INTEGRATING AND INNOVATING METHODOLOGICALLY AN INTRODUCTORY ENGINEERING COURSE: USING SERVICE LEARNING

Solange Loyer,
Civil Engineering Department, UCSC

Manuel Loyola
Language Department, UCSC

Hernán Silva, Marco Gómez
Cocrea Consultants

Karla Contreras, Felipe González
Civil Engineering Department, UCSC

ABSTRACT

This paper describes the new design and implementation of the Introduction to Civil Engineering course at UCSC in 2015. With the previous course structure students were not acquiring the intended personal and interpersonal learning outcomes and showed very low interest and motivation for the communication skills. An interdisciplinary team composed of civil engineers, a Spanish professor, a therapist in Psychogenealogy and an Industrial Engineer/organizational coach with expertise in positive psychology, was put together to re-design and implement the course. The result was a course that integrated all the disciplines (engineering role, communication and personal/interpersonal skills) by means of a service-learning project that was developed during the whole semester. This project sets the context and the purpose for the other learning outcomes that are addressed in the course, which were planned out in the semester in a way that they were delivered just in time when the students needed them for a specific part of the project. The project requires them to conceive, design, implement and raise funds for its implementation. The students were assigned 8 hours/week, which were distributed among the different disciplines that were taught by the same faculty that participated in the course design. As a result, students were highly motivated and learned more than previous years. Faculty were able to perceive changes induced by the experience and the self-awareness process that was intentionally provoked and that resulted in positive changes in their attitude and behaviour.

KEYWORDS

Service Learning, introduction to engineering course, personal and interpersonal skills, leadership skills, teaching community, Standards: 1, 4, 5, 7, 8, 11.

INTRODUCTION

More engineering schools are acknowledging the benefits of an introduction to engineering course in the first year (Johns, 2006) & (Crawley et al.,2007). According to the CDIO Standards, an introductory course not only provides a framework for engineering practice, but also "introduces essential personal and interpersonal skills" (Crawley et al., 2007).

When receiving first year students, it is important to shape them from the very start in order for them to meet the profile by the end of their program. Therefore, learning outcomes related to attitudes, teamwork, leadership and communication skills are of the essence. But developing these skills is not easy, especially in an engineering program.

In 2011, the School of Engineering of the Universidad Católica de la Santísima Concepción (UCSC), began the implementation process of a CDIO based curriculum for 5 of its undergraduate programs (Loyer et al., 2011). As part of the changes, each program incorporated a first year *Introduction to Engineering* course using as guidelines CDIO standards 1, 4 and 8 (Loyer et al., 2011).

In the case of the Civil Engineering program, the introduction course had good results in terms of motivation and knowing more about civil engineering, but not regarding the other learning outcomes. With this in mind, the school's authorities entrusted the redesign of this course to an interdisciplinary team, with the interesting results that will be presented further on.

INTRODUCTION TO CIVIL ENGINEERING COURSE

Original Introduction to Civil Engineering Structure

The Introduction to Civil Engineering course focuses on developing engineering, personal and interpersonal skills, as well as on having the students understand the role of Civil Engineers in the world. The CDIO skills considered are presented in the following table:

Table 1: CDIO syllabus skills associated with the course

Technical knowledge and reasoning	1.2. Core engineering fundamental knowledge
Personal and professional skills and attributes	2.1. Analytucal reasoning and problem solving
	2.4. Attitudes, thought and learning
	2.5. Ethics, equity and other responsibilities
Interpersonal skills: teamwork and communication	3.1. Teamwork
	3.2. Communication
Conceiving, designing, implmenting and operating systems in the enterprise and societal contex	4.1. External, societal and environmental context
	4.1.1. Roles and responsibility of engineers
	4.3. Conceiving, systems engineering and management
	4.4. Designing
	4.5. Implementing
	4.7. Leading Engineering endeavors

The course was assigned 8 hours/week. It was originally dictated by civil engineers and a professor of Spanish who was in charge of the communication skills (written reports and oral presentations). Students would have 2 hours/week of oral and written communication (OWC) classes and 6 hours of "engineering". In the last quarter students developed a final project related to an engineering area. The original course structure is shown in figure 1.

As a way to develop communication skills, the original oral and written communications course was incorporated inside the Introduction to Engineering course, under the presumption that by putting the together it would somehow add context of engineering and students would learn these skills better.

