.3%
Difference between Chemistry Exam Average and Exam Average	-0.35%	1.63%	-2.73%	13.6%
Std. Dev. of difference between Chemistry Exam Ave. and Exam Ave.	10.9%	8.5%	12.4%	7.0%
Std. Dev. of Chemistry Exam Ave.	15.0%	12.3%	15.9%	10.3%

1 – Chemistry Related Questions on CIVE 326 Exams.

Performance on the chemistry exam questions is a second area of interest. The students with the strongest chemistry background were those who took the chemistry for chemistry majors (Chem 113+). As expected, the Chem 113+ students did much better on the chemistry portions of the 326 exams than any other group. Students who had taken two semesters of chemistry (Chem 109 and Chem 110) did slightly better on the chemistry exam questions than those who had taken only one semester (Chem 111 followed by Chem 109).

A third observation concerns the difference between overall exam average and chemistry exam question average. By comparing the difference between the overall exam average and the chemistry exam question average, part of the variation in the academic ability of the students can be removed. Once again, the students with the strongest chemistry background (Chem 113+) did better on the chemistry portions of the exams than the exams as a whole (+13.6%). Students who had taken two semesters of chemistry (Chem 109 and Chem 110) also did better on the chemistry portions of the exams than the exams as a whole (1.6%). Students with only one semester of college chemistry background performed slightly worse on the chemistry portions of the exams than the exams as a whole. Interestingly, the Chem 109 only students actually performed slightly better relatively on the chemistry portions of the exams than the Chem 111 students (-0.4% versus –2.7%), although this difference may not be meaningful.

The last observation from the data in Table 3 concerns the differences between the standard deviations of the chemistry exam question average and that for the overall course average. The biggest difference between the two standard deviations is for students who took Chem 111. In other words, there was more relative variation in the performance on the chemistry portions of the exams for the Chem 111 students than students with other chemistry backgrounds.

In order to evaluate the source of the large variation in the performance of students with Chem 111 as their college chemistry background, the student records were separated into three categories by their overall course grade. The three groups were the top third (>84.0%), middle third (84.8 - 77.2%), and bottom third (<77.2%) of the CIVE 326 class. Thirds were used to maximize the sample size of each group. This data is provided in Table 5.

The relative ranking of the best to worst chemistry performance is the same in Table 5 as that discussed for Table 4. The most significant trend found by separating the student records into thirds (by overall performance in CIVE 326) is that students in the bottom third of the class performed much more poorly on the chemistry exam questions. Though the Chem 111 students had an overall exam average of 72.8% (vs. 68.0% for Chem 109 only students), their chemistry exam question average was 64.4% (vs. 67.2% for Chem 109 only students). This information suggests that students (whose performance was) in the bottom third of the class who took the intensive one semester chemistry course (Chem 111) retain the least from their college chemistry course and are least likely to be able to make up for that lack of preparation through their own review of chemistry.

Table 5. Assessment of Chemistry Performance (1997-2000): Divided By Thirds. Each Semester's Exam Data Standardized to an 80% Course Average.

Third		Chem 109 only	Chem 109 & 110	Chem 111	Chem 113+
Top	Number of Students	12	8	26	5
Top	Difference between Chemistry Exam Average and Exam Average	**0.6%**	**1.3%**	**-1.1%**	**14.1%**
Top	Std. Dev. Of difference between Chemistry Exam Ave. and Exam Ave.	6.7%	8.1%	8.5%	8.7%
Middle	Number of Students	17	11	17	5
Middle	Difference between Chemistry Exam Average and Exam Average	**-0.5%**	**2.5%**	**-0.3%**	**13.6%**
Middle	Std. Dev. Of difference between Chemistry Exam Ave. and Exam Ave.	9.6%	8.9%	10.8%	5.4%
Bottom	Number of Students	19	7	15	2
Bottom	Difference between Chemistry Exam Average and Exam Average	**-0.8%**	**0.7%**	**-8.4%**	**12.2%**
Bottom	Std. Dev. Of difference between Chemistry Exam Ave. and Exam Ave.	14.0%	9.4%	17.7%	10.7%

The Chem 111 students in the bottom third of CIVE 326 were a diverse group. Table 6 includes a listing of the composite ACT scores and the freshman year GPA for all CIVE 326 students who completed Chem 111; the data in Table 6 is from the same student data set used for Table 5. There was not a significant difference between the middle and bottom third of the students in ACT scores (and in the high school class rank – not shown). There was a significant difference between the grades that each third of CIVE 326 received in Chem 111. This data suggests that the students' performance in Chem 111 affects their ability to subsequently succeed in CIVE 326, especially on the chemistry components. Unfortunately it is not be easy to predict from ACT scores which students may be most affected due to the overlap of ACT scores.

