Engineering capstone design course adaptation after a catastrophic event:
from industrial scope to community impact

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Abstract—**In spring of 2017, the chemical engineering design course at our institution was offered as a capstone course in collaboration with industry. Industrial projects were to be solved by teams of students with both academic and industrial mentors. Teams were built according to learning styles preferences and other attributes of the students, according to the topics involved in each project. Students often visited the industrial site, observed the processes and interacted with different personnel that provided information towards project solution. During the fall 2017 semester, the capstone course started as described above, but a catastrophic event prevented the industry-academic collaboration to continue after classes were resumed. The scope of the capstone course was adapted to incorporate new projects aligned to the needs of the society brought forth by the emergency situation caused by the event.**

The description and assessments of both capstone design course experiences will be presented and contrasted. Under both modalities the team building strategy was a common feature. Teamwork is a "soft skill" required in both industrial- and community impact-scoped projects. Successful peace engineering projects must rely in efficient team building strategies in order to effectively impact society.

Keywords—engineering capstone course; mandate industrial capstone project; teamwork building; capstone assessment; mandate social impact capstone project

I. INTRODUCTION

Capstone courses are "a culminating experience in which students are expected to integrate, extend, critique, and apply knowledge gained in the major [1]." Ideally, capstone courses will help students bridge the gap between the end of their specialty studies and the application of the previously acquired knowledge in real world situations such as industrial projects, community service, or applied research. On the other hand, capstone courses serve as excellent assessment tools for their school's established learning outcomes and accreditation requirements, as well as their outcomes serve as invaluable indicators on whether curricular changes must be undertaken or not, following capstone projects stakeholder perceptions and recommendations.

A. Capstone Design Surveys

In the US, the most recent publication of the decennial capstone design survey initiative [2] reported 522 responding engineering schools, where about 19 different engineering disciplines that were represented include a capstone design course in their curricula; only two of the responding schools did not report to be offering a capstone experience in their programs. The authors of the study reported a substantial variability of capstone course implementation strategies. For example, capstone was offered as a two-semester sequence by 55% of the respondents, while a single semester mode was reported by another 31%. Many topics were reported to be covered, spanning from the so called "soft skills" (leadership, oral and written communications, teamwork, etc.) to the engineering hard core skills (analysis, problem solving, decision making, project management, etc.).

B. Organizing Models for Capstone Courses

Rowles, Koch, Hundley, and Hamilton [3] introduced a nomenclature for capstone course models as: Mountaintops, Magnets, Mandates, and Mirrors to distinguish among the different approaches to structure a capstone course experience. *Mointaintop* experiences are inter/multi-disciplinary, students from different disciplines and backgrounds "meet at the summit" to propose the solution of the capstone problem. *Magnets* refer to capstone experiences that are discipline-specific, they use the whole spectrum of knowledge in the discipline to solve the problem in a summative manner. *Mandates* are capstone experiences that meet the needs of an external constituency that provides the project, for instance, an industry, a government agency, or a community. The *mirror* framework refers to students reflecting on their experiences and learning in relation to goals and outcomes of their discipline [4].

II. Chemical Engineering Capstone Course Framework in our Institution

In our institution, the chemical engineering design course has been taught in a two-semester format, where the first semester is dedicated to the analysis and design aspects of reactors and unit operations in mass and heat transfer, and fluid flow systems. The second semester integrates the use of chemical engineering concepts and economics to design and estimate construction costs of a new plant or a chemical process. Traditionally, our design experience has been offered under the *magnet* format: faculty assign a project where students work out all of the considerations in the design of a plant or process under a theoretical framework, no third-party constituent will benefit from the outcomes of this exercise. This paper will report a different strategy, starting in the 2017 spring semester, real world industrial projects have been worked out by students under the *mandate* framework, with industry as one of the key constituents. We will also describe a switch of the *mandate* constituents from industry to community impact, due to the extraordinary circumstances brought forth by the effects of a catastrophic event that prevented our institution to pursue the industrial goals in a specific semester (2017 fall) of our capstone course *mandate* modality.

