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Work in Progress: Designing a First-Year Hands-on Civil Engineering Course to Reduce Students Dropout and Improve the Overall College Experience

MariaEmilia Mariño

Cryseyda Jacoba Ubidia (Civil Engineer)

Jacoba Ubidia is a research assistant at Universidad San Francisco de Quito in the Civil Engineering department. She holds a B.A. on Architectural Studies & Environmental Science from the University of Toronto and a B.Sc. in Civil Engineering from Universidad San Francisco de Quito.

Miguelandres Guerra (Professor of Civil Engineering and Architecture)

MiguelAndres is an Assistant Professor in the departments of Civil Engineering and Architecture at Universidad San Francisco de Quito USFQ, in Ecuador. MiguelAndres is a civil engineer from USFQ (2009), was awarded a MSc in Civil Engineering – Construction Engineering and Management at Iowa State University (Fulbright scholar, 2012)and his PhD in Civil Engineering at Virginia Tech (2019), as well as two Graduate Certificate in Engineering Education and Future Professoriate. (i) ENGINEERING EXPERIENCE: Miguel Andrés was Project Manager of PREINGESA where he has directed construction projects in the development of urban infrastructure for urbanizations such as earthworks, drinking water works, sewerage, underground electrical cables and fiber optics, roads, aqueducts, water reservoirs, housing construction, among others. He was also a Project Management Associate for a Habitat For Humanity housing project in the USA. (ii) RESEARCH: MiguelAndrés' research focuses on (1) decision-making for the design and construction of infrastructure projects, (2) the planning of sustainable, smart and resilient cities, and (3) the development of engineers who not only have solid technical and practical knowledge, but also social understanding for, through infrastructure, address local and global challenges on humanitarian, environmental, social and equity issues. (iii) EDUCATION RESEARCH: Related to STEM education, Miguel Andrés is developing and applying contemporary pedagogies and tools for innovation and student empowerment to address climate change. Currently, MiguelAndrés is developing teaching and evaluation pedagogy that directs a philosophy of seeking excellence as a pillar to eradicate corruption.

Francisco Wladimir Jativa Valverde

Work in Progress: Designing a First-Year Hands-on Civil Engineering Course to Reduce Students Dropout and Improve the Overall College Experience

María Emilia Mariño[1], Jacoba Ubidia[1], MiguelAndrés Guerra[2*], Francisco Játiva[2]

1 Undergraduate student, Universidad San Francisco de Quito USFQ, Colegio de Ciencias e Ingenierías, Departamento de Ingeniería Civil, Casilla Postal 17-1200-841, Quito 170901, Ecuador.
2 Assistant Professor, Universidad San Francisco de Quito USFQ, Colegio de Ciencias e Ingenierías, Departamento de Ingeniería Civil, Casilla Postal 17-1200-841, Quito 170901, Ecuador.

* Correspondence: MiguelAndrés Guerra, MAGuerra@usfq.edu.ec.

Abstract

Civil engineering dropout is a complex construct because it involves many dimensions, some of which come from societal status quo. There is significant research on understanding the barriers, both personal and institutional, that cause student desertion throughout the major. This paper presents a work in progress that analyzes the designing process of a first-year introductory course in civil engineering that aims to reduce students' dropout and improve students' overall college experience. The study showcases the design process of the course including the pedagogy for teaching the course, the course content, the hands-on learning activities, instructor characteristics, and the diverse distribution of course assessment. The course aims to show a taste of the experience expected for the next college years. The authors reflect on the design of the course in a civil engineering department and open the discussion to develop new pedagogical approaches to reduce student dropout in civil engineering schools. Implications for research and practice are provided.

Introduction

Targeting dropout rates in developing countries is crucial to ensure a larger population of qualified professionals entering the workforce [1]–[4]. In some Latin American countries withdrawal from STEM careers almost represents a 70% of the entire dropout population [5]. Although, this multi-dimensional phenomenon can take on different definitions, in this research paper we refer to dropout as a voluntary and permanent abandonment of academic studies before graduating [6].

Over the past decades, dropout rates have increased around the world. Many attribute this increment to the low minimum requirements to enter higher education as opposed to in the past. However, student dropout is a multi-dimensional phenomenon which cannot only be attributed to students lacking the specific knowledge. Current research signals towards two main categories of dropout factors: specific personal context outside academic life and flaws in how students relate to the academic system as defined by Tinto's Model [7]–[9]. On one hand, personal context may vary from age, gender, ethnicity, and economic status to more intangible factors like parental level of education [5], [10]–[13]. On the other, students' relationship with the academic system relates to four key components such as student satisfaction, level of integration, commitment, and intention to finish a specific career [7], [14]–[16].