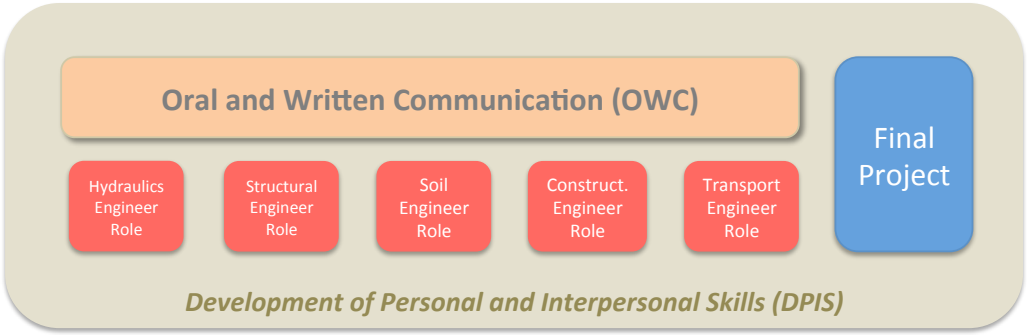

Figure 1. Original Introduction to Civil Engineering Course Structure

Students were motivated by this course, especially with the active learning engineering experiences. But the communication skills and the other personal and interpersonal learning outcomes were not being satisfactorily achieved.

We believe that one of the reasons was the lack of integration of the activities designed for the course. For example, students complained about the OWC classes, because they did not see their purpose in the course, since they were not integrated in a proper way. Another reason was that no one was taking charge of the other personal and interpersonal learning outcomes. They were declared in the syllabus, but they were not being properly or sufficiently addressed in the course. And finally, there was not sufficient communication and coordination between the faculty involved.

New Introduction to Civil Engineering Structure

An interdisciplinary team composed of civil engineers, a Spanish teacher/actor, a therapist in psychogenealogy and an industrial engineer/organizational coach with expertise in positive psychology did the new design of the Introduction to Civil Engineer course. This group was set up and headed by a civil engineering professor with experience in engineering education, the CDIO framework, and teaching communities.

Although the original task was to integrate the different disciplines keeping the basic structure of the course, the final product was slightly different. As a result of the interdisciplinary work, the new course structure integrated all of the disciplines in a very innovative way. In the course three disciplines are identified, in response to the learning outcomes: Engineering Role (ER), Oral and Written Communication Skills (OWC) and Development of Personal and interpersonal Skills (DPIS). The main innovation is that these disciplines are integrated through a Service Learning Project (SLP), as is seen in figure 2.

During the first three quarters of the semester, the students' weekly schedule would be structured in the 4 modules described below, while during the last quarter, all 8 hours would be destined to the service-learning project.

- Module 1: 2 hours of "Engineering Role" (ER)
- Module 2: 2 hours of Oral and Written Communication (OWC)
- Module 3: 2 hours of Development of Personal and Interpersonal Skills (DPIS)
- Module 4: 2 hours of workshop for ER or for SLP (depending on the schedule).

Each module is under the guidance and supervision of a specialist in that field. Each discipline has a specific syllabus, but everything is planned out or synchronized during the semester in a

way that the topics are addressed *just in time* when the students will need them for a specific part of the project. This was considered important in the integration of the different disciplines in the course, because not only is it more effective, learning-wise, but it also gives each issue addressed a sense of purpose for the students.

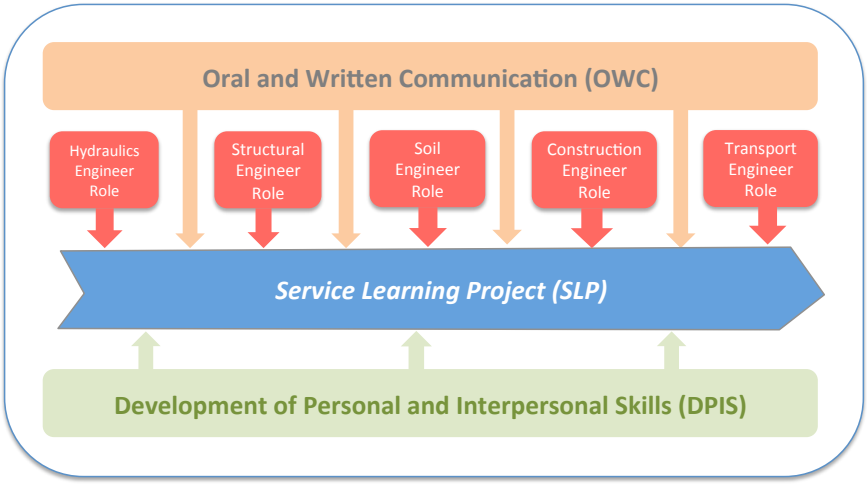

Figure 2. New Introduction to Civil Engineering Course Model

Service Learning Project (SLP)

