Board 33: Persistence of First Year Engineering Majors with a Design-Based Chemistry Laboratory Curriculum In- and Out-of-Sequence

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ChANgE Chem is a curriculum reform model which was created to address the retention of engineering students taking general chemistry in their first two years as undergraduates [1],[2]. Currently, we are using this model to develop a curriculum of laboratory activities called Design Challenges (Figure 1), which translates the chemistry concepts into contextualized problems and methods unique to the way engineering students are expected to learn, think and collaborate (Table 1). This new curriculum is designed to maintain student motivation for an engineering major by helping them to better understand the profession and practice [3].

Figure 1. Concept design for a Design Challenge.
Table 1. Overview of the Design Challenges (DC) for a first semester chemistry course.

<table>
<thead>
<tr>
<th>NAE Grand Challenge</th>
<th>DC-0</th>
<th>DC-1</th>
<th>DC-2</th>
<th>DC-3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Restore and Improve Urban Infrastructure</td>
<td>Engineer the Tools of Scientific Discovery</td>
<td>Make Solar Energy Economical</td>
<td>Develop Carbon Sequestration Methods</td>
<td></td>
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<tr>
<td><strong>Design Challenge for Students</strong></td>
<td>Use knowledge regarding density of materials to assess the quality of concrete used to make double T beams. Make certification recommendation.</td>
<td>Use knowledge on the type and number of ions in a water sample to design a protocol for testing water hardness. A field technician should be able to assess whether water quality meets the DEQ standard.</td>
<td>Use specific heat capacity to determine what composition of materials is a best for storage of solar energy in a 250 ft. concentrated solar power (CSP) facility with building cost not exceeding $20M.</td>
<td>Use gas laws and kinetics of reaction to determine the amount and conditions of calcium hydroxide solution to best sequester 5.0 GtC CO$_2$ in 24 hours.</td>
</tr>
<tr>
<td><strong>Description</strong></td>
<td>Students measure the density of concrete in-air and in-water to determine the actual density of the concrete considering air entrained.</td>
<td>Established analytical methods (titration and conductivity) are tested and revised as model processes to gather data for the design challenge.</td>
<td>Student teams create a physical model of a CSP to gather specific heat capacity data and transform this model to a dual-y axis graph to address the DC.</td>
<td>Student teams gather kinetics data and use it to determine the optimum amount and time for calcium hydroxide as carbon sequestration method.</td>
</tr>
</tbody>
</table>

One of the major goals of our effort is to build student’s persistence—their commitment and capacity for remaining in pursuit of an academic goal [4]. For undergraduates, particularly female engineering majors, the first two years on campus are typically the period in which persistence is of most concern [5]. A course like chemistry may challenge students without ever helping them to apply the knowledge gained to their interests or to later courses that are directly relevant to their major. By building a student’s capacity and commitment to their major, they can use this new-found motivation to support their academic success.

Self-efficacy, defined as “beliefs in one’s capabilities to organize and execute the courses of action required to produce given attainments” [6](p. 3), is a critical form of motivation and basis for evaluating persistence. It is one of the strongest predictors for undergraduate student achievement [7],[8] and a lack of self-efficacy has been shown to foreshadow a change of majors and leaving engineering for underrepresented students [9],[10]. For engineering students, self-efficacy predicts interest, achievement and persistence in the major [11],[12],[13]. Self-efficacy is most likely to drop during the first two years a student spends at a university [14].

This paper reports on a field study of student self-efficacy and persistence across a semester for three groups taking general chemistry laboratory for engineers, comparing the use of the new curriculum with a more typical curriculum which represents business-as-usual. The study addressed the following research questions: Compared to a Business-as-Usual laboratory curriculum and taking into consideration whether the course was taken In- (fall) or Out-of-Sequence (spring):

1. What is the level of student self-efficacy across a semester?
2. What is the level of student academic and professional persistence?
Methodology

This field test involved a quasi-experimental study across three separate conditions comparing student self-efficacy, academic and career persistence at four milestones across one semester. This data was collected using four milestone surveys that were given to students starting with a pre-survey before the semester began and then again after each Design Challenge was completed (approximately every three weeks). The survey included scales from two validated instruments. The self-efficacy data was collected using the 10 questions from the Motivated Strategies for Learning Questionnaire (MSLQ) [15]. The persistence variables were scales from a revised version of the APPLES instrument [16]. A one-way ANOVA with post hoc comparisons using the Tukey HSD test was used to determine differences in outcomes for the four iterations of the design challenges within one semester. An independent samples t-test was used to compare changes in the outcomes across the conditions.

