Reversing the Hierarchy of Causation and Effect in Civil Engineering and Construction Management Courses

Dr. Sami Maalouf, California State University, Northridge

My research and teaching interests are based on developing and enhancing techniques that can be used to improve the environment. My research interests are centered on environmental fluid mechanics (water quality models, turbulence, transport phenomena, stratified flow, surface and groundwater flow and contamination) and sustainable development (heat disposal, alternative energy systems, hydro-electric power and energy conservation).

Current research focuses on modeling of the fate and transport of constituents and contaminants in large water bodies, especially around coastal zones. The ongoing work addresses measures to deal with brine effluent from seawater reverse osmosis desalination plants. This research explores practical measures on what is required to be done (both in light of coastal water salinity rise, due to brine discharge, and in terms of economic measures in constructing optimal and cost-efficient outfalls) when desalination facilities are present.

Besides coastal and environmental matters, I have an interest in researching engineering education and finding ways to enhance and optimize the teaching/learning experience and build a bridge between fundamental engineering disciplines and practical applications in the civil engineering field.

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Anwar Alroomi currently is an Assistant Professor working at California State University - Northridge (CSUN). She taught a year as adjunct professor at Oklahoma State University. She earned her Ph.D. degree in Civil and Environmental Engineering from Oklahoma State University (2013), and earned her BS. and MS. degrees in Civil and Environmental Engineering from Kuwait University.

REVERSING THE HIERARCHY OF CAUSATION AND EFFECT IN CIVIL ENGINEERING AND CONSTRUCTION MANAGEMENT COURSES

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ABSTRACT

This paper establishes an approach for integrating civic engagement and service learning into freshman courses and senior capstone classes within civil engineering and construction management (CECM). The aim is to help produce an environment where students learn from each other while on internship. This may create a greater synergy between their coursework and actual community projects.

The CECM curriculum prepares students to be operative members in the society's infrastructure. As such, CECM faculty recognizes the benefit in combining service learning activities into beginning engineering courses, as well as capstone courses. This is done by planning a feasible project with a community-based organization, having both beginning and senior level engineering students engage in it over a period of one to two semesters.

The paper discusses an effective approach on how to integrate learning in a reverse hierarchical manner. It also presents measures to evaluate both successes and failures of this approach. The projected longevity of the approach, tackling various projects, is integrated into the study. The two CECM faculty members also discuss the viability of transferring this approach to other universities and engineering colleges.

INTRODUCTION

A recent report showcased the nation's top Science, Technology, Engineering, and Math (STEM) careers in 2016. Three disciplines within the report were directly related to Civil engineering (Snider 2016). Civil engineering and construction management (CECM) academic programs prepare undergraduate students to become an active workforce that builds and enhances the society's infrastructure. CECM academic programs seem to be among a few promising fields that are great entry-level careers for new college graduates as they are often viewed as the most direct path to immediate employment. The past decade has seen a large influx of interest in these fields of study and as a result have given rise to a new generation of young engineers entering the workforce.

Current U.S. Department of Labor's Bureau of Labor Statistics data indicates that employment opportunities for civil engineers are projected to be constantly on the rise. This may be in large part due to the aging U.S. infrastructure system that is in dire need of revitalization, among other factors. Other drivers that will open more opportunities for new CECM college graduates include

seismic retrofit programs that every municipality in seismically hazardous areas of this nation is enforcing. This may ascertain additional growth in the CECM sector. However, new CECM college graduates entering the workforce usually face difficult choices in acclimating to a new environment. While entry-level engineers are equipped with the technical knowledge and skills required to begin a design or construction engineering career, conducting activities in a multifaceted diverse team under the direction of a project manager may be a daunting experience. This is especially true when it comes to new graduates who had very minimal to no work experience. Thus, the need to prepare CECM college students for a smooth transition from the academic program to the workplace becomes necessary.

Civic engagement and service learning have increasingly become an integral part of learning and teaching strategies across many universities and colleges nationwide. As such, CECM faculty recognizes the benefit in combining civic engagement and service learning activities with the CECM curriculum. Introduced at beginning engineering courses and capstone courses, this is done by planning a feasible civil engineering design or construction project with a community-based organization, categorizing activities that students can achieve, and proposing a timeline for each of these activities.

To accomplish this, two CECM faculty members identified community partners, listened to their needs and established common areas of work within a few projects that students are able to achieve. The faculty worked with the community partners to clearly address the goal, desired value and sustainability of each activity. Coupling valuable civic service projects along with classical instructional models proved to enhance the learning experience and enable students to reflect on how their collective deeds may support the communities around their campus. In addition, from the point of view of students, learning while working (and *vice versa*) activities enable the freshman-senior student teams to increase their academic innovation and learn about employment measures. It is also expected that this experience will enhance the students' adaptation to various sectors in the community and advance their lifelong learning ambitions. Moreover, these activities may help generate a greater synergy between the university and community partners.