Current research suggests that first-year interventions are necessary to reduce dropout rates in the long-term. Many interventions focus on organizing mentorship programs and increasing group interaction through the creation of extracurricular activities. However, specific interventions are highly dependent on cultural dimensions [17], [18]. As a result, this study focuses on the design of a first-year intervention which aims to reduce dropout rates at the undergraduate program of Civil Engineering at a private university in Ecuador, Universidad San Francisco de Quito USFQ.

Background

Student dropout in STEM tracks is often larger than in any other areas of study [5], [19]–[21]. There is no singular cause driving this phenomenon. In fact, current studies use computational methods of data mining to profile and identify at-risk students who are more likely to dropout. For example, generalized mixed-effect random forests (GMERF) and sensitivity tests are conducted to find out the main drivers for specific contexts [12], [13], [22]. However, there is also a body of research that provides theoretical approaches to this issue [14], [16].

In this paper, student dropout is referred to as the voluntary interruption of studies before graduation [23]. Academic research associated with this phenomenon suggests that two overarching realms that drive student dropout in STEM careers are related to academic and personal factors [12]–[14], [16], [19], [24]–[26]. Considering causes related to personal factors, research employing computational methods suggests that there are personal and environmental factors outside of the academic setting that make students prone to dropping out. Such factors may include age, parental level of education, gender, ethnicity, employment, etc. [12], [22], [25].

Considering causes related to academic factors, research also indicates that student dropout pertains to how the student relates to the academic system [6], [12], [14], [16]–[18]. For example, Tinto's model suggests that the level of social and intellectual integration, the intention to follow an academic path, and the commitment to finish the career, are the main areas driving student dropout. At the same time, Gorky [27] proposes that student satisfaction with academic services can drive a student's decision to drop out. Student satisfaction refers to the fulfillment of mainly three categories when providing the academic service which are reliability, empathy, and responsiveness. These last factors are mainly related to the student-teacher relation and the university as a service provider.

Understanding the causes of student dropout provides a benchmark for developing systems of support for students who are prone to do so. The designed course intervention for first year students in civil engineering at Universidad San Francisco de Quito USFQ focusses on both driving realm of factors. Personal factors include factors such as connection to a role model, improving personal habits and picturing themselves in their future profession; and academic factors such as the level of intention, commitment, integration, and student satisfaction. Intention can be defined in terms of desired goals followed by personal reasons for which the student decided to study a particular career in a particular institution. Intentions, however, are not sufficient to complete a desired career, therefore Tinto includes commitment as another factor that may suggests student's dropout. Commitment can be defined as effort, time, and energy that students attain to reach that goal. Higher education also requires social and intellectual skills to adapt which is referred to the level of integration.

Finally, there is evidence that voluntary withdrawal is attached to low level of personal interaction with faculty members and their classmates [7]. While this last point pertains to integration, it also reflects poor student satisfaction with the academic service. These qualitative factors can be correlated with other quantifiable variables. For instance, the lower the GPA the more likely is a student to dropout. A low GPA may not only suggest a lack commitment or intention, but also a low capacity for integration or a poor service from teachers and university's administration. Although multiple factors are similar among different institutions, the origin of such factors are directly related to each institution's context, values, and culture [28], [29].

Dropout interventions

In the last years, student dropout has increased at a higher rate [30]. While dropout can happen because of personal reasons, student's interaction with their academic setting is also relevant [18]. Consequently, institutions must develop or include interventions that increase student engagement [17]. Around the world, universities are working throughout different strategies to reduce dropout such as academic mentorship and group interaction. First year interventions have also shown to be an effective approach to decrease dropout rates in later years [30], [31].

Academic mentorship programs promote students' interest, academic integration, and commitment through the creation of a supportive relationship between the mentor and the mentee. Mentorship programs may include student-teacher interactions or student-student interactions [32]. The latter proposes an older student mentoring a first-year student. A positive relationship between a student and a tutor increases the integration level and the quality of social and academic skills [24], [32]. Including this intervention during the first year of university may generate positive effects such as academic motivation and a lower dropout rate in the future. For example, Laval University in Quebec promoted a voluntary academic mentoring between first year students and undergraduate student in STEM majors with the objective to fill the knowledge gap. School scheduled meetings throughout the academic year, at the end of the program students where more decisive about their career. However, it was identified that not all at-risk students benefited from this type of interventions due to their non-mandatory nature. [32].

The other main intervention pertains to group interaction. This intervention aims to develop a sense of belonging and having positive relationships among people in a particular community [30]. For example, a study performed within the United States among Alaskan Native students proposed social belonging intervention to address dropout problems. The study suggests developing activities to engage students, for example, creating courses directed to target their interests and goals. This study showed that social belonging among stigmatized groups improved GPA and increased academic involvement. At the same time, this results correlated with a higher student commitment and intention to graduate among said population [33]. When students start to make relationship inside university, they start developing engagement not only to the campus but also to the class, where students may spend more hours on their course apart from the class, attend more regularly to classes, and develop such habits to reduce academic failure and dropout likelihood.

