Are All Engineering Students Capable of Recognizing Ethical and Professional Issues? An Assessment Approach to Engineering Ethics

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Abstract

Engineering schools offer ethical training along with the transfer of technical knowledge and the development of other professional skills. The primary objective of this training is to prepare engineering graduates to face diverse ethical issues in the workplace. Thus, exhaustive information is needed to assess whether students are able to recognize potential conflicts that may arise during practice. Despite its importance, there are few studies about the assessment of this ability. This study presents a sequential mixed methodology to assess rigorously the ethics teaching and learning experience in a selective engineering school in Chile. First, we interviewed school authorities, faculty and undergraduate students about their perceptions of the school's approaches to teach ethics. Second, we designed a quantitative instrument to measure students' ability to recognize ethical and professional issues, to accept personal responsibility, to be aware of ethical codes, and to obtain learning benefits from different ethics training activities. Significant differences were found in individual ethical reasoning to identify issues by gender and socioeconomic status. Implications regarding improvement actions in the research site were discussed. Additionally, considerations for adopting the assessment approach by other institutions were also presented.

Introduction

Engineering solutions have a long-term impact on society, as the work of engineers can affect public health, safety, business practices and even politics¹. For this reason, schools of engineering not only develop technical skills in their students, but also prepare them to work collaboratively with others, to communicate effectively, and to assume professional and ethical responsibilities in engineering situations².

Since the Accreditation Board for Engineering and Technology (ABET) adopted the Engineering Criteria 2000 (EC2000) in 1996, engineering programs have been required to assess students' understanding of professional and ethical responsibility³. Recently, ABET revised criterion 3, reframing this professional skill as the 'ability to recognize ethical and professional responsibilities in engineering situations and make informed judgements, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts'⁴. Although ABET's proposed revision has already raised some critical opinions among researchers, academics sustain that the ethical competency is both assessable and relevant⁵.

Few studies have explored the assessment of the effectiveness of engineering teaching to develop students' ethical reasoning. On the one hand, researchers have proposed ethical reasoning tests and case study analysis for measuring students' abilities to recognize an ethical issue^{6,7}. On the other hand, questionnaires have been applied for assessing ethical teaching activities from the students' perspective. Institutions would benefit from assessment methodologies that integrate these two approaches, aligning constructively the appraisal of teaching activities with students' understanding of professional ethics.

The research questions that motivated this study are:

RQ1: What are the aspects to assess the effectiveness of ethics education in an engineering school?

RQ2: Are all engineering students capable of identifying ethical and professional issues that arise in engineering education and practice?

This study addresses several important issues in the assessment of engineering ethics teaching. First, it explores the perspectives of school authorities, faculty, and students of the same research site about ethics teaching and its learning benefits. Second, it proposes an instrument to assess individual ethical reasoning. By individual ethical reasoning, we refer to the ability to recognize ethical and professional issues regarding personal standards and professional codes. A holistic assessment approach was adopted to contribute to the existing knowledge of engineering ethics.

The article is structured as follows. First, we present a theoretical framework about the assessment of engineering ethics. Second, we describe the sequential mixed methodology that we used to explore the ethics teaching and learning experience of a selective engineering school in Chile. Then we present the findings from the qualitative information collected through interviewing school authorities, faculty, and undergraduate students about ethics teaching and learning activities within the institution. We also show the results of a quantitative questionnaire that was given to a stratified sample of undergraduate students. Finally, implications of our work are discussed.

Theoretical framework

Ethical dilemmas that are part of the engineering workplace have no absolute solution, same as any dilemma in other contexts¹. Future engineers may find themselves in a difficult situation where they need to make decisions considering multiple restrictions. An effective decision-making process needs to ensure the quality of their work for the safety of the population. Consequently, engineering ethical training should be aimed to develop students' ethical reasoning rather than overwhelming them to discover a correct answer and execute it unhesitatingly¹⁵. To prepare future engineers face ethical issues in the workplace, students need to identify and discuss dilemmas related to safety, environmental sustainability, cost and time pressures, among other issues⁹. Therefore, future engineers must be trained to deal with diverse conflictive scenarios.