BACKGROUND

The origins of service learning in the United States trace back to the mid-nineteenth century (Toncar, et al. 2006). It has traditionally advocated to promote experiential education, encourage community involvement and enhance teamwork. Recently, service learning has been adopted by classrooms at various levels as an educational experience that builds bridges between the needs of the community and academic course content (Petkus 2000).

Service learning tools have been used in engineering and management. Elmes and Loiacono (2009) reported on project-based service-learning activities that offered teams of undergraduate students the opportunity to frame and investigate complex, unscripted problems with social and technological dimensions for non-profit organizations and government agency sponsors. Goggins (2012) reported a European experience where service learning was implemented in civil engineering. Such opportunities promoted completing engineering projects in the community and enabled students to learn by doing actual engineering duties.

Previous studies were conducted by one of the authors on factors affecting freshman retention (that is to stay the number of students returning to CECM after successfully completing the first year). While most of the entering freshman level students had adequate math and science preparedness, freshman retention was observed by examining individual student records and determined that students who failed freshman courses typically failed in one or more math and science courses as well as one or more general education courses. Conversely, students who successfully completed freshman courses typically passed in one or more math and science courses and did fine in one or more general education courses. The degree of commitment to the program and individual motivation played a more critical role (Mau and Maalouf 2015). Historical observations are shown below. These observations cover information on undergraduates at the CECM Department (Figure 1 through Figure 6 cover data for students who joined the CECM Department in 2006, 2007, 2008, 2009, 2010 and 2011). Gathered between 2006 and 2016, the information provides a breakdown on the number of students who enrolled in the programs, those who completed the requirements to get a degree at the CECM Department and others who dropped out or changed their respective major (data were retrieved from https://www.csun.edu/counts/).

In 2006, 23 students enrolled in the CECM Department, 15 of which graduated in four years and 3 students graduated in two years (transferring from another institution). A total of 13 out of 15 students who started as freshmen graduated in four years within this major. The remaining 2 students who started as freshmen graduated in four years outside this major. Seven students dropped out. One of those who dropped out, did so in the first year. This data above is illustrated in Figure 1.

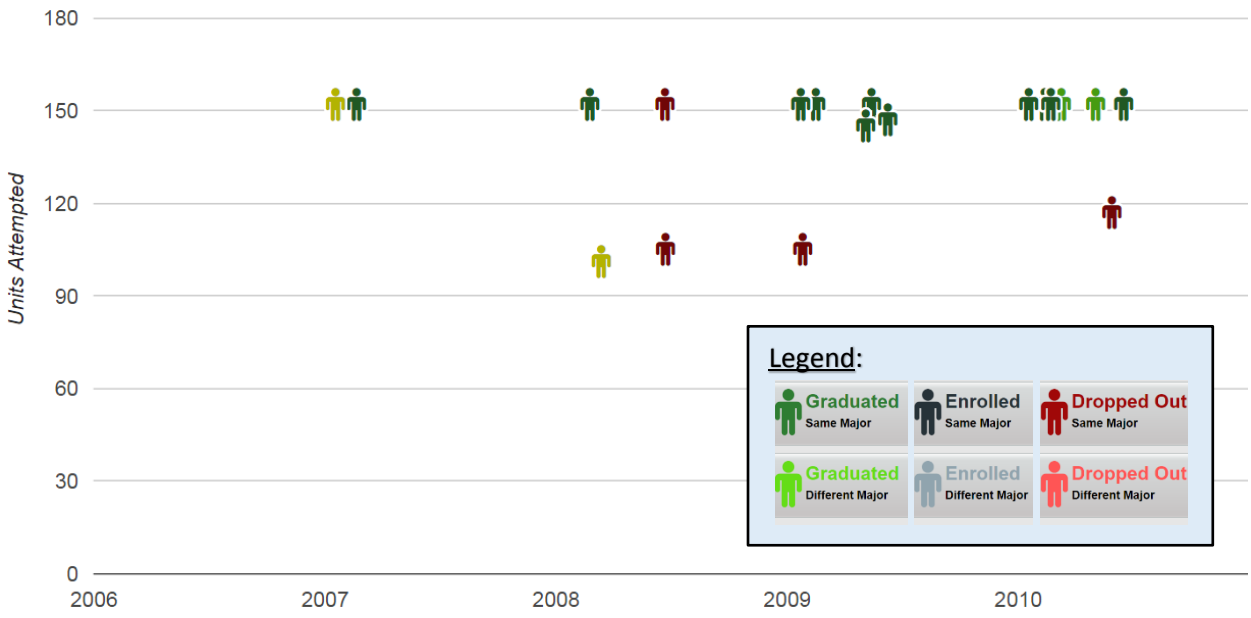

Figure 1: Degree progress for Fall 2006 entering students.

In 2007, 24 students enrolled in the CECM Department, 13 of which graduated in four years and 3 students graduated in two years (transferring from another institution). A total of 10 out of the 13 students who started as freshmen graduated in four years within this major. The remaining 3 students who started as freshmen graduated in four years outside this major. Six students dropped out. Two of those who dropped out did so in the first year (see Figure 2).