Table 6. Analysis of CIVE 326 Students Who Completed Chem 111.

Third	average	Std. Dev.	maximum	minimum
Composite ACT				
top	29.3	2.6	33	24
middle	26.8	2.2	30	22
bottom	27.1	2.6	31	24
Freshman Year GPA				
top	3.59	0.38	4.00	2.53
middle	3.39	0.40	4.00	2.60
bottom	3.15	0.28	3.58	2.66
Chem 111 GPA				
top	3.42	0.63	4.00	2.00
middle	3.16	0.68	4.00	2.00
bottom	2.60	0.57	4.00	2.00

Methods: Comparison of Performance in Chem 109 and Chem 111

Five years of data (fall semesters 1995 through 1999) from Chem 109 and Chem 111 were analyzed with the objective of developing rules of thumb for identifying the best chemistry course for in-coming freshman. The data was obtained at the request of the UNL Associate Dean of Engineering from the UNL Records office. The Records office staff wrote a program to collect student data from the records that met the following criteria: (1) data from fall semesters of 1995-99, (2) Chem 109 data included only from students enrolled in Engineering at the time, (3) included all students enrolled in Chem 111 (except for a dozen students enrolled in the Construction Management program). These data included the following information on each student record: course term, student name, course grade, rank in high school class, class size, ACT score (composite, math, reading, and science), and freshman year Grade point averages (GPA). GPAs were calculated in this study using the UNL standard scale of A+ and A = 4.0, B+ = 3.5, B= 3.0, C+ = 2.5, C = 2.0, D+ = 1.5, D = 1.0, and F = 0.0.

About 3% of the students took one of the courses twice (since they did not pass it the first time); in these cases, data from the second time the student took the course was dropped from the data set (we were interested in how a student did the first time he or she took the course).
Student records were also eliminated from this study if they did not include an ACT score and/or percentage rank within their high school class. For Chem 109 and Chem 111, 21.5% and 8.8%, respectively, of the database was eliminated on this basis. Students without ACT scores were either those who had taken the SAT (typically from outside of the Midwest where the ACT is the most common college entrance exam) or those who transferred to UNL from a Nebraska Community College. Students without a percentage rank within their high school class were either international students or transfer students from another university or community college.

Students who withdrew from any of the chemistry courses were considered to have received a “D” for the purposes of this study. Undergraduate students at UNL may withdraw from a course through the three-quarter point of the semester without obtaining special permission. After this point, withdrawals will only be granted by special appeal and because of extraordinary circumstances. A withdrawal after the first two weeks of a regular semester remains on a student’s academic record after a withdrawal as a "W" grade. The assumption of a grade of a “D” was based on the fact that the average freshman GPA of Chem 111 students with a “W” was equivalent to that of those who had received a “D” in Chem 111. Nearly all students in both large data sets (Chem 109 had 509 student records and Chem 111 had 767 student records) were listed as Engineering majors at the time they enrolled in either course. The specific majors that were enrolled in each course varied slightly.

Results: Comparison of Performance in Chem 109 and Chem 111

In order to develop rules of thumb for identifying the best chemistry course for in-coming freshman, the data was analyzed to identify the best predictive factors that are readily available in UNL freshman student files. A regression analysis of the Chem 111 student grades

versus all possible predictive factors: ACT (composite, math, reading, and science) and percentage rank in high school graduating class, found the best correlation (both R^2=0.20) to be the composite ACT and math ACT score. The science and reading ACT scores resulted in R^2 of 0.12 and 0.09, respectively. The percentage rank in high school graduating class resulted in the lowest R^2 (0.05). Based on these results, the composite ACT score was selected for further use in this study.