There are different teaching approaches to develop the ability to identify ethical dilemmas among engineering students, so they become capable of recognizing ethical and professional responsibilities. A first approach consists in offering ethics courses, either provided by the engineering school itself or by a philosophy department^{9,10}. The second approach is represented by brief discussions on ethics and professional responsibility in specific courses. A third method implies the development of modules or talks on engineering ethics and professional responsibility, which typically consist of two or three class sessions⁹. Finally, ethics teaching could be adopted as a transversal approach across the engineering curriculum¹¹.

Recent research has documented a number of difficulties in integrating ethical training into engineering curriculum. Nowadays, one of the limitations is related to time constraints. There is no time available in engineering curriculums to include ethics and other activities for developing a broader set of skills, such as entrepreneurship, and research based learning¹⁶. This

barrier is not only related to the time allocation within a curriculum period, but also with the challenge of ensuring time for continuous assessment and effective feedback provision. Studies also allude to other constraints such as budgeting, potentially conflicting interests within an institution, and roles' complexity¹⁶. Concerning these barriers, collaborative efforts are needed to integrate ethics to engineering training, particularly among engineering faculty. They can provide further guidance on how ethics education should be delivered, and when and where to integrate ethics instruction into the core engineering courses¹⁷.

Concerning engineering ethical education, it is also necessary to revise the ethical standards at the professional level are. Around methodologies of teaching ethical codes, there are different teaching approaches discussed in literature. The most relevant is case-based teaching to encourage students to apply ethical codes in courses of their later years⁹. Other authors suggest that ethical teaching can be linked with team methodologies around project design¹². This collective approach facilitates the assessment of the understanding of important norms and decision making processes, which could be a difficult aspect to assess individually.

In spite of the differences that may exist among disciplines or countries, all engineering ethical codes share certain core values. These values are: contributing to the human well-being, the responsibility of the profession towards the population, public safety, environmental sustainability, and broad public mission^{9,10}. Other overarching cornerstones of codes are public safety, environmental sustainability, and a broad public mission⁹. Therefore, ethical teaching and learning activities are expected to generate certain results, such as an increase in ethical sensitivity, greater knowledge of relevant standards of conduct, and improved ethical judgment to act ethically when desired or required^{11,13}.

There are few studies on the assessment of ethics teaching and learning. Some academics have asserted that values and ethical reasoning are not commensurable, quantifiable, or capable of being subject to empirical and objective analysis⁷. However, there are researchers that still sustain that ethical teaching and learning is assessable⁵. According to Self and Ellison (1998), one way to verify ethical learning is the Defining Issues Test (DIT)⁷. This test is a quantitative instrument that has been widely used to evaluate moral development. Another form of evaluation that differs from quantitative questionnaires is the one suggested by Shuman et al. (2004). He provided a guideline for evaluating the responses to analysis of a case study⁶. This approach has prevailed along with reflective essays, besides other emerging methods used to accountability on ethical understanding and multiperspective thinking⁵.

From an institutional perspective, Finelli et al. (2012) presented the results of a study of students' ethics regarding their exposure to learning opportunities during an engineering program, regarding core courses and elective courses, as well as extracurricular activities⁸. This study determined that the exposition occurs mainly in the first years of the program without having much possibility of discussing the real implications of their ethical understanding in their future work as engineers. Another assessment attempt was made by May and Luth (2013)¹⁴. By a quasi-experimental design, they sought to determine the impact of ethics teaching on several dimensions: the student's perspective, moral efficiency, moral courage and moral sense, as well as knowledge about responsible behavior¹⁵. This study showed a positive effect for moral meaningfulness in those students who took a class with an ethics module.

More research needs to propose holistic assessments of engineering ethics education. There are different aspects of the ethical competency that constitute observable behaviors, such as individual ethical reasoning, the understanding of professional codes, and the ability to recognize individual or shared responsibilities. Additionally, there are different teaching approaches that affect ethical understanding, such as ethics courses, talks or modules about ethical issues, or case-based teaching. A holistic assessment method of ethics teaching would not only be useful for measuring students' achievement in different areas of ethics mastery, but it would also contribute to an improvement of teaching methodologies with valuable information.

Methods

Objectives of the Study

The primary objective of this study is to contribute to the existing body of knowledge about assessment of engineering ethical training. The specific objectives of this study are the following:

- To explore the perspectives of school authorities, faculty and students about the teaching and learning experiences on engineering ethics in a specific school of engineering.
- To develop a quantitative instrument based on the perspectives of authorities, faculty, and students to assess holistically the engineering ethics education in a specific school of engineering.
- To measure students' ability to recognize ethical and professional issues, to accept personal responsibility and to be aware of ethical codes.
- To compare results of these measurements among different students' subgroups.