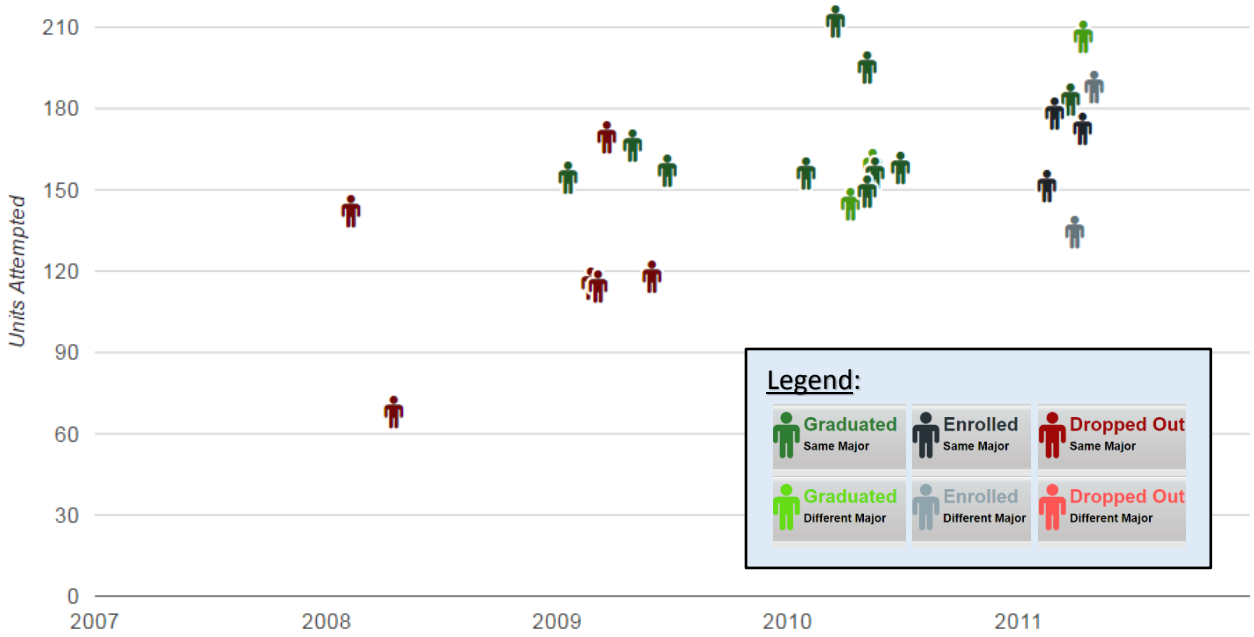

Figure 2: Degree progress for Fall 2007 entering students.

In 2008, 36 students enrolled in the CECM Department, 25 of which graduated in four years and 2 students graduated in two years (transferring from another institution). A total of 18 out of the 25 students who started as freshmen graduated in four years within this major. The remaining 7 students who started as freshmen graduated in four years outside this major. Seven students dropped out. Four of those who dropped out did so in the first year. (see Figure 3).

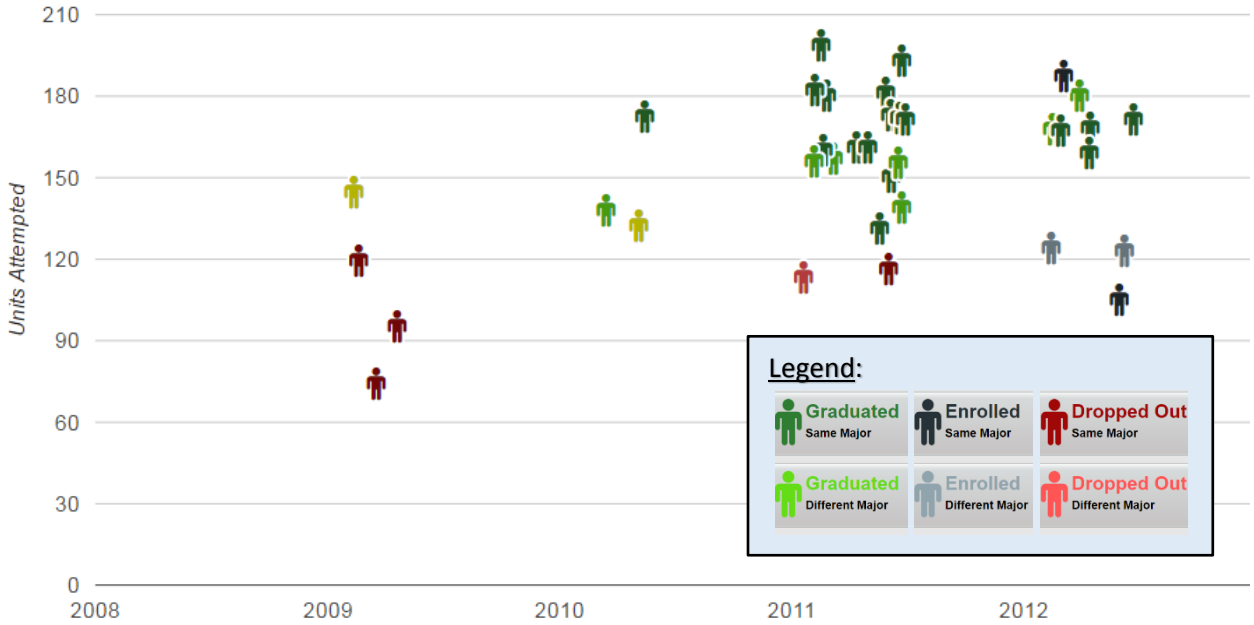

Figure 3: Degree progress for Fall 2008 entering students.