The project is developed for a social organization or community (called community partner) and it should focus on something that students can design and build in order to solve the problem or requirement that they had previously identified, but related to civil engineering. Students get to conceive (C), design (D) and implement (I) their project, so it complies with CDIO standard 1. The different stages of the service learning project are shown in figure 3. The *first phase* considers four stages and is carried out in small groups of 5 students. The second phase consists of only two stages but with bigger teams that must interact with each other.

The first stage is to identify the community partner's needs. This stage requires students to visit the facilities, meet with the different actors and research regarding that specific type of organization or community. Once each team has identified the problem that they will address, they go on to stage two and design their solution. The third stage is a formal presentation by each team where they get to present their proposal in front of all the faculty and class. Faculty choose the three best projects which will be formally presented to the community partner (stage four). Together with the community partner, the best project is selected and leading to phase 2, where the whole class must work on the same project.

Phase two starts by regrouping the students in teams that have to carry out the different activities needed to develop the project (planning, budget, design, construction, etc.). First stage is redesigning, planning, etc., and the final one is the construction.
In terms of budget, the school puts a part, and the rest of the funds had to be raised by the students, so there was a team assigned for this task. This activity started with phase two, but it definitely has to start at the beginning of the semester as is illustrated in figure 3.

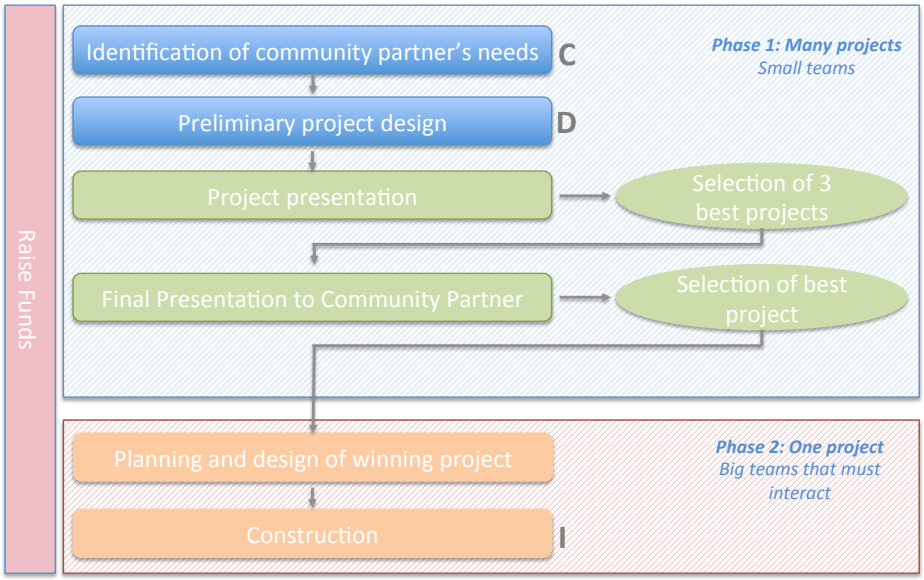

Figure 3. Service Learning Project Scheme

For the first phase, students work on their project during specific workshop hours (module 4), which were planned for this purpose. The working space was appropriate for developing team work, and the engineering professor and a teacher assistant were present at all times to guide and aid the work that the students were developing.

For the second phase new teams were assembled and they had to select their team leader. This part of the project was supervised and guided by an engineering professor. The reasons were basically three: a) To insure the proper development of the project, since it was a real project that was going to be built for a real community partner. b) As a way to coach students on how engineering teams were assembled and work together in big projects, so the engineer professor's experience is very important. c) To give the students a certain ease. This was a big project so it can be very scary for first year students, so the professor also plays a father/mother role and encourages them and helps them build their confidence. Not just any engineer professor can work with these students. Certain personal characteristics are needed in order to play the role that is needed.

Engineering Role

This part of the course was not modified from the previous course design. It consisted of two main activities:

- Lectures, seminars and presentations by faculty, engineers from the industry and alumni (Module 2). The purpose is for the students to understand the different areas of civil engineering (structural, hydraulics, soil, transportation, construction), and their role in society, but from different points of views.