Research site

The research site consisted in a private and confessional institution of higher education in Chile. Its engineering school is part of a multi-school campus. Despite the full academic and administrative autonomy conferred by law in the 1930s, this institution claims a public role. Yet, it has a close relationship with the private sector and a strong commitment to entrepreneurship and innovation. It attracts students with high scores according to the Chilean national admission system for higher education, who in most cases were educated in private fee-paying schools (see Table 1).

Table 1: Overall demographic trends of students admitted at the research site.

	2011	2012	2013	2014	2015
Total number of students admitted (n)	(584)	(603)	(762)	(783)	(759)
Female students	20%	20%	21%	27%	24%
Graduates from private fee-paying schools	77%	77%	74%	71%	72%
Graduates from private subsidized schools	12%	14%	18%	21%	20%
Graduates from municipal schools	11%	9%	8%	8%	8%

Participants, Sampling and Data Gathering Techniques

In this study, we adopted a sequential exploratory design of an initial qualitative phase followed by a quantitative phase. The aim of employing this research design was to create an instrument to assess holistically different aspects of engineering ethics teaching in a prestigious engineering school in Chile (see Figure 1).

Figure 1: A Sequential Exploratory Design to Assess Different Aspects of Engineering Ethics Teaching and Learning

Table 2 describes the number of participants per qualitative data gathering technique. Concerning students, the population of interest were students close to the moment of graduates, besides freshmen that have recently taken a first-year ethics course. The method used for inviting them to participate in group, semi-structured interviews was stratified random sampling. We used this sampling method to ensure the participation of minorities, such as women and students that did not graduate from private-fee paying schools (see Table 1). There was a higher number of participants in the group interviews with future graduates. Thus, two interviews were held simultaneously with 15 students each. Concerning freshmen, there was a low number of participants so we cannot assure that information was saturated in that group semi-structured interview. The method used for inviting associate deans and faculty members was convenience sampling. Two of eight associate deans and eight of 150 faculty members participated in individual interviews.

Table 2: Number of Participants per Data Gathering Technique during the Qualitative Phase of the Study

Data Gathering Technique	Number of Participants
Group interview with freshmen	3
Group interview with students close to graduation	30
Individual interviews with school authorities and faculty	10

We established certain dimensions of analysis to define questions for interviewing school authorities and faculty (see Table 3 and 4 respectively). These dimensions are coherent and consistent with the previous theoretical framework.

Table 3: Dimensions to Define Questions for Semi-structured Interviews with School Authorities

Dimensions	Sub-dimensions	Justification
School approach towards ethical teaching and learning	Guiding principles to teach ethics in engineering	These sub dimensions intended to create a common ground between

Dimensions	Sub-dimensions	Justification
	Main goals of ethics teaching in the school	the interviewee and the research. Besides, they explore curricular and extracurricular activities towards ethics teaching.
	Existing ethical teaching activities within the school	
School authorities perspective on students' attainment of ethical understanding at an individual and professional level	Ethical behavior in the school context	These sub-dimensions were used in order to integrate authorities' perceptions of the effectiveness of the current approaches towards ethics teaching.
	Aspects that affect students' ethical understanding	
	Alumni abilities to assume ethical responsibilities	

Table 4: Dimensions to Define Questions for Semi-structured Interviews with Faculty

Dimensions	Sub-dimensions	Justification
Participation in ethical training activities	Description of the ethical training activity that the faculty leads	These sub-dimensions were used to explore the role assumed by the interviewed faculty in the school's approach towards ethics teaching.
	Learning outcomes expected of the ethical training activity	
	Challenges of ethical training activity	
Assessment of ethical learning	Description of classroom assessment techniques used for measuring ethical learning	These sub-dimensions intended to reveal faculty's perceptions of the effectiveness of their approaches to teach ethics, besides their responsibility concerning students' outcome attainment.
	Description of actions informed by ethical learning results	
Faculty perceptions on students' attitudes towards ethical training	Description of students' motivation during ethical training	These sub-dimensions explored students' attitudes towards ethical training from the faculty perspective.
	Importance given by students to ethical learning concerning their future in the workplace	

Regarding group, semi-structured interviews with two students, we interviewed freshmen separately from students close to graduation. As in the individual interviews with associate deans and faculty, we established certain dimensions of analysis to define the questions (see Table 5 and 6 respectively). These dimensions are also coherent and consistent with the previous theoretical framework.