Within a given composite ACT score range, another analysis of Chem 111 student data was performed. For example, data from students with a composite ACT between 24-28 was analyzed. It was determined that the best correlation with a student's Chem 111 grade was with the percentage rank in high school graduating class (R^2=0.12). The second best correlation was with the math ACT (R^2=0.06). Regressions with the science ACT and composite ACT scores resulted in R^2 of 0.003 and 0.02, respectively. Thus, the yielded composite ACT and percentage rank in high school graduating class were used as the two best predictive factors in the following analysis.

The student records in the Chem 109 and Chem 111 data sets were separated into groups according to the students' composite ACT and percentage rank in their high school graduating class. In Table 7, data for both Chem 109 and Chem 111 (gray rows) is provided. For each group of students, the average grade earned in the chemistry class is given, as well as the percentage of students who received a grade equal to or above a "B" and a "C." The number of students in the group is also listed.

Table 7. Comparison of Chemistry 109 and Chemistry 111 Results.

Composite ACT Score	Chem	GPA[1]	%≥B	%≥C	#
All students	111	2.41	44%	81%	767
All students	109	2.42	45%	78%	509

Composite ACT Score	Chem	Student Class Rank Top 10 % GPA[1]	%≥B	%≥C	#	Student Class Rank 10-30% GPA[1]	%≥B	%≥C	#	Student Class Rank Less than top 30 % GPA[1]	%≥B	%≥C	#
< 24	111	2.07	28%	78%	14	1.85	12%	79%	25	1.08	2%	53%	43
< 24	109	2.78	56%	89%	9	2.10	21%	81%	39	1.73	23%	58%	31
24 – 26	111	2.78	56%	92%	39	2.13	23%	79%	134	1.60	9%	62%	64
24 – 26	109	2.92	69%	88%	38	2.15	29%	78%	96	1.66	18%	59%	61
27 - 28	111	2.88	70%	91%	60	2.03	32%	79%	74	1.53	20%	53%	57
27 - 28	109	3.11	77%	91%	22	2.22	39%	77%	41	1.64	22%	61%	18
29 and greater	111	3.30	81%	96%	177	2.63	57%	84%	93	1.79	20%	50%	29
29 and greater	109	3.54	85%	98%	80	2.73	64%	84%	45	1.71	21%	58%	19

1 – Average Grade Point in Chem 109 or Chem 111.

The overall results listed at the bottom of Table 7 for the two chemistry classes are remarkably similar. The average GPA earned and percentage with grades above a "B" and "C" are nearly identical. This similarity is likely due to the efforts of the faculty that teach Chem 111 to maintain a similar grade curve to Chem 109, even though students who enroll in Chem 111 enter college with better preparation to succeed in chemistry than those in Chem 109. A higher fraction of the Chem 111 class than the Chem 109 class is represented in the high ACT/class rank categories. 52% of the Chem 111 class (versus 37% for Chem 109) had an ACT > 29 and was in the top 30% of their high school graduating class. The average composite ACT of the Chem 111 students was higher than their Chem 109 counterparts (27.3 versus 26.5). The average class rank of the Chem 111 students was higher than their Chem 109 counterparts (18.9% versus 21.3%). Also, students advised to take Chem 111 were partially selected for success in chemistry since students who felt their high school chemistry preparation was weak were advised to take Chem 109.

When chemistry success was considered for groups of students with similar composite ACT scores and class ranks, nearly all groups of students received a lower grade in Chem 111 than their counterparts in Chem 109. The most significant difference between the success of students in Chem 109 and Chem 111 was for students with composite ACT scores below 24.

Table 8 lists the overall chemistry GPA difference by similar composite ACT score and class rank between Chem 109 and Chem 111 students. The number of students in each ACT/class rank group are also listed. This data shows that students who take Chem 111 are at risk of getting a lower grade than if they take Chem 109. The average Chem 111 student in this study received a chemistry grade 0.17 lower than Engineering students in Chem 109 with similar composite ACT scores and high school class rank standing. This average grade difference was estimated by multiplying the grade difference in a ACT/class rank category times the fraction of Chem 111 students in the ACT/class rank category, and then summing up the value for all categories. For students with a composite ACT > 27 and in the top 30% of their high school class, the chemistry grade difference was 0.20. The differences in chemistry grade may become significant for students who must maintain a specific GPA in order to renew a scholarship. It also may make a difference in retaining some students in Engineering.