In 2009, 33 students enrolled in the CECM Department, 17 of which graduated in four years and 7 students graduated in two years (transferring from another institution). A total of 10 out of the

17 students who started as freshmen graduated in four years within this major. The remaining 7 students who started as freshmen graduated in four years outside this major. Seven students dropped out. Three of those who dropped out did so in the first year (see Figure 4).

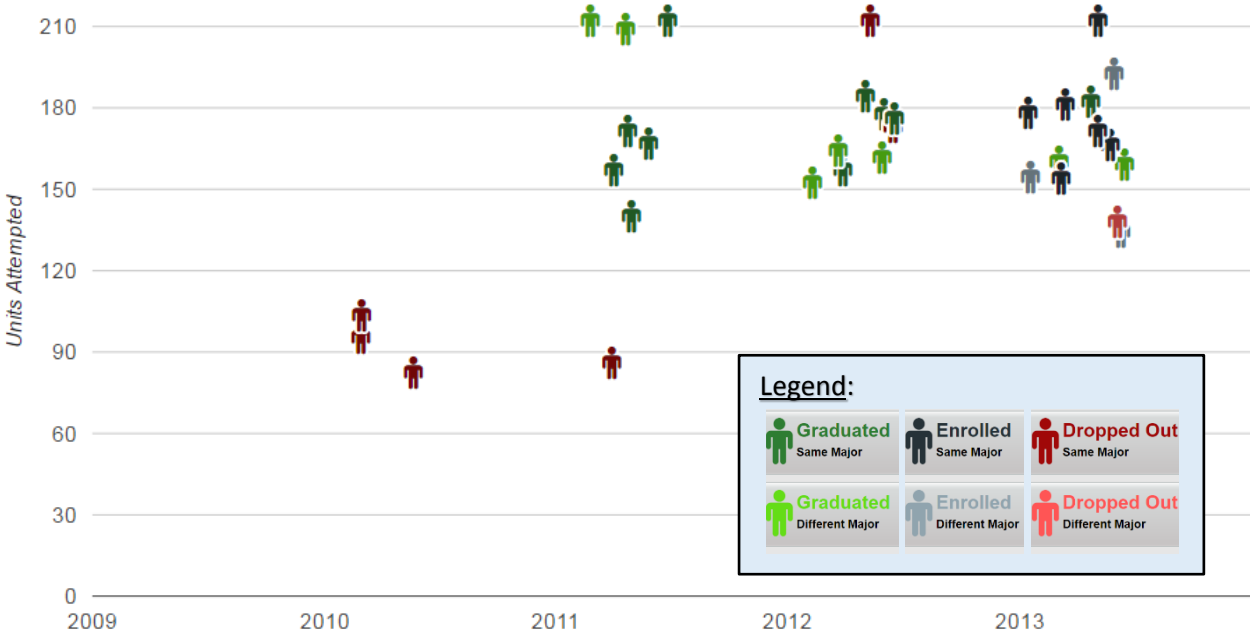

Figure 4: Degree progress for Fall 2009 entering students.

In 2010, 62 students enrolled in the CECM Department, 44 of which graduated in four years and 9 students graduated in two years (transferring from another institution). A total of 32 out of the 44 students who started as freshmen graduated in four years within this major. The remaining 12 students who started as freshmen graduated in four years outside this major. Seventeen students dropped out. Nine of those who dropped out did so in the first year (see Figure 5).