This study focuses on a first-year intervention at Universidad San Francisco de Quito USFQ, where civil engineering professors designed a course catered to expose first year students to a taste of the upcoming years. The purpose of this course was to provide entering students a macro perspective of what they were going to experience along the career. This primary goal focused on reinforcing students' commitment and intention to continue the civil engineering path. At the same time, through the development of group and class projects the course aimed to create a space of integration where students could interact with civil engineering professors and their civil engineering peers. Finally, the pedagogy of the course focused on empathy, reliability, and responsiveness to achieve student satisfaction.

Methodology

The professors of the civil engineering department at the Universidad San Francisco de Quito USFQ in Quito, Ecuador followed various stages to design and implement a hands-on course for first year student in civil engineering. The aim was to support less dropout cases and to improve students' overall college experience. The methodology to design the course followed the guidelines stated by the National Charrette Institute for charrette design [34]–[36]. The first step consisted in meeting with current students to inquire about their college experience and how they would improve the different areas of the experience. To gather information from students who decided to dropout, meetings with the students or with the advisors (when meeting the student was not advisable) occurred. This step provided a benchmark to start ideating about crafting the course.

The second step was to conduct charrette meetings with professors from all fields of knowledge in the civil engineering department to develop the course objectives, the course content, and the desired student experience. Eleven professors (6 are Alumni and 5 are not Alumni) participated in the charrette meetings. The professors' areas of expertise were *construction materials, structures and seismic analysis, environment, and water resources, geotechnic and soils mechanics, highways and transportation, and construction Engineering and sustainability. Table below shows the distribution of areas of expertise*

Table 1. Professors that participated in the course design

Civil Engineering department areas	# professors	Alumni
Construction materials	3	2
Structures and seismic analysis	3	1
Environment and water resources	1	0
Geotechnic and soils mechanics	1	1
Highway and transportation	1	0
Construction engineering and sustainability	2	2

At the charrette meetings, the course was divided into an introductory module plus six knowledge modules, one for each of the civil engineering areas at the school. The duration of each module was around 2 weeks but depending on the activity and content it could vary. The purpose of this approach was to expose students to what civil engineering encompasses to increase student intention and commitment to finishing the career path. Adversely, an early exposure to the practical matters of civil engineering may influence a decision to change a career path instead of completely dropping out of school. Therefore, the course pedagogy combined lecture-type sessions with a learning activity. The learning activities could vary from construction or industry site visits, lab practices, experiential learning, role-model activities, among others [37]–[41]. In general, the learning activities throughout this course aimed to provide students with the opportunity to have hands-on experience with laboratories, connect with the industry through site visits and role playing, understand the application of their theory lessons and their involvement with academic student chapters to connect with upper-level students—tutoring and mentorship.

Results

The following sections presents the outcome of the course design process. The pedagogy of the course including learning activities, course content, student evaluation, and instructor overall guidelines.

Learning activities characteristics

Within each two-week module, students were exposed to different types of activities that would address intention and commitment to the program. The course integrated 5 dimensions: hands-on projects, experiential learning, job site visits, mentorship, and quizzes/tests. A brief description of all dimensions is provided below.

Hands-on activities refer to laboratory practices that help students correlate theory and practice by doing simple experiments in the laboratory. The second category, experiential learning, refers to the development of group projects that challenge students to build or design a structure with a specific purpose. For example, students were asked to build noddle bridges and noddle-marshmallow structures. Furthermore, the course allowed spaces for mentorship opportunities through interaction with student chapters, guest speakers, and upper-level students like Engineers Without Borders and ACI Student Chapter. At the same time, students were taken to different site visits to familiarize them with the industry and current construction methods.

Course content – Areas of learning

Construction Materials: This course module is designed to familiarize the student with common materials often used in the design and construction of civil engineering structures. In this module, concrete, asphalt, steel, wood, and plastic are studied. The explanation of each topic follows a chronological order as to engage the student over where were these materials first used and how they evolved in time. This approach invites the student to question and therefore to be engaged to investigate and learn more about the different construction materials used in iconic civil engineering projects. Learning activities in this module are done by laboratory tours where students whiteness the testing of these materials followed by a safety talk at the end of the tour.

Structures and seismic analysis: This course module is designed to show the student the basic components that make up a structure, how these components create different structures, and how these structures respond to different forces. The explanation of the module showcases the importance and impact that civil engineering structures have in everyday life, helping students realize the relevance of civil engineering. Learning activities are done in the laboratory by using premade structures capable of projecting moment and shear diagrams automatically upon an applied force, giving students a 'real feel' of how a structure responds. Also, experiential learning is applied by asking students to build the tallest possible tower by using spaghetti, masking tape and a marshmallow.

