Board 160: General Chemistry Laboratory as Situated Engineering Design

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Introduction

ChANgE Chem Labs is an NSF-funded Improving Undergraduate STEM Education (IUSE) project that involves curriculum reform for improving the experience of freshman engineering students taking general chemistry. Our current work builds upon prior success with recitation reform [1], [2] to include engineering Design Challenges (DCs) as laboratory activities that are based upon the NAE Grand Challenges for Engineering™.

The laboratory has long been viewed as an important component of a chemistry course [3], offering a unique opportunity for students to practice doing science and form links between macroscopic phenomena and molecular-level interpretations. Moreover, laboratory activities can motivate students to learn more about chemical concepts [4]. For engineering majors, situating these activities in authentic practice strengthens the connection between the domain knowledge of chemistry and its application in everyday work. Such activities target student retention by focusing their work on authentic collaboration and learning chemistry in context, which leverages student interest in order to build personal identity with being an engineer as well as the necessary self-efficacy for persisting with challenging coursework [5]-[6].

In this paper, we present results from usability testing to illustrate our iterative evidence-based development process and offer results of an initial pilot study from across one semester of student use. The perspective for this research is user-centered design and the theoretical framework is chemistry problem solving as situated engineering practice.

Design Challenge as Laboratory Work

Using ABET's Student Outcomes (criteria b), each Design Challenge involves a three-phase format and addresses one of the Grand Challenges that relate to general chemistry topics (Figure 1). The Challenges are based upon the model-eliciting activities (MEA) format and emphasize graphical representation and experimental design (Table 1). DCs are grounded in the principles of MEA for engineering education [7]. Students create, test and refine a model, then present their findings as an authentic deliverable to a client (e.g., proposal, technical memo). This project builds on the work of [7] by expanding the scope to include prerequisite general chemistry courses.

Table 1. Overview of the Design Challenges (DCs).

	DC-0	DC-1	DC-2	DC-3
Grand Challenge	Restore and Improve Urban Infrastructure	Provide Universal Access to Clean Water	Make Solar Energy Economical	Develop Carbon Sequestration Methods
Description	Use density to assess the quality of concrete used to make double T beams.	Identify/quantify ions in hard water using different analytical methods (titration and conductivity).	Use specific heat capacity to determine what composition of material is a best fit as storage of solar energy.	Use gas laws to determine the solution/reaction best suited for carbon sequestration.
Chemistry Skills and Concepts (Eng skills & concepts in all DCs)	density measurement; obtaining and reporting measurement properly	preparation of solutions; dilution; titration; conductivity; understanding and using graphical representation	calorimetry; thermal energy flow; specific heat capacity; understanding and using graphical representation	gas laws; half-life, rate of reaction, stoichiometry; preparation of solution; chemical reaction