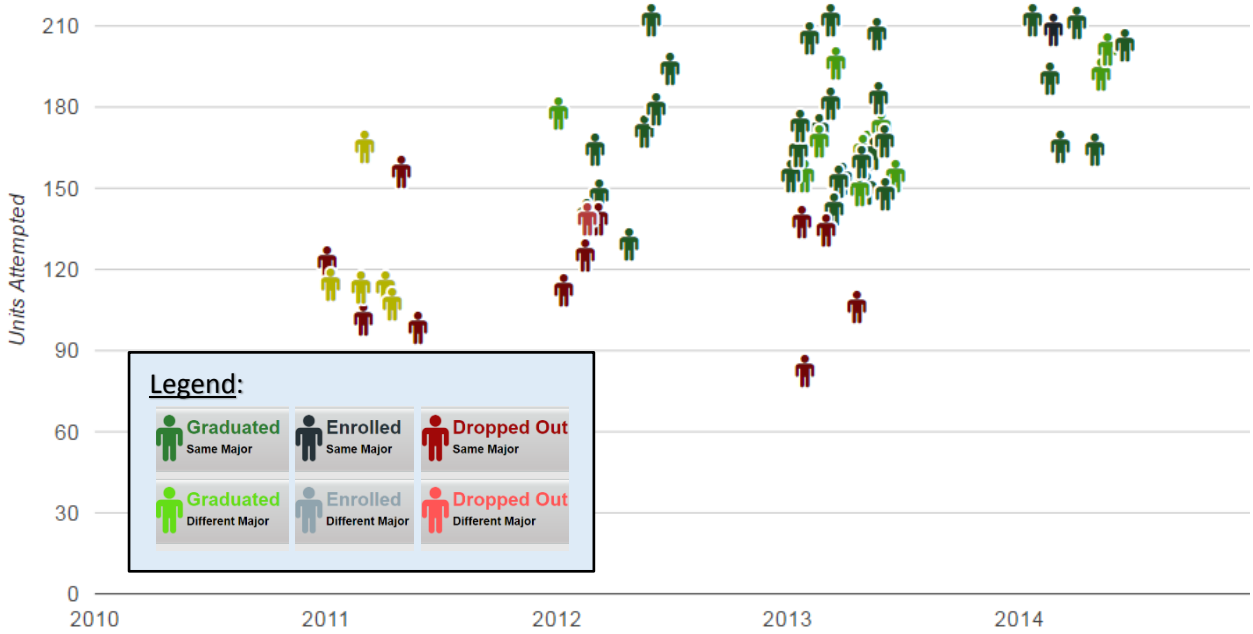

Figure 5: Degree progress for Fall 2010 entering students.

In 2011, 76 students enrolled in the CECM Department, 47 of which graduated in four years and 5 students graduated in two years (transferring from another institution). A total of 36 out of the 47 students who started as freshmen graduated within this major. The remaining 11 students who started as freshmen graduated in four years outside this major. Twenty students dropped out. Eight of those who dropped out did so in the first year (see Figure 6).

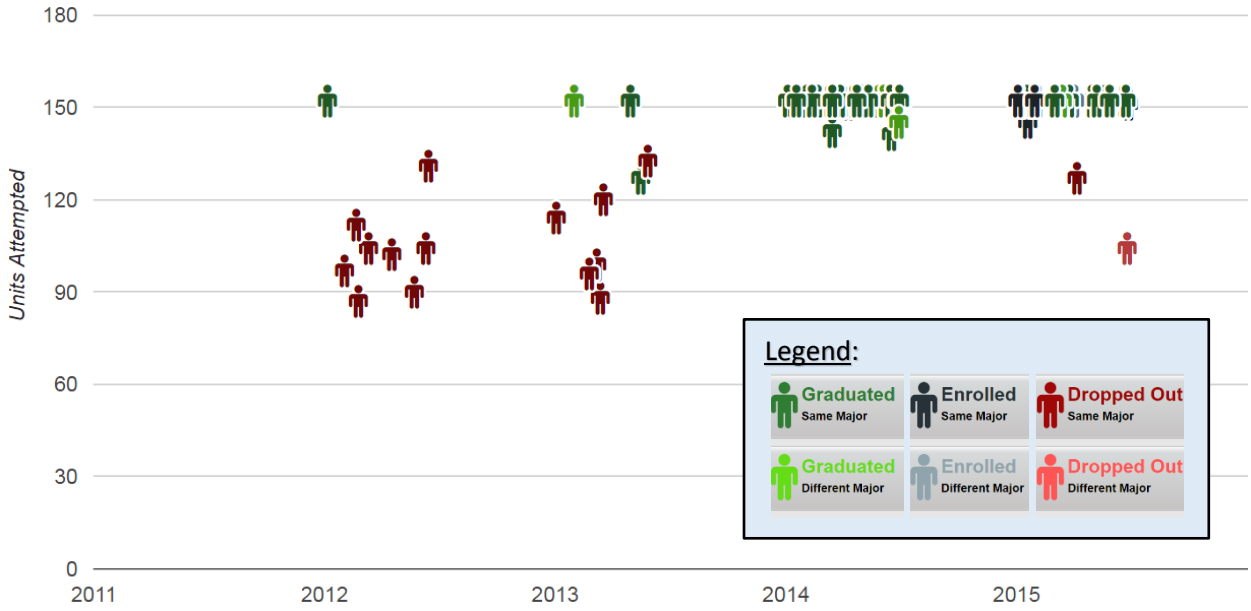

Figure 6: Degree progress for all Fall 2011 entering students.

Teaching students how to learn may deem effective during the first year and throughout college life. In a recent study, Davis-Wiley and Wooten (2015) applied a technique of notes taking to enhance metacognitive literacy. The development of learning and thinking skills among students who took notes using sticky notes while reading was investigated. Analysis revealed that using sticky notes enabled students to take notes but also underscore questions, connections, thoughts, ideas, and reactions. This simple tool assisted in achieving higher-order thinking skills and provided the opportunity to internalize and reflect upon the students' readings. In addition, the study found that using sticky notes helped students to remember information more readily from what they read, refresh their memory and contextualize their comments during discussions. The study also found that embracing and interacting with the text may empower people with a lifelong learning strategy.