The participants were 73 undergraduate students enrolled in general chemistry for engineering majors. The In-Sequence group consisted of 26 students enrolled in the fall semester. The Out-of-Sequence group consisted of 21 students enrolled in the spring semester. The third, a Business-as-Usual group was comprised of 26 students enrolled in the same lecture section of general chemistry for engineering majors, but were not enrolled in the special laboratory section. The rationale for comparing the two semesters against each other come from the institutional perspective that the students in the spring semester are functionally different than those enrolled for the fall semester. The idea being that because general chemistry is typically a two-semester course, students who enroll in the spring semester will be Out-of-Sequence from their peers. The university assumes that these students are different than their In-Sequence peers because they believe that there is some outside factor that prevented them from starting the course in the fall. These factors could range from delayed acceptance, failed courses or other personal matters. Due to this institutional bias these students may face more persistence related issues than their In-Sequence peers.

Results and Discussion

To compare changes in the average total self-efficacy for the three groups, a one-way ANOVA was conducted on the gain scores (post-pre). The result showed a significant difference in gain among the three groups (F(2,70)= 8.877, p= 0.000). A Tukey post hoc test revealed that the gain in average total self-efficacy of the Business-as-Usual group (-8.38 +/- 10.79) was significantly lower than that of the In-Sequence (-0.23 +/- 7.97, p= 0.007) and Out-of-Sequence groups (2.48 +/- 9.02, p= 0.001). However, there was no difference between the In-Sequence and Out-of-Sequence groups (p=0.588). This shows that students using the Business-as-Usual curriculum experienced the same loss of self-efficacy that has been predicted by the literature. On average, students in the Business-as-Usual group had a final reported self-efficacy over eight points lower at the end of their first semester of chemistry compared to when they started the semester. Students using the new laboratory curriculum, both In-Sequence and Out-of-Sequence groups, maintained their self-efficacy from the beginning to the end of the semester (Figure 2). Changes across the semester were further explored. The Business-as-Usual group demonstrated a significant difference only in the drop from pre to post (F(3,100)= 2.743, p=0.048). For the In-
Sequence and Out-of-Sequence groups, there was no difference between any of the self-efficacy scores on the four milestone surveys, \( (F(3,100)=2.063, p=0.110) \) and \( (F(3,79)= 0.386, p=0.763) \) respectively.

Figure 2. A comparison of average self-efficacy by group across a semester

There were two additional types of motivation analyzed for this study, Academic Persistence—commitment to completing an engineering degree—and Professional Persistence—commitment to working or attending graduate school as an engineer. The results of this analysis showed that there was no difference in the level of academic persistence when comparing the three different groups of students \( (F(2,70)= 2.53, p=0.087) \). The analysis for professional persistence also showed no difference comparing the In-Sequence, Out-of-Sequence and Business-as-Usual groups \( (F(2,70)= 1.578, p= 0.214) \). This analysis shows that our Out-of-Sequence students in the spring semester showed similar changes to their academic and professional persistence when compared to their In-Sequence peers, both with and without the intervention. The results validate the institutional perspective that students in the spring semester are different than those enrolled in the fall semester. They have significantly lower levels of motivation and thus, are more at risk academically.

An independent samples t-test was conducted for the motivation variable of academic persistence to determine if the groups showed significant change over the course of the semester. For the Business-as-Usual group, there was a significant decrease \( (t(25)= 2.74, p=0.005) \) when comparing the pre-test \( (M=4.65, SD= 0.63) \) and the post-test \( (M=4.19, SD= 1.27) \). For the In-Sequence group there was not a difference \( (t(25)= 0.30, p=0.384) \) comparing the pre-test \( (M=4.65, SD= 0.49) \) and the post-test \( (M=4.62, SD= 0.57) \). For the Out-of-Sequence group there
was a significant decrease, similar to that of the Business-as-Usual group (t(20) = 2.20, p=0.02). These results suggest that for our In-Sequence students, use of the new curriculum supports their academic persistence. In both the Business-as-Usual group and the Out-of-Sequence group, the academic persistence was lower at the end of the semester (Figure 3). This suggests that the new curriculum is helping with academic persistence for the In-Sequence students.

Figure 3. A comparison of academic persistence by group across a semester.
Figure 4. A comparison of professional persistence by group across a semester.

Regarding professional persistence, the posttest score for Business-as-Usual (M=3.20, SD= 0.70) was significantly lower (t(25)= 3.03, p=0.003) than the pretest score (M=3.55, SD= 0.34). For the In-Sequence group, the pretest (M=3.58, SD= 0.42) and the posttest (M=3.46, SD= 0.41) were not different (t(25)= 1.54, p=0.07). The Out-of-Sequence group was also not different (t(20)= 1.50, p=0.076). As shown in Figure 4, this result shows that students not using the new curriculum had a lower commitment to engineering at the end of the semester. This suggests that the new curriculum for both In- and Out-of-Sequence students may provide needed career support. This may be attributable to the design of the laboratories themselves, which focus on authentic problems and require deliverables which are specific to the professional career context of engineering.

References