Environment and water resources: This course module is designed to familiarize the student about the importance of water management and the impact that this has on the environment. This module follows a chronological order regarding how the environment and water resources have developed along human history and how civil engineers play a vital role to manage this precious resource. Learning activities are based on site visits to local dams and potable water plants, providing a great opportunity for students to connect to professionals in the field and learn more about industrial water recourse processes.

Geotech and soils mechanics: This course module is designed to showcase the importance of the interaction between soils and structures. In this module, different types of soils are presented to students and a brief explanation of each one is given. Then, case projects are discussed in class regarding projects where structural damage happened product of poor soil quality. Learning activities are based on guest speakers that explain in a general manner how in their projects soil mechanics are relevant.

Highways and transportation: This course module is intended to familiarize the student with the design and characteristics of roads and highways, introducing basic concepts for traffic and transportation management. In this module, students are given local examples for highway design and traffic management to engage them with current issues surrounding transportation. Learning activities are based on guest speakers that explain in a broad manner the issues and solutions that highways and transportation presents.

Construction Engineering and Sustainability: This course module is designed to show students how to interpret basic structural blueprints and to calculate a construction budget. In this module, students are given a series of structural and architectural blueprints based on a basic one-floor housing plan from which they calculated a construction budget. The budget is calculated considering the foundation, walls, windows, doors, and electrical connections of the house. Learning activities are based on job site visits where students are shown how blueprints are interpreted on site and how to look for construction details.

Student evaluation

The student evaluation throughout the course aimed to expose student to different assessment methods that they will experience throughout the college courses. Five categories were selected to evaluate students learning outcomes. These categories were divided into (1) oral and written presentations, (2) hands-on projects and experiential learning, (3) participation in mentoring programs, (4) reports and reflections about the relationship with the industry—guest speakers and site visits—and (5) traditional tests and quizzes. All categories should have similar weights, around 20 ± 5points out the 100 final grade points.

Oral and written presentations involved a general overview of the student performance throughout the specific module. In terms of hands-on projects and experiential learning, all laboratories and challenges proposed in each module such as the construction of a noddle bridge or the concrete casting of a scaled stairway were marked under this category. Additionally, participation in mentorship activities like attending ACI Student Chapter and Engineers Without Boarders events was also evaluated. The engagement with the industry through job site visits was evaluated through the production of reports and reflections. Finally, traditional tests were used to measure student understanding of the presented theory.

Instructor characteristics

Two recommendations emerged from the charrette meetings among the professors. The first recommendation for who should teach such class was related to having high scores in the courses evaluation by students. The second recommendation was for instructors who are alumni of the institution. USFQ makes special emphasis on the university's culture, which is a main trait of the university. Thus, having instructors who know the school's culture can help students find role models and mentors from the same major, which can create a sense of integration and community.

Conclusions

This study aimed to develop a first-year course in civil engineering to target dropout rates and improves students' overall college experience. The course was designed considering common factors influencing student dropout along their academic life. The four factors addressed are: commitment, intention, integration, and student satisfaction. To design this first-year course, the methodology used was through the charrette design process, involving professors' ideation and student feedback.

The course was divided into two-week modules that exposed students to every possible track within Civil Engineering. Every module combines lectures with a learning activity. The learning activities could be among five types of activities such as hands-on projects, experiential learning, connection with the industry, participation in mentorship programs and standard tests. The weight of each type of activity per module was about 20±5%. The course brought together the best ranking professors in standard student evaluations, with special emphasis—not a must—professors who are also USFQ Alumni. These factors were crucial for the design of this course because it was a way to account student satisfaction with the course. These factors to pass university's values to increase students' perception of integration into the academic life.

The activity categories involving hands-on projects, experiential learning, and job-site visits target potential indecisiveness and therefore, focus on increasing commitment and intention to study civil engineering. In terms of integration, participation in mentorship programs connects first-year students to both advanced students who are actively involved in student life and professionals who may provide insights on the career path they have chosen. Additionally, it is important to mention that these types of interventions may also work as a filter for those who have no interest in what civil engineering has to offer. However, having this early exposure may increase the probability for people who are not actually invested on the program to change career paths and not fully dropout of school in later semesters.

Finally, future steps for this study encompass developing pre and post-course surveys with open and closed ended questionnaires for students taking the course. These questionnaires will help qualitatively and quantitively assess the levels of commitment, intention, integration, and student satisfaction with the civil engineering program after the first-year intervention. Additionally, a long-term 4-year study will help to assess the course effectiveness on dropout rates compared to previous data. At the same time, this 4-year study will provide evidence on how this type of courses improves student experience throughout their academic life.

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