Table 5: Dimensions of Questions for Group, Semi-structured Interviews with Freshmen

Dimensions	Sub-dimensions	Justification
Students' attitudes towards ethical training	Importance of ethical training in engineering education	These sub-dimensions explored students' attitudes towards ethical training.
	Main goal of compulsory ethics course	
	Role of engineers in social issues	
Assessment of ethical teaching and learning activities	Ethical content addressed in compulsory ethics course	These sub dimensions intended to reveal students' perceptions of the effectiveness of the approaches adopted to teach ethics, particularly regarding the compulsory ethics course for freshmen.
	Learning benefits of compulsory ethics course	
	Students' motivation during ethics course	

Table 6: Dimensions of Questions for Group, Semi-structured Interviews with Students Close to Graduation

Dimensions	Sub-dimensions	Justification
Students' attitudes towards ethical training	Importance of ethical training in engineering education	These sub-dimensions explored students' attitudes towards ethical training in order to assess the effectiveness of the current approach of ethical training.
	Exposure to ethical dilemmas in engineering	
	Importance of ethical training in engineering workplace	
Assessment of ethical teaching and learning activities	Effective ethical training activities experienced during the engineering studies	These sub-dimensions intended to reveal students' perceptions of the effectiveness of faculty's approaches to teach ethics, besides their awareness of the ethical training for their future.
	Description of actions informed by ethical learning results	
	Importance given to ethical learning concerning their future	

Consequently, a quantitative instrument was designed based on the findings of the qualitative data analysis. The purpose of this instrument is to measure students' ability to recognize ethical and professional issues, to accept personal responsibility and to be aware of ethical codes. Considering students admitted between 2011 and 2015, the research site has an overall enrollment of 4,015 students. Thus, the quantitative instrument was applied online in a random population of half of the enrollment (2,090 students). We carried out a one-stage stratified sampling to define this population. The strata were formed based on gender, type of high school of graduation, and admission cohort (see Table 7). We over-represented female students, freshmen and students that graduated from municipal and private-subsidized schools because they characterize minorities in the overall enrollment (see Table 1). The students were invited to participate voluntarily by email (an informed consent form was included in the first page of the questionnaire). The questionnaire was both anonymous and confidential.

Table 7: Descriptive Statistics of the Sample for Quantitative Data Collection

		Sample	School enrollment
Gender	Female students	31.5%	23.5%
	Male Students	68.5%	76.5%
Students' admission cohort	2011	8.2%	13.1%
	2012	12.4%	15.0%
	2013	17.5%	18.1%
	2014	15.3%	18.9%

		Sample	School enrollment
Ethics course	2015	17.5%	16.7%
	2016	29.1%	18.3%
	Not taken yet	15.9%	10.3%
	Taking or having taken Ethics Course	84.1%	89.7%
Type of High School of Graduation	Municipal or Privately- Subsidized without copayment	9.6%	8.7%
	Privately Subsidized with copayment	30.7%	16.7%
	Privately-fee paying school	59.8%	74.6%

Data Analysis Plan

Concerning the qualitative data analysis, two reviewers codified the transcripts of the semi-structured interviews in NVivo, and peer-checking was used to guarantee consistency. Concept maps were developed to reduce information and clarify themes, codes and categories. A data matrix was obtained to inform the development of the quantitative instrument. Although we cannot generalize findings, there is evidence from different actors to address internal validity.

Regarding the quantitative data analysis, 18% of the sample answered the quantitative instrument (379 students). This instrument assessed students' ability to recognize ethical and professional issues to accept personal responsibility, to be aware of ethical codes, and to obtain learning benefits from different ethical teaching activities. The ability to recognize issues was measured in a 7-point scale of 13 items: seven potential ethical issues in engineering education and six in engineering practice (see items of the ethical reasoning scale in Appendix 1). Students were asked to define how ethically wrong were the situations stated in each item from 1 to 7 (1: not wrong at all, 7: completely wrong). We used the exploratory factor analysis (EFA) to reduce responses to all items into one factor. In this case, EFA, as well as other techniques that attempt to identify a latent structure, served our purposes. We obtained a Kaiser Meyer Olkin Coefficient (KMO) of 0.83, so the data loaded well into one factor¹⁸. Thus, we developed an ethical reasoning index concerning engineering students' responses, which ranged between between -5.4 and 1.6 (see Figure 2).