No studies discussed how to integrate civic engagement and service learning activities in a reverse hierarchical manner. Rather, most of these studies reported on student groups (usually from a specific engineering course) that joined a local or regional organization and performed duties that left a positive impact on the community that was served. While this generates great synergy between the university and community partners, it is imperative at present to equip undergraduate students with skills that keep them motivated throughout their undergraduate experience, enable them to become active participants in communities and match future employment needs.

Ahissar et al. (2009) reported on perceptual learning and procedures to improve learning using the reverse hierarchy theory (RHT). They asserted that practicing specific tasks will lead to great

improvement as these tasks become increasingly more difficult. A single prolonged presentation suffices to initiate learning. A learning cascade implies that easy conditions guide the learning of harder ones.

In another more recent study, Gelman and Imbens (2013) discussed the difference between forward causal questions, that is to say "effects of causes," and reverse causal inference that they defined as "causes of effects." They argued that causal questions are usually framed by manipulating related aspects, units, or items in terms of asking "what if?" questions. On the other hand, reverse causal questions are typically framed in term of "why?" questions. This motivates research, experiments, and observational studies. Forward causal questions are about model estimation (implicit), while reverse causal inference is about asking questions and searching for new variables that aid in model checking and hypothesis generation (explicit).

MATERIALS AND METHODS

An approach for integrating civic engagement and service learning into freshman level courses and senior capstone classes within the CECM Department is presented below. The aim is to help produce an environment where students learn from each other while on internship. This will also help to better understand engineering and ethical codes and standards. Moreover, it is anticipated that this approach will create a greater synergy between the university and community partners.

Traditionally, a beginning freshman level student enters the CECM Department at California State University at Northridge (CSUN) and has minimal to no interaction with students at levels above him/her. This places the freshman level student in a marginal position. Senior level students, on the other hand, are privileged. Typically, they are about to graduate, their theoretical knowledge is practically complete, they participate in various activities on campus and are active members of engineering clubs and societies. To reverse this traditional hierarchy, we propose that the marginal becomes privileged and *vice versa*. Enabling senior level engineering students to interact and mentor freshman level students and aid the latter group of students to comfortably ask the "why" questions (as opposed to be shown how to do things as it has been traditionally done in most classrooms) may become an effective gateway that promotes learning and enhances retention.

This gateway may also encourage leadership. Leithwood et al. (2004) found that leadership plays a significant role in bridging between reform initiatives and their impact on students' learning. They reported that classical improvements focused on improving teaching and learning. For example, some reforms focus on improving all schools within a district, other methods focus on teaching and learning approaches within a program, whereas some may focus on developing innovative curricula for a program. While the success and effectiveness of such reforms mainly depend on the motivation and capacities of local leadership, it was concluded that a greater impact on learning is attained when large challenges arise or when duties are performed in different circumstances. Also shown that when leaders are engaged with other agencies (or organizations), they provide support for students, while emphasis on learning is maintained.

While enrolled in a typical semester, freshman students–paired with senior students–are sent as teams to community-based organizations for an internship. The freshman-senior team will perform duties and responsibilities that may include drafting, design, field visits (accompanied with a

community-based employee), observations of projects under construction, and solving moderate to complex problems. Such activities are usually conducted in a multifaceted diverse team under the direction of a project manager. Through effective leadership and guidance, learning may be enhanced in a system that is outside the university's traditional structure. Once the freshman students–paired with senior students–are working at a community-based organization, and after some training has taken place, the freshman level students are urged to take a leadership role in guiding their teams. This will make them think outside the box and gain them a great deal of confidence.

It is assumed that the time spent by the freshman-senior team at the community-based organization is temporary (one to two semesters at the most). During this time learning takes place in a cascading manner, where tasks are learned from easier conditions to more difficult ones. Improvements may originate from a sequential top-down process by introducing students to tasks and projects. The cascading top-to-bottom process will enhance task-relevant, and prune irrelevant information (Figure 2, modified from Ahissar et al. 2009).