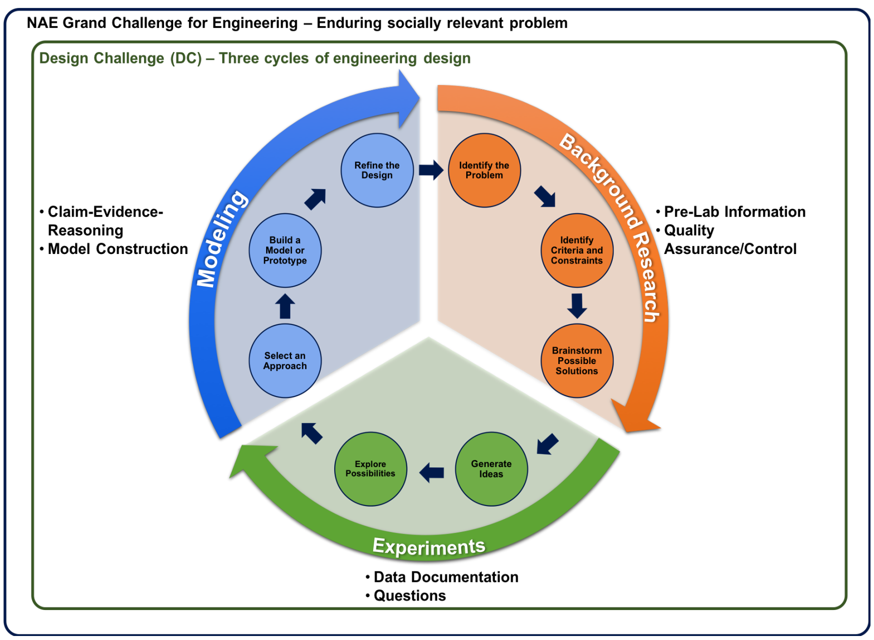

Figure 1. The phases and essential features of a Design Challenge.

Methodology

Educational design-based research is the recursive research and development framework for *ChANgE Chem Labs* with usability testing for refining the design framework and quasi-experimental pilot study for assessing the outcomes. For usability, data sources include surveys, video-recorded observations, field notes and student artifacts. For the pilot study, the assessed outcomes included course performance, self-efficacy and motivational variables. Both qualitative and quantitative analyses were used.

Survey items for demographics and participant perspectives (e.g., difficulty) were presented in a closed form using a Likert-type scale based upon the construct to be assessed. This included the 10-item System Usability Scale. Video-recordings were coded by subtask for time, help (e.g., asking others) and issues (e.g., frustration, off-task behavior, misinterpretation). Researchers also rated the overall task success and scored the artifacts based upon a standard rubric. All qualitative data was analyzed with content analysis. Statistical comparisons for usability results involved independent samples t-tests and one-way ANOVA with post hoc comparisons using the Tukey HSD test. Between group comparisons for the pilot study involved ANCOVA with the pretest values for each measure as the covariate. All participants were enrolled in the same lecture section of the course. The *ChANgE Chem Labs* group was a subset of 26 participants who randomly enrolled in two laboratory sections where the *Change Chem Labs* materials were used. For comparison, an additional 162 participants were in laboratory sections that used a traditional set of laboratory materials (i.e. Regular Lab group) and a very small number of participants (n=10) took no laboratory instruction (i.e. No Lab group).

Usability Results

All three DCs were rated as moderately usable with usability decreasing slightly throughout the semester and not differing from the Regular Lab materials (Figure 2). With a raw score of 70 recognized by many as a standard for usable materials, additional work is needed.

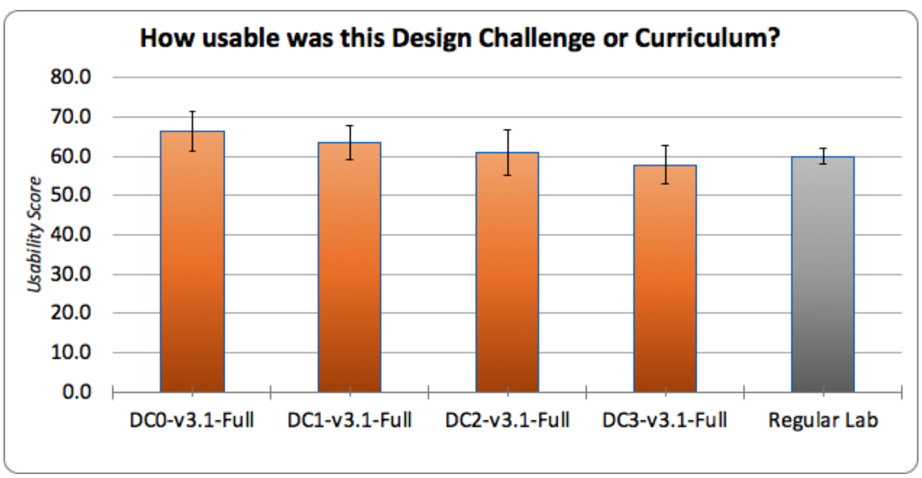

Figure 2. Usability results for each DC compared to Regular Lab.