Figure 2: Ethical reasoning index (from -5.4 to 1.6). Lower values indicate that the respondent does not consider a misconduct as unethically wrong as other participants might consider.

In order to compare the ethical reasoning index among different subgroups, we used the Ordinary Least Squares (OLS) to estimate the significance of strata characteristics over students' ability to recognize issues. We used a regression rather than a Chi-square test to conceive the index as the dependent variable. Linear regression was conducted because the index is a numerical continuous variable. The independent variables were gender, high school of graduation, the admission cohort and having taken the first-year ethics course. We considered the first two variables because female students and those who graduated from private-subsidized and municipal schools are a minority within the student body (see Table 1). Therefore, we wanted to analyze whether there were significant differences in the ethical reasoning of minorities and prevailing students. In case of the other two variables, we wanted to analyze if being freshmen and having taken the ethics course implied any difference in the ability of recognizing ethical issues.

Results

Interviewees distinguished between formal and informal ethics teaching activities. Formal activities were associated with ethical training embedded in the engineering curriculum. Informal activities were associated with extracurricular experiences that could contribute to students' ethical understanding, such as individual learning and volunteering activities. Regarding learning outcomes, interviewees referred to the ability to recognize professional responsibilities by using ethical codes separately from the individual ethical understanding. From interviewees' perspective, individual ethical reasoning is subject to family and peer influence, besides religion.

Figures 3 and 4 show concept maps that were used to identify visually main themes, codes, and categories.

Figure 3: Concept Map about Ethics Teaching Activities in the Research Site

Figure 4: Concept Map about Expected Learning Outcomes of Ethics Teaching

Table 8 shows the qualitative dimensions that were considered in the design of a quantitative questionnaire to assess ethics teaching and learning within the research site. It also shows the explored factors and the questions addressed in the quantitative approach.

Table 8: Qualitative Dimensions used for designing a Quantitative Questionnaire to Assess Different Aspects of Ethics Teaching and Learning within the Research Site

Qualitative dimensions	Explored factors	Questions to be addressed in the quantitative questionnaire
Formal teaching activities	Learning benefits of first year ethics course	Single-choice question on the importance of the first-year ethics course for ethical understanding.
	Teaching methods perceived as beneficial	Multiple-choice question on teaching methods perceived as beneficial for developing ethical understanding (8 response options).

Qualitative dimensions	Explored factors	Questions to be addressed in the quantitative questionnaire
Informal teaching activities	Extracurricular activities perceived as beneficial	Multiple-choice question on extracurricular activities perceived as beneficial for developing ethical understanding (8 response options).
Moral understanding of ethical issues during their engineering studies	Student misconducts observed	Multiple-choice question on misconducts observed in other students (6 response options).
	Student misconducts committed	Multiple-choice question on misconducts committed as a student (6 response options).
Use of ethics codes	Knowledge of ethics codes	Single choice question on how familiar you are with ethical codes (4 response options)
Individual moral reasoning	Moral understanding of ethical issues during their undergraduate studies Moral understanding of ethical issues in the engineering workplace	7-point Likert Scale ranging from 1: Not unethical to 7: Completely unethical. 7 items over students' issues and 7 items over workplace issues.

Table 9 shows that most of the respondents that have taken the first-year ethics course consider that was somewhat important for their current ethical understanding. Nonetheless, more than a third of the respondents consider that it had no importance. Concerning the findings of the qualitative data analysis, this is the only formal training in engineering ethics so far, besides case discussions and ethics lectures that might be included in further courses on engineering topics.

Table 9: Learning benefits perceived from first-year ethics course by questionnaire respondents.

Response options	Percentage of students (out of 379)
The course of ethics was not important for my current ethical understanding.	35%
The course of ethics was somewhat important for my current ethical understanding.	54%
The course of ethics was crucial for my current ethical understanding.	11%

Table 10 shows the percentage of respondents that consider specific teaching methodologies as beneficial for developing ethical understanding. The teaching methodology that most respondents mentioned as beneficial was guided discussions in class (79% of respondents). The ethics course relies mainly on content-based instruction according to the qualitative information collected in this study. This type of instruction is typically delivered by lectures, which were considered beneficial by 34% of the respondents.

