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Curriculum analysis of ethics in engineering: a case study

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Abstract
For several decades, there have been warnings about certain ethical faults in engineers regarding corruption in different works, which lead to collapses and the death of people, calling engineering into question and affecting the social development of communities. Ethics is an educational responsibility, the ethical debate must take place inside and outside the classroom, since studies carried out in different universities indicate that ethics continues to be a pending subject in engineering programs. This study seeks to contribute to educational innovation for the teaching of ethics in engineering through documentary review and interviews with students and teachers. It was found that the education of ethics in engineering should be included in the curriculum as an important factor in the training of engineers, from a practical dimension, which includes the study of cases, moral dilemmas, and based on problems applied to the environment.

Keywords: professional ethics; corruption; educational innovation; university teaching, curriculum.

Análisis curricular de la ética en la ingeniería: un estudio de caso

Resumen
Durante varias décadas, se ha alertado sobre ciertas faltas éticas en ingenieros respecto a corrupción en diferentes obras, que llevan a colapsos y la muerte de personas, poniendo en tela de juicio la ingeniería y afectando el desarrollo social de las comunidades. La ética es una responsabilidad educativa, el debate ético debe darse dentro y fuera del aula, pues estudios realizados en diferentes universidades, indican que la ética sigue siendo una asignatura pendiente en los programas de ingeniería. El presente estudio busca aportar a la innovación educativa para la enseñanza de la ética en la ingeniería a través de revisión documental y entrevistas a estudiantes y profesores. Se encontró que la educación de la ética en la ingeniería debe incluirse en el currículo como un factor importante en la formación de ingenieros, desde una dimensión práctica, que incluya el estudio de casos, dilemas morales, y basada en problemas aplicados al entorno.

Palabras clave: ética profesional; corrupción; innovación educativa; docencia universitaria; currículo

1. Introduction

For several decades, there have been warnings about how certain ethical faults in engineers have significantly affected the social development of communities, corruption, collapses in different works, budgets, and excessive expenses, which have even led to the death of people, which has put engineering is being called into question not only nationally but globally [1,2].

There are multiple engineering companies that are characterized by their various ethical faults in their operations. For example, the Inter-American Development Bank -IDB, mentions as of July 2022, 1,048 companies and individuals from 89 countries that have been sanctioned for having been involved in fraudulent and corrupt practices, among which are mainly engineering, construction, technology, logistics, manufacturing, energy, consulting among others. Engineering companies such as Eastern Builders and Engineers Limited in Uganda, Metal Engineering Eood in Bulgaria, OAS International Engineering GmbH in Austria, China CAMC Engineering Co. Ltd. in China, Ramky Enviro Engineers Middle East FZ-LLC in the United Arab Emirates, Ramky Enviro Engineers in Bangladesh, Tractebel Engineering S.A. in Belgium,

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among others. In the top 10, the majority of sanctioned companies are from China with 99, from India with 87, from Kenya with 80, from Brazil 59, from Guatemala 51, from Nigeria 49, from Colombia 44, from Honduras 40, from Bolivia 38 and from Vietnam 32 [23].

In Colombia, out of 33,199 engineers enrolled in the National Professional Council of Engineering - COPNIA as of 2019 [3], 3,172 (9.55%) have undergone disciplinary proceedings. These cases are publicly noted due to their effects on the community, which includes, for example, the construction of dams without water (4), the collapse of buildings, collapse of bridges, corruption in hydroelectric plants, which also show some cases of an inadequate exercise of engineering, which "is not the most ethical" [4].

Thus, engineers affect the quality of life of all members of a society [5], they have a high professional responsibility, which must always be framed by a technical ethic, which implies the proper use of their knowledge, a professional ethic, which seeks an ethical interaction with the other actors and a social ethic, directed towards adequate sociopolitical participation [6].

Ethics in engineering is not only an individual matter, it is also an educational responsibility, teachers must join the ethical debate inside and outside the classroom, not turning ethics into a subject, but making ethics have a practical dimension, encouraging co-responsibility between the teacher who teaches it and the professional who applies it [4]. Ethics, according to COPNIA, is an issue that must continue to be worked on, "in the academic training and ethical training of human resources, as an irreplaceable factor to recover the ethical culture" [4], because when exercising the profession, engineers “face ethical dilemmas that require reflection on the moral acts of a community [4]. Therefore, it is necessary to think about the education of ethics in engineering.

Studies carried out in different universities indicate that ethics continues to be a pending subject in engineering programs, and it is noted in work and social spaces where professionals act, reporting ethically questionable facts [7]. Historical research has shown that ethics in engineering should be addressed in universities [8]. In studies conducted in 2003 [9], it was reported that engineering programs should seek to incorporate greater ethical and professional responsibility, as well as understand the impact of engineering in the global and social context.

In another investigations with university students of industrial engineering among others [10], it is concluded that it is necessary to integrate ethics through university training, both for students and teachers. In another study with professors who taught engineering ethics classes in 43 institutions [11], it was concluded that the gaps in ethics education in undergraduate engineering require an urgent review of the profiles of professors and the training of teachers. the same. Other research [9] concluded that engineering programs should seek to understand ethical and professional responsibility and understand the impact of engineering in the global and social context.

Engineering ethics should be included as an important subject in the curriculum [13,14], including the teaching of ethical principles and human values [20]. For the benefit of the community [15], it should be taught in a practical way with the study of cases [19], social problems and moral dilemmas [16]. That imply a reflection [4] articulated with the social reality [17,18]. Teachers should also be trained in ethics [4,10,11].

The foregoing allows us to see that there is a gap in ethical training for engineers in the different university programs. Ultimately leading to multiple forms of corruption and failures in engineering quality. The contribution of this paper is to show how this gap can be filled through different teaching strategies that can be considered in the curriculum to achieve ethical training with greater impact.

2. Methodology

This study is based on the interest in improving ethical training in engineers, which is considered one of the causes in affecting the development of communities. The question of how one can contribute to the proper formation of ethics in engineering was raised, so the objective of the research was to describe and analyze how ethics education in engineering has been imparted and to propose different forms of educational innovation for the teaching ethics in engineering. The methodology was carried out from a mixed approach (quantitative and qualitative), with a descriptive scope, the research design was transversal, not experimental, and