- Small engineering projects. For each engineering area, there was an active learning activity that was developed during the workshop hours (module 4). In some cases it would be to build a structure and test it, others they would have to go out on the street in wheel chairs, crutches, blindfolds and/or strollers and diagnose the transportation infrastructure facilities for people with mobility disadvantages. These are very hands-on experiences that students appreciate.


Figure 4. Small engineering projects for Engineering Role Module

Oral and Written Communication (OWC)

In terms of communication skills, students are expected to learn how to write reports and make oral presentations. The main difference with previous years is that now all the reports and presentations are necessary for the project, so students now see a purpose. Also, since there is a competition (only one project is finally selected), students value more the importance of having a good report and presentation. They are assigned 2 hours a week (Module 2), where they have traditional lectures and active learning activities. Also, the teacher films their presentations so students get to observe themselves, which is very helpful.

Personal and Interpersonal Skills

This module was designed using the Cocrea model (Silva, 2016), which presents the development of these skills as a continuous learning process that must begin with the development of self-knowledge, after which it is possible to develop interpersonal skills, such as leadership. Students work 2 hours every week (module 3) with two specialists. During the first half of the semester they focus on developing self-awareness and self-knowledge through a psychogenealogy approach. This is done through different active learning activities that are designed by the therapist. The final goal of this part is for the students to know themselves and be able to lead themselves. During the second half students focus on personal skills such as emotional intelligence, self-discipline, tolerance to frustration, among others, and interpersonal skills like effective communication and empathy, all based on the Delta Leadership model (Jordán & Garay, 2014). All of these skills are necessary for the Service Learning Project; therefore they experience teamwork with transcendental goals.

Course Assessment

Each module had its own set of assessment instruments. In spite of having several instruments, there was not an overall strategy and not all of the learning outcomes were properly assessed. Five assessment instruments were used for the *personal and interpersonal* module: a) Faculty perception of students' achievement of learning outcomes; b) Students' perceptions of learning outcomes; c) Self-esteem test; d) Leadership skills test; e) Motivation towards leadership test. The last three were applied at the beginning and at the end of the semester. For the *engineering role module* the small engineering projects were assessed using a rubric. The assessment of the *communication skills* strategy was through a written report and an oral presentation of the projects. The instrument used for both cases was a rubric. There wasn't a specific strategy for the *service learning project*, and it was indirectly assessed through the reports and presentation.

RESULTS

All of the results presented in this section are preliminary, since the new course design has been implemented once, so some results could only be compared to one previous year.

Regarding the communicational skills, there was an interesting improvement compared to previous years. The grading scale used in Chile is from 1 to 7, being 4 the passing grade. In written reports there was a 9% increase in the average grade respect the previous year. But when analyzing how the grades were distributed (figure 5), this number does not say much. There is not a clear pattern, and the results for 2014 are very strange but interesting. There is a large group of students that had very low grades (over 35%), and then an almost equally large group of students that had a very good grade (over 30%). This polarized result is not observed in 2015, where student results are more spread out. The only explanation that we found for this has to do with the level of students' motivation. As was stated before, in previous years students were not very motivated for the oral and written communication classes, since they saw no purpose in them. Therefore, we interpret the low OWC grade results in 2014 as students that were not motivated, and therefore did not put much effort in the work. On the other hand, the over 30% high grades of that same year, we interpret as students with intrinsic motivation (Fischman, 2014).