Table 10: Teaching methodologies perceived as beneficial for developing ethical understanding according to questionnaire respondents.

Response options	Percentage of students (out of 379)
Guided discussion in class	79%
Guest lecture	52%
Peer discussion	50%
Lecture	34%
Documentary or movie	23%
Role-play activity	17%
Gaming-based teaching	11%
Online material	9%
Other	8%

Table 11 shows the percentage of respondents that consider specific extracurricular activities beneficial for developing ethical understanding. The extracurricular activity that most respondents mentioned beneficial was conversations with family and peers (85% of respondents). This response option emerged from qualitative information. Although it does not necessarily depend on the school approach, it reflects the concern on family influence over individual moral reasoning (see Figure 4). Other extracurricular activities that most respondents reported as beneficial were individual learning and volunteering activities (63% and 52% respectively).

Table 11: Extracurricular activities perceived as beneficial for developing ethical understanding according to questionnaire respondents.

Response options	Percentage of students (out of 379)
Conversations with family and peers	85%
Individual learning	63%
Volunteering activities	52%
Informal conversations with faculty	47%
Sports activities	32%
Student work outside the classroom	22%
Participation in student associations	10%
Others	10%

Table 12 shows the percentage of respondents that have observed a specific student misconduct in the last 12 months, besides showing the percentage that recognized having committed a misconduct themselves over the same period of time. The misconducts were defined as respondent options according to the qualitative information collected in group interviews with students. There are student issues such as the free-rider problem that are highly prevalent in the student body, besides the act of signing the attendance list on someone's behalf and cheating in activities within a laboratory module. Furthermore, more than 19% of the respondents admitted committing those misconducts themselves.

Table 12: Students' misconducts that respondents declared that they have observed and/or committed in the last 12 months.

Response options (students' misconducts mentioned in the qualitative phase of the study)	Percentage of students that admit having observed the misconduct (out of 379)	Percentage of students that admit having committed the misconduct (out of 379)
Free-riding in a teamwork activity	90%	24%
Signing on behalf of someone in an attendance list	70%	19%
Cheating in a lab activity	65%	27%
Cheating in an exam	44%	8%
Presenting a false certificate for not attending an exam	43%	8%
Submitting homework that is not their own	38%	3%

Table 13 shows the distribution of respondents according to their knowledge level of ethical codes in engineering. Most of the respondents are aware of the existence of ethical codes, but they neither know their content nor how to apply them when necessary.

Table 13: Respondents' distribution according to how familiar they are with ethical codes and its use in the engineering practice.

Response options	Percentage of students (out of 379)
I do not know about the existence of ethical codes.	11%
I know about the existence of ethical codes, but I do not know about their content.	59%
I know about the content of ethical codes, but I do not know how these codes are applicable.	5%
I know about the content of ethical codes, and I know how to apply them when necessary.	24%

Table 14 shows the results from OLS regression considering the ethical reasoning index as the dependent variable and strata characteristics as the independent variables (see Table 14). Male students showed a significantly lower ethical reasoning index than female students (negative regression coefficient). Additionally, students that graduated from privately-fee paid schools showed a significantly lower ethical reasoning than student that graduated from municipal or privately-subsidized schools without copayment. These type of schools represent Chilean public education, which typically educates students from lower socioeconomic backgrounds^{19, 20}. Finally, there is a positive effect of taking the first year ethics course on the index.

Table 14: Results from Ordinary Least Squares Regression considering the ethical reasoning index as the dependent variable and personal characteristics as the independent variable (*** Significance with a confidence level of 99%; ** Significance with confidence level of 95%; * Significance with a confidence level of 90%)

Independent variables according to strata	Coefficient of Regression (Standard Error)
Gender	
Being a male student (vs. being a female student)	-0.453 (0.097) ***
High School of Graduation	
Having attended a privately-subsidized high school with copayment (vs. municipal or privately subsidized school without copayment)	-0.057 (0.165)
Having attended a privately-fee paying high school (vs. municipal or privately subsidized school without copayment)	-0.346 (0.169) **
Admission cohort	
Freshmen	0.132 (0.165)
Having taken the ethics course	0.342 (0.155)**
Constant Coefficient	0.331 (0.205)
Adjusted Coefficient of determination (R²)	11.4%

Discussion

From the qualitative information, it is observed that the formal ethical training is disarticulated from extracurricular activities. Regarding the formal training, interviewees alluded exclusively to a first-year course that addresses engineering ethics fundamentals. However, there is no formal training close to the moment of graduation. This confirms difficulties to integrate engineering ethics teaching across the curriculum¹⁶.