Table 8. GPA Difference Between Students Who Took Chemistry 109 and Chemistry 111.

	Student Class Rank					
	Top 10 %		10-30%		Less than top 30 %	
Composite ACT Score	Δ109–111 GPA	#109/111	Δ109–111 GPA	#109/111	Δ109–111 GPA	#109/111
< 24	0.71	9 / 14	0.25	39 / 25	0.65	31 / 43
24 – 26	0.14	39 / 38	0.02	96 / 134	0.06	61 / 64
27 - 28	0.23	22 / 60	0.19	41 / 74	0.11	18 / 57
29 and greater	0.24	80 / 177	0.10	45 / 93	-0.08	19 / 29

Conclusions

1. Students with the strongest chemistry background (Chem 113+) did significantly better on the chemistry portions of the CIVE 326 exams than the exams as a whole and appear to have benefited significantly from their strong chemistry background as compared to the other CIVE 326 students.

2. The results from the *entire class* related to students who took the other chemistry courses (109, 110, and 111) showed only small differences in the relative performance (chemistry portions of the exams versus the exams as a whole) of each chemistry option. The differences were sufficiently small that we do feel that one can conclude that there is a difference in chemistry performance in CIVE 326 between students who Chem 109 and Chem 110, Chem 109 only, and Chem 111.

3. Students whose performance was in the bottom third of the CIVE 326 class and who took the intensive one semester chemistry course (Chem 111) appear to be particularly hampered in their ability to succeed in applying chemistry in CIVE 326.

4. Composite ACT and percentage rank in high school graduating class were the two best predictive factors of success in a freshman chemistry course.

5. The available data concerning in-coming freshman (e.g., ACT and class rank) can not be used to predict (with any precision) which students will be most affected later in their academic career by the intensive chemistry course.

6. Although the students who enroll in Chem 111 (Chemistry for Engineers) enter college with better preparation to succeed in chemistry than those in Chem 109 (General Chemistry I), the two groups receive nearly identical grades (in their chemistry class). When chemistry success is considered for groups of students with similar composite ACT scores and class ranks, nearly all groups of students received a lower grade in Chem 111 than their counterparts in Chem 109.

7. One of the specific objectives of this study was to create a new set of heuristics for advising in-coming freshman Civil Engineering students concerning which college chemistry course(s) to take. Based on the results of this study, we recommend that the UNL faculty advising in-coming freshman use the following heuristics for advising.
   a. If a student does not have a strong high school chemistry background, the student should take Chem 109 and 110. This can be qualitatively evaluated by determining the time elapsed since the student completed their high school chemistry, the grade the student received for high school chemistry, and the student's evaluation of the quality of instruction in high school chemistry.
   b. Students with a composite ACT less than 24 should take Chem 109 and 110.
   c. Students that are wavering between engineering and non-engineering majors (and may become swayed by the intensity of Chem 111) should take Chem 109 and 110.

d. Students that are interested in working in a sub-discipline where chemistry may be important, such as Environmental Engineering or Materials Engineering should take two semesters of chemistry. The student should take either Chem 113 and 114 if the student has a strong preparation, or Chem 109 and 110.
e. Students who are willing to take the risk of getting a (slightly) lower grade in order to avoid taking an additional 4-credit hours of class work should take Chem 111, otherwise the student should take Chem 109 and 110. The average Chem 111 student in this study's database received a chemistry course grade 0.17 lower than Engineering students in Chem 109 with similar composite ACT scores and high school class rank standing.
f. For students with a composite ACT > 27 and in the top 30% of their high school class, the chemistry grade difference was 0.20. In other words, about 40% of the students who take Chem 111 will receive a grade that is half a letter grade lower than students with similar preparation who take Chem 109.

8. Investigate changing the CIVE undergraduate curriculum to make Chem 109 and 110 the required classes, allow Chem 113 and 114 to be taken by students as an acceptable substitute.

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