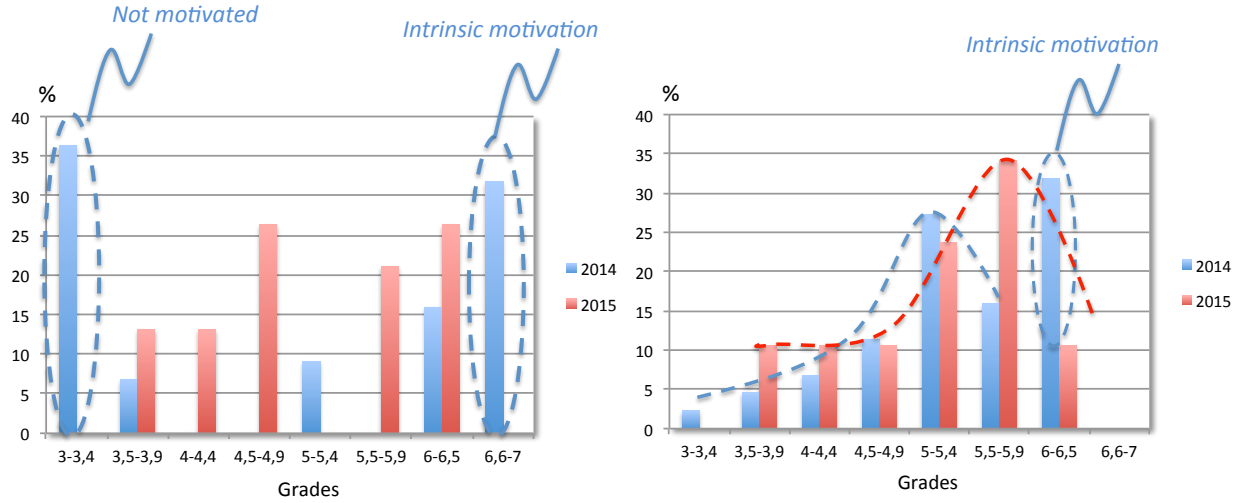

Figure 5. Final grades of written reports (left) and oral presentations (right); 2014 and 2015

The results of the oral presentation grades are also presented in figure 5. Here it is possible to see a pattern that is illustrated by the blue (2014) and red (2015) segmented lines. There was a shift towards the right (higher grades) of the grade distribution in 2015 compared to 2014. However, there is a high number of students (around 30%) that got a high grade in 2014 and not fitting in the distribution. This is the same percentage of students that got a very high grade in the written reports that same year; therefore we interpret this once again as students with intrinsic motivation. As opposed to the written reports, in the year 2014 the grades weren't as low for the oral presentation. One possible explanation is that this might have to do with the fact that these were presentations in public, and students don't want to be embarrassed in front of others, therefore they are willing to make some effort, as opposed to written reports where the only one that sees their work is the teacher. Another possible explanation is that students master more oral communication skills than written, but at the moment we don't have evidence to support this. Another interesting result is that in 2014, 20% of the students had a failing grade in the OWC module as opposed to only 3% in 2015.

When asked, the OWC teacher said that students were more willing to work compared to previous years. He also noticed that students now got a better understanding of what a report at a university level is like, compared to previous years where they still wrote reports like they did in high school. He also observed a greater sense of commitment from the students and they established relations with him, something that hadn't happened in previous years. Another interesting fact is that they asked him questions about other modules of the course (which did not happen in previous years also), which may be interpreted as students conceiving the course in an integrative way, therefore they could ask any of the teachers.

Regarding the Engineering Role modules, there was not any change compared to previous years in terms of motivation, quality of the students' work or motivation. This was expected, since this module did not change in the new design, and students had always been highly motivated for the active learning/design activities that are carried out.

An instrument was used to measure faculty perception of students' achievements of learning outcomes (personal and interpersonal). The high level of detail of the learning outcomes as well as the high number of students made this task very difficult, therefore resulting in a not very good assessing instrument. In average most of the learning outcomes were assessed at level 4 on a scale from 1 to 5 (4: skillful in the practice or implementation of), but the answers among the faculty were very disperse. The same instrument was applied to the students at the end of the semester in order to measure their perception of their proficiency level. 72 of the 120 students (60%) registered in course in 2015 answered the instrument. The results presented in Table 1 show that students in general perceive high levels of proficiency in most of the CDIO skills. These perceptions are consistent with the instructors' opinions of the same students during the same and following semester, which are detailed further below.

Table 2. Students' perceptions of their learning outcomes by the end of semester, 2015

CDIO Skills	1	2	3	4	5
2.1. Analytical reasoning and problem solving	2%	10%	39%	27%	20%
2.4. Personal skills and attitudes	3%	11%	25%	38%	21%
2.5. Proffesional skills and attitudes	0%	10%	28%	38%	25%
3.1. Teamwork	3%	10%	29%	36%	20%
3.2. Communications	3%	15%	35%	30%	15%
4.1. External and societal context	1%	7%	25%	37%	28%
4.3. Conceiving, system engineering and management	1%	7%	25%	37%	28%
4.4. Designing	0%	13%	25%	40%	21%
4.5. Implementing	6%	11%	42%	30%	7%

Note: 1) To have experienced or been exposed to; 2) To be able to participate in and contribute to; 3) To be able to understand and explain; 4) To be skilled in the practice or implementation; 5) To be able to lead or innovate in

Detailed results of the other three instruments are a matter of another article being presented in this conference (Silva, 2016), but some results are presented. 50% of the students showed an improvement of their leadership skills by the end of the semester. Also, 55% of the students had an increase in their motivation towards exercising their leadership. Regarding self esteem, the general self-esteem had a 38% increase.