Task difficulty and ease of use were found to be two components that could be adjusted in order to improve overall usability. For the individual phases of the DCs, the materials were deemed easy to use and not particularly difficult (Figure 3). The initial design intent was for the materials to be moderately difficult and progressively more difficult with each phase. When the results for DC1 indicated the opposite, the amount of direction was lessened and calculations were added (e.g., standard deviation, standard error) in order to increase the level of difficulty. The results for DC2 and DC3 indicate a resulting positive change in difficulty while providing evidence that the structural changes were effective.

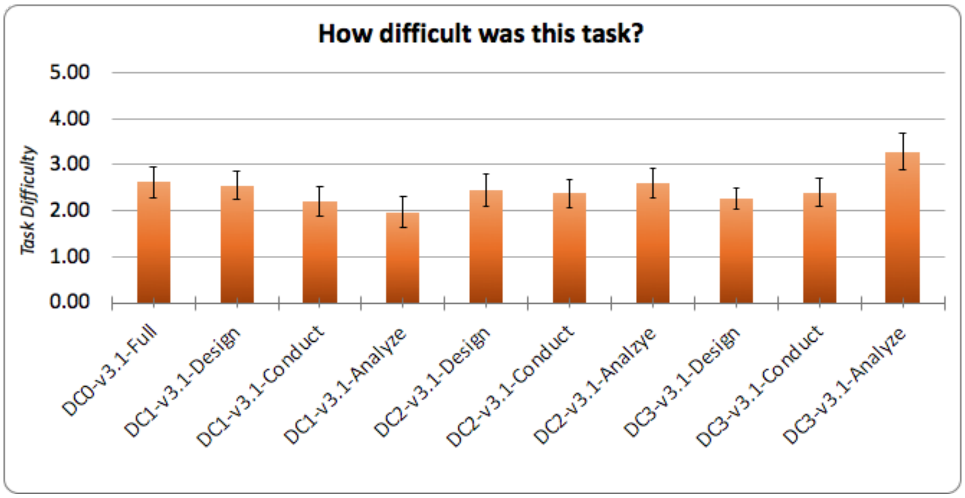

Figure 3. Task difficulty by phase for three DCs.

The materials were effective at giving participants the impression of working as an engineer and for helping them understand how to work collaboratively in order to solve a problem (Figures 4&5). Interestingly, as the level of difficulty was increased for DC3-Analyze, this did not have an effect on perceptions of collaboration or improved feelings of working like an engineer.

**Please note that these are partial results, intended to be illustrative of the full complement that will be presented in our poster at the conference.