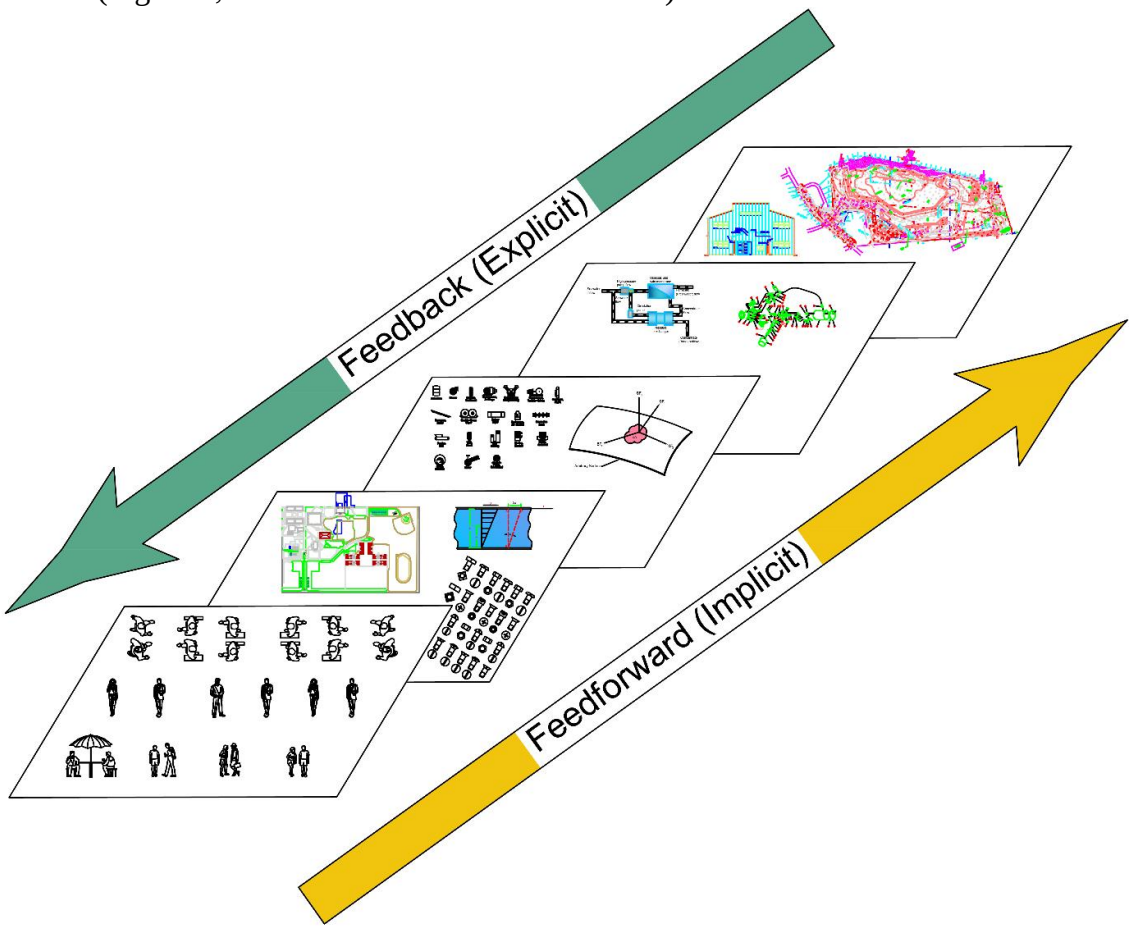

Figure 2: A top-down guided reverse hierarchal learning process.

All civic engagement and service learning activities are administered and processed at a specialized university center that promotes students' engagement with the community. The center acts as a liaison between the university and community organizations that provide learning sites. The university center's personnel conducts visits to these learning sites to identify potential risks and ascertain that students who engage in community activities are safe. The center also collects

data that evaluate students' service learning experience. The authors, after identifying community-based organizations and projects that can be incorporated in the respective courses, paired freshman-senior teams and prepared them to be sent to project sites. The community-based organizations were interviewed and were given the following checklist (Exhibit 1).

Exhibit 1. An excerpt from questions to the community-based organization

	Yes	No
1. Will a representative come to campus to introduce the organization and the project?		
2. Does your site comply with accessibility codes?		
3. Will the organization provide on-site orientations for students? If yes, will the orientations include the following:		
a. Hours available for students to be at the learning site(s)		
b. Informing students where to park		
c. Informing students of the closest public transportation options		
d. Procedures for checking-in at the learning site(s)		
e. Procedures for students and supervisors to track students' hours		
f. Organizational dress-code		
g. Tours of the learning site(s)		
h. Introduction to the students' work areas		
i. Introduction to other employees/volunteers		
j. Confidentiality training:		
k. Safety and emergency training, inclusive of the following: i. Emergency evacuation plan ii. Safety drills & local emergency plans (i.e. lock-downs, earthquake, etc.) iii. Risks associated with the population(s) served by the organization iv. Risks associated with the community in which the learning site(s) are located v. First-Aid/CPR training vi. Sexual harassment training vii. Hazardous materials training viii. Defensive driving training		

Because this study is navigated at a place outside the university's edifices, initial goals were established and were termed DEEPSEA, shown as Exhibit 2 below (modified from NASA's 2014 Strategic Plan).

Exhibit 2. Civic engagement and service learning goals - DEEPSEA

Goal 1: Develop, encompass and sustain students' activities across engineering assignments.
Goal 2: Expand engineering applications to contribute to the community.
Goal 3: Enable senior level students to mentor freshman level engineering students.
Goal 4: Provide students with opportunities to participate in real projects.
Goal 5: Share this model's success with other educators and institutions.
Goal 6: Explore how leveraging collective strength can enhance individual lives.
Goal 7: Advance service-learning research to foster innovation.