A. Chemical Engineering Mandate Capstone Course Structure

There is an immense variety of engineering capstone courses under the *mandate* framework all over the world's engineering schools. In the bullets to follow, we will describe how our capstone experience was structured:

- Industrial projects are chosen in agreement between the course instructor and the industrial capstone coordinators, who seek potential capstone projects in their plant site.
- Each project must meet the following requirements: must involve a significant level of chemical engineering concepts; must have a significant level of difficulty, but should be finished in 10-15 weeks; must involve a cost analysis; each project will have an industrial mentor(s) who must be available for student's inquiries; students must be able to visit the plant site when needed, if site is not adversely impacted by their presence; students will have opportunity to deliver a mid-term and a final oral presentation to the industry associates related to the project's area of impact.
- A first plant visit of the student teams and instructor is made, where teams are described their projects by their respective industrial mentors. Time is allotted for individual team meetings with their mentors to clear doubts and establish communication strategies.
- Teams begin to work out capstone project solution with the feedback of their industrial mentors and the instructor. This procedure will proceed along the semester with frequent communications between student teams-mentors-professor in a progressive pursuit of the most viable project solution/outcomes.
- The mid-term oral presentation will propose alternative solutions to be project, which will be considered by the industrial associates, who will finally approve or suggest new lines of possible solutions.
- The final oral presentation will provide the industrial associates with the final outcomes and recommendations of the project, including related costs of implementation.

B. Project-Solving/Analytical/Engineering Skills

The capstone project will require of the hard skills pertinent to the engineering major for which it is scheduled. The engineering analysis of our chemical engineering capstone design course is based on the criteria stated in the above section. All industrial projects have an industrial mentor or mentors, subject matter experts on the proposed project with a wide knowledge on how processes operate, function and are an excellent source of the know-how which academia definitely cannot provide. Concurrently, the capstone professor is the student teams academic mentor, who keeps track of student's solution process and ensures theoretical, conceptual and robustness of procedures. Once started, the capstone project solution will be achieved through a progressive succession of interactive consulting by the students with their academic and industrial mentors. This paper will not go in too much detail on this aspect, we will focus more on the soft skills development that we have implemented to make capstone teams successful and better prepared after they graduate.

1) Assessment of engineering skills: The capstone learning outcomes basically cover all of the (a) to (l) ABET criteria. During the capstone course offered in spring 2018 semester for the technical assessment we adapted the excellent assessment rubrics published by F. Tio, J. Kong, R. Lim, and E. Teo [5] from the School of Engineering, Nanyang Polytechnic of Singapore.

C. Oral Presentations

Verbal communications skills were ranked the fifth category of skills most desired by employers in 2016 [6], totaling 68.9% of the surveyed companies. As described earlier, the chemical engineering capstone course was organized so that teams would have a mid-term and a final oral presentation to be delivered at the industrial site with project mentors and related associates attending. Previous to the presentations, one workshop is offered to the capstone class to provide with useful tips and recommendations on the best practices to use PowerPoint, and appropriate techniques to orally deliver their presentations to a diverse audience.

In general, the mid-term presentation will show how teams have interpreted, brainstormed, and consulted with the industrial subject matter experts and academic professor, and convey to the audience possible ways to further work out the solution to their project. From this mid-term meeting, all attendees provide feedback and more definite strategies towards seeking for the best possible route of solution. Teams go back to work and by the end of the semester, have their final presentation, which with no exception, have always resulted in a final delivery of well-though solutions that can be implemented in the industrial site. Before both oral presentation activities, the teams practice in the classroom their presentations and receive feedback from the course instructor and their classmates. In some occasions, this kind of feedback helps improve the visual material and the oral delivery techniques, before being officially delivered at the industrial site.

1) Assessment of oral presentations: The mid-term and final oral presentation assessment forms were filled out by all industrial associates, including capstone coordinators and project mentors plus the course instructor. The rubrics were developed following ABET's learning outcomes and are divided in two main subjects: problem solution approach (9 criteria) and oral presentation quality (11 criteria). Each criteria has a score from 1 to 4, where 1 is poor and 4 is excellent. The criteria is listed below.

a) Problem solution approach: Definition and statement of problem; evidence of team-thought process; logical and viable steps to follow; planned problem solving strategy and engineering approach; identification of required variables and facts; acquisition of relevant and accurate information; definition of technical terms; knowledge of required theoretical background; and timely accomplishment of milestones.

b) Oral presentation skills: Appropriateness for the topic and the audience; logics of sequence; voice quality; language and pronunciation; communication of information; quality of delivery; level of enthusiasm and motivation; preparation of visual aids; length of presentation; completeness of answers; and willingness to accept suggestions, criticism, etc.