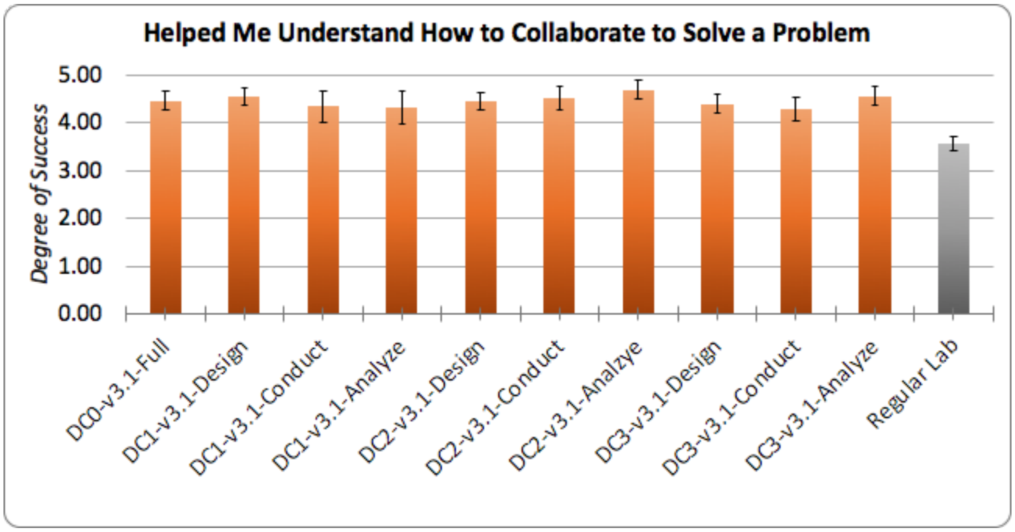

Figure 4. Collaboration rating by phase for three DCs compared to Regular Lab.

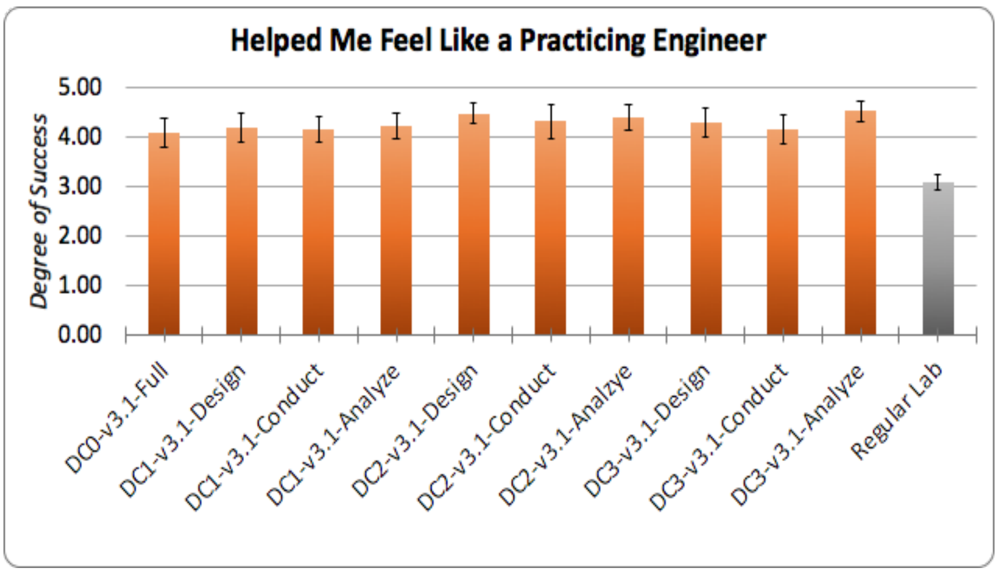

Figure 5. Perception of engineering by phase for three DCs compared to Regular Lab.

Pilot Study Results

Across the semester, the *ChANgE Chem Labs* group maintained their level of academic persistence while the Regular Lab group decreased significantly ($F(2,56) = 3.894$, $p = .054$, partial $\eta^2 = .074$). Confidence for open-ended problem solving increased for the *ChANgE Chem Labs* group and did not change for the Regular Lab group ($F(2,56) = 4.811$, $p = .033$, partial $\eta^2 = .089$). Most notably, the *ChANgE Chem Labs* group maintained their level of self-efficacy across the semester while the Regular Lab group demonstrated a significant decline ($F(2,56) = 10.818$,

p = .002, partial η^2 = 1.81) (Figure 6). There were no other differences in variables for the two groups across the semester.

Table 2. Comparison of pilot study results.

Variable	Condition	Pretest N	Pretest M	Pretest SD	Posttest N	Posttest M	Posttest SD
Academic Persistence	Regular Lab	162	4.56	.69	162	4.14	1.10
	ChANgE Chem Labs	26	4.65	.49	26	4.62	.57
Conf Open-ended Prob Solv	Regular Lab	162	10.27	1.41	162	10.28	1.73
	ChANgE Chem Labs	26	10.23	1.28	26	10.73	1.59
Self-Efficacy	Regular Lab	162	46.62	6.86	162	43.43	10.56
	ChANgE Chem Labs	26	48.49	5.82	26	48.46	8.01

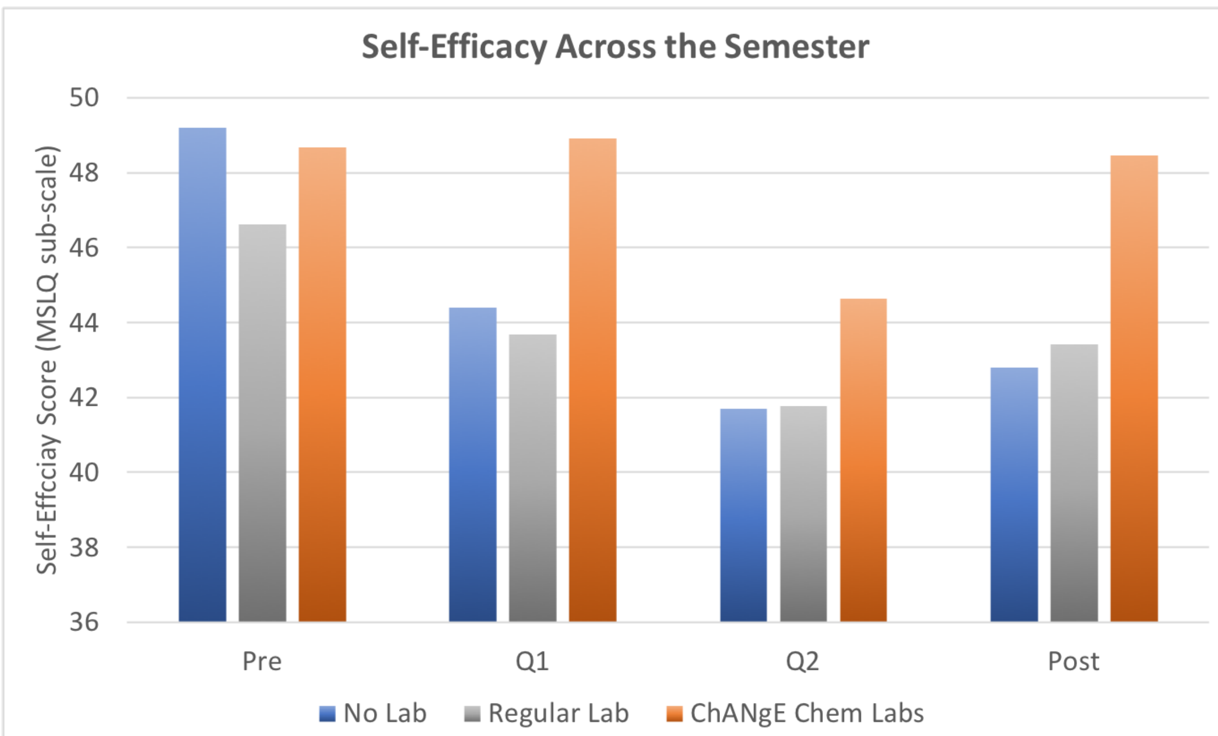

Figure 6. Self-efficacy scores at four points throughout the semester.

Discussion

These results indicate that *ChANgE Chem Labs* supports learning, motivation and perceptions of self as an engineer, important variables for long-term retention. The consistency in academic persistence and self-efficacy are encouraging, since these variables are consistent with the design intent for the curriculum intervention. The improved confidence for open-ended problem solving and self-efficacy are likely related to the successful creation of a collaborative learning environment [8]-[9]. This adaptive change in motivation may also be influenced by the use of three phases for a DC instead of the more traditional one-day activity. Current revisions involve maintaining collaboration and feelings about self as an engineer, efforts to increase difficulty and usability, while decreasing persistent issues and overall fidelity of implementation. The specifics of these revisions as well as the plan for an additional study will be provided during the presentation.

References

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