Concerning learning outcomes, interviewees associated the ability to apply ethical codes with ethical training activities such as case discussions. This is aligned to what has been documented in literature⁹. Furthermore, quantitative results revealed that this is an aspect to be improved within the research site. Most respondents were aware of the existence of ethical codes but they did not know how to apply them. Faculty should collaborate with school authorities in order to explore how to integrate the teaching of ethical codes in the core curriculum courses¹⁷. This also applies to the reinforcement of codes of conduct. Although respondents were able to recognize potential ethical issues in engineering education, there was a high percentage of students' misconducts observed such as free-riding, falsification and plagiarism (see Table 12).

Regarding individual ethical reasoning, engineering students were not necessarily equally capable of recognizing ethical and professional responsibilities. These differences were partially explained by personal characteristics, such as gender and high school of graduation. Therefore, schools of engineering have to offer multiple learning opportunities to ensure that all students increase ethical sensitivity^{11,13}. A holistic approach could be used to assess the effects of these opportunities on students' personal standards.

Conclusions

There are different aspects to assess the effectiveness of the ethical teaching and learning approach adopted by an engineering school:

- Learning benefits obtained from different curricular and extracurricular activities.
- Learning benefits obtained from different teaching methodologies.
- Students' understanding of codes of conduct and ethical codes.
- Individual ethical reasoning to recognize ethical and professional issues in their current setting and in the future workplace.

The use of qualitative methodology followed by a quantitative approach led to an instrument that assessed different aspects of engineering ethics training. Within the context of a particular engineering school, the questionnaire responses revealed differences among students in learning benefits obtained from the existing formal training (e.g., first year ethics course). It also revealed prevalent problems concerning the understanding of professional ethics (e.g., lack of ethical code awareness) and students' conduct (e.g., free-riding in teamwork activities).

The ethical reasoning scale showed differences in the understanding of different subgroups. Moreover, the prevailing student type at the research site is the one that experienced more difficulties to recognize how ethically wrong a potential issue was. By prevailing students, we are referring to a male youngster who graduated from a privately-fee paid school (see Table 8). Thus, future work might imply exploring deeply the dominant culture of the research site in order to understand how personal characteristics shape ethical decision-making.

Towards continuous improvement, most respondents revealed that a first-year course could be somewhat important for developing ethical understanding among students. Then, an ethics course is not enough for ensuring that all students are prepared to face diverse ethical issues in the workplace. Nonetheless, respondents identified teaching methodologies and extracurricular activities that were perceived as beneficial among students, such as guided discussions in class and informal conversations with peers. Therefore, the assessment approach adopted in this study could be implemented in other institutions to identify strategies for integrating ethics teaching across the curriculum.

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Appendix 1. Ethical Reasoning scale

Items
Engineering education
<ol style="list-style-type: none">1. Not to act in the presence of a case of psychological abuse observed in the university2. Not to help a classmate to study who has difficulties to learn (*)3. To work less than my classmates in a team-based project (*)4. To ask a classmate to share his/her work in order to use it as a basis for your assignment (*)5. To develop an individual piece of homework between two or more people (*)6. To justify missing a test using a false medical certificate7. To pay someone to do homework that you should develop yourself
Engineering practice
<ol style="list-style-type: none">1. To recommend a friend for a job position knowing that he/she is not the optimum candidate (*)2. To work extra hours required to complete a project deliverable without paying attention to the stipulated schedules of the different coworkers involved (*)3. To pursue a career in a company whose productive processes are detrimental to surrounding communities (*)4. To develop a product that meets minimum technical standards disregarding features that beneficial for its potential users (*)5. To deny permission to miss work to an employee who does not have medical problems but has significant family problems6. To validate an alternative solution that meets economic criterion but does not necessarily meet all technical, social and environmental standards

Note:

(*) These were the most discriminating items.