All faculty involved in the course agreed that the students were highly motivated and they perceived that they were learning more. They also observed a positive change in the attitude and behavior of the students during the semester and also compared to previous years. There was a greater respect for the faculty and greater commitment. We believe this is because of the self-awareness process that the students were exposed to.

Faculty that had these students in the following semester expressed that they perceived a difference in comparison to other years. Students were more focused and “present”. They didn’t seem like freshmen students, but rather like older students. When asked about the civil engineering students to professors who taught other courses in the same semester, they said that they observed a difference in their behavior in contrast with students of other engineering programs; ours behaved better and paid more attention.

CONCLUSIONS AND FUTURE WORK

With the new course design students were highly motivated and learned more than previous years. Faculty were able to perceive changes induced by the experience and the self-awareness process that was intentionally provoked and that resulted in positive changes in their attitude and behaviour. The integrated design allowed students to see a purpose for each one of the personal and interpersonal outcomes, particularly the communication skills that had been neglected by the students in previous years. As a result of this, students were more motivated, and more conscious of their own learning processes and therefore more willing to work. Faculty that had these students during the same and following semester acknowledged this change of behaviour, expressing it as being more *focused or present*.

The main challenge that must be tackled for future experiences is improving the assessment strategies and tools. Not only for the course, but also to do a follow up in the following courses. Another challenge is how to prepare for changes in the staff that is involved in the course. There should be some kind of protocol or system in order to facilitate the transition.

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BIOGRAPHICAL INFORMATION

Solange Loyer is professor of Statics, Mechanics, Introduction to Civil Engineering and Transport Engineering for the Civil Engineering program at UCSC. She is a Civil Engineer with an MBA. She was head of the Port Maritime Engineering Program from 2000 to 2006 but has devoted the last 16 years to her biggest passion: engineering education. She lead the curriculum reform under a CDIO approach for the Civil Engineering program in 2010. Her research and consulting interests are transport engineer and engineering education.

Marco Gómez is professor of Development of Personal Skills at UCSC since 2015. He is a therapist with a Diploma in Integral Psychology, specialized in Psychogenealogy and Psychomagic, with a Diploma in Shamanic Art-Therapy. He is a certified monitor of Laughter Yoga and Co-founder of CoCrea Consultants that developed the CoCrea Model of personal innovation based on self-knowledge. He is also instructor for Technical Training Organisms (OTEC) and does Educational Techincal Consultancy (ATE).

Hernán Silva is a part time professor of the Civil Engineering Department at USCS. He is an Industrial Engineer with a Diploma in Operations Management, Organizational Coaching and Human Capital Management. He has training in Appreciative Inquiry, Leadership, Positive Psychology and Healthy Organizations. He was Productive Plant Manager from 2002-2013, until he founded CoCrea Consultants, with the purpose of transferring his experience to future professionals and organizations.

Manuel Loyola is Professor of Spanish, Master in Arts and professional actor. He works at the Language Department at UCSC and imparts classes to under-graduate and graduate Language programs, Pedagogy Programs and Engineering programs. Since 2000 he is Director of the "Teatro del Oráculo" Company. He has won many grants for the development of theatrical projects and has had formal acting training in India, Bolivia, UK, Spain and Argentina. His company has presented in many stages in Chile and abroad and, he has been advisor of the Education Ministry and the Ministry of Culture and Arts of Chile.

Karla Contreras is a graduate student at UCSC. She has been teacher assistant since 2011 of Fundamentals of Statics, Applied Statics, Hydraulics, Hydrology and Computer Hydraulics. Since 2015 she is instructor of Mechanics and Introduction to Civil Engineering.

Felipe González is a Civil Engineer from the Civil Engineering Department at UCSC. He teaches Topography, Engineering Drawing, Construction and Introduction to Civil Engineering. He has implemented service-learning in his topography course since the year 2013. He also works as a Construction Inspector.

Corresponding author
Solange Loyer
Civil Engineering Department
Univ. Católica de la Santísima Concepción
Alonso de Ribera 2850
Concepción, Chile 02139
56-41-234-5339
sloyer@ucsc.cl