D. Teamwork and Team Building Approach

In order to successfully accomplish capstone design course projects objectives, to achieve effective teamwork is crucial for the success of the project solution. Teamwork is a "soft skill" used on a daily basis in all business and industrial tasks. Ability to work in a team ranked second in the previously cited 2016 survey to employers [6], with 78.9% of the responding companies. Teamwork promotes active learning, helps to develop and strengthen interpersonal skills and conflict management.

Teams were formed following two basic criteria: personal affinity among students and their learning styles profiles, following Felder and Soloman [7, 8]. In this way, teams would minimally have personal differences while having a minimal diversity in their different approaches towards learning and working different project's issues.

After teams were formed, a workshop followed, where various activities were programmed to begin the teambuilding experience. Throughout these exercises, our approach to teambuilding followed Tuckman's theory [9] where forming, storming, norming and performing were catalyzed by the following activities:

- First, students were made to reflex on previous teamwork they had to perform along their academic life. Positive as well as negative facts were discussed with them.
- Some facts were shown to them to highlight the importance of teamwork in various scenarios: classroom, work place, research laboratories; and the importance of diversity in learning styles, which might bring forth the need to deal with conflict management.
- Another exercise was asked to them regarding which attributes they thought were important to build successful teams, discuss with their team mates and rank them. A result from this exercise resulted in the assessment forms for teamwork that were prepared based on the criteria they generated. In the most recent semester, criteria such as clear communication with other team members, contributing new ideas, ethical behavior, and completing individual tasks on time and with quality were adopted as assessment points.
- During this first teambuilding activity, another exercise performed to promote bonding among members was to challenge teams with the "Grand Spaghetti Challenge." Teams were provided with spaghetti, marshmallows and masking tape and were requested to build the tallest spaghetti tower capable to remain stable and hold a marshmallow on top.
- As a homework, each team was asked to adopt a "company" name and design a logo, which would be presented orally in class and would be used in all of their oral and written reports thereafter.

This initial teambuilding activity catalyzed each members' affinities and commitments in their pursuit of accepting the challenge to solve their assigned capstone project.

1) Assessment of teamwork: The mid-term and final oral presentation assessment forms were filled out by all industrial associates, including capstone coordinators and project mentors plus the course instructor. The rubrics were developed following ABET's learning outcomes and are divided in two main subjects: problem solution approach (9 criteria) and oral presentation

III. Assessments

In the following sections we will discuss the assessments performed for the chemical engineering industrial capstone design course. Some assessments were taken from existing literature and adapted to our specific circumstances, other assessments were custom made. Below a brief description and exposition of the ones done for last spring 2018 semester.

A. Assessment of Teamwork

1) Positioning Figures and Tables: Place figures and tables at the top and bottom of columns. Avoid placing them in the middle of columns. Large figures and tables may span across both columns. Figure captions should be below the figures; table heads should appear above the tables. Insert *figures and tables after they are cited in the text. Use the abbreviation "Fig. 1," even at the beginning of a sentence.*

TABLE I. TABLE STYLES

Table Head	**Table Column Head**		
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[a.] Sample of a Table footnote. *(Table footnote)*

b.

Fig. 1. Example of a figure caption. *(figure caption)*

Figure Labels: Use 8 point Times New Roman for Figure labels. Use words rather than symbols or abbreviations when writing Figure axis labels to avoid confusing the reader. As an example, write the quantity "Magnetization," or "Magnetization, M," not just "M." If including units in the label, present them within parentheses. Do not label axes only with units. In the example, write "Magnetization (A/m)" or "Magnetization (A (m(1)," not just "A/m." Do not label axes with a ratio of quantities and units. For example, write "Temperature (K)," not "Temperature/K."

ACKNOWLEDGMENT *(Heading 5)*

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