Whether the projects are simple or complex, it is essential to observe how all students are performing at the community-based organization. To do this, the questionnaire below (Exhibit 3) was prepared to monitor, on an interim basis, the process and avoid unnecessary situations. In this questionnaire, mathematical notations (∞: Agree or High, μ: Neutral or Average and ∅: Disagree or Low) were used in lieu of typical scales that are usually found in most questionnaires (such as extremely agree to extremely disagree). Aside from highlighting the importance of mathematical notations (especially among freshman level students), this scale was chosen so that the respondent takes absolute and rigid measures as he/she goes through the questionnaire.

Exhibit 3. Interim Service Evaluation Questionnaire

	∞	μ	∅
I am satisfied with this project as it motivates me to learn more			
I am pleased with this opportunity			
This organization is dedicated to my academic development			
I am satisfied with the training this organization offers			
I am satisfied with the educational investment this organization offers			
I am satisfied that I have the opportunity to apply my talents			
I am inspired to meet my goals at work and school			
I feel completely involved in my work and school			
I get more excited nowadays about going to work and school			
I am often so involved in my work that the hours go by very quickly			
I am determined to give my best effort at work and school each day			
When at work, I am completely focused on my job duties			
When at school, I am completely focused on my academic duties			
In my organization, teams adapt quickly to difficult situations			
My team proactively identifies challenges and opportunities			
This organization takes the initiative to help students when the need arises			
I am satisfied with my overall experience			
Communication between senior leader and freshman student is good			
I am able to make decisions affecting my work			
Management within my organization recognizes strong job performance			
My supervisor and I have a good working relationship			
My coworkers and I have a good working relationship			
Senior management trusts me			
Other members treat each other with respect			
I am satisfied with the workplace flexibility offered by this organization			
My organization has a safe work environment			
I am satisfied with security overall			
This organization's work positively impacts people's lives			
This organization operates in a socially responsible manner			
I am satisfied with the culture of my workplace			
My organization is dedicated to diversity and inclusiveness			
I understand how my work impacts the organization's goals			

∞: Agree (High). μ: Neutral (Average). ∅: Disagree (Low).

Once the internship is concluded, a certificate is issued to participating students and their performance is observed. To do this, the following questionnaire was prepared (Exhibit 4).

Exhibit 4. Post Service Evaluation Questionnaire

	∞	μ	∅
How much of an impact do you feel your work had?			
How convenient were the training sessions at the organization?			
How useful were the training sessions at the organization?			
How easy was it to get along with the other workers at the organization?			
How friendly are the employees at the organization?			
How appreciated did your supervisor make you feel?			
How knowledgeable was your supervisor?			
How clearly did your supervisor explain the project?			
How concerned was your supervisor that students were learning the project?			
How was the speed with which your supervisor presented project material?			
How easy was it to get in contact with your supervisor outside of the organization?			
How respectfully did your supervisor treat you?			
How helpful was the project to your understanding of academic material?			
Overall, were you satisfied with your experience with the organization?			
How likely are you to continue working at this organization in the future?			
How likely is it that you would recommend this organization to a friend or colleague?			

∞: Agree (High). μ: Neutral (Average). ∅: Disagree (Low).

INITIAL CONCLUSIONS AND FUTURE RESEARCH

The newly implemented civic engagement and service learning model at this university, enabled two faculty members from Civil Engineering and Construction Management (CECM) to engage their students with community organizations in a manner that was not practiced in the past. Teams that are comprised of paired freshman and senior students were simultaneously placed at a community-based organization. A campus-community partnership has been formed. This partnership enabled student teams to be assigned actual engineering projects within the participating community-based organizations. The overall consensus of the students involved in the service learning classes was that the classes were very useful in enhancing their knowledge of the subject matter covered in these classes. It made them realize how team work is very effective and how actual projects work. The experience that the students acquired buttressed their understanding of engineering concepts being taught in their curriculum. This experience also enabled them to understand their roles as future engineers and effective community members. More importantly, coupling a freshman student with a senior student enhanced leadership skills for both members of the team, allowed for a mentor-protégé role between the two and also motivated the freshman student to stay in the program and understand what he or she will learn in the upcoming academic years.

However, these were only two classes that used this method over a period of one semester. In order for effective conclusions to be drawn, the authors would have to make this a longitudinal study over a period of three to four years (6 to 8 semesters) and study the results over a period of time.

Adult learning may be coupled between academia and the workplace. This may develop to be the foundation for a lifelong learning endeavor where the students (paired collectively or acting alone) become the future mentors and supervisors of interns. This reverse hierarchal top-down practice-induced learning approach may deem effective as interactions between engineering academic departments and the industry grow. Service learning (and learning in general) requires an initial stage of becoming acquainted with a certain system. It is our hope that if we immerse future engineering professionals early in established systems, the transition between scholastic life and professional pursuits will become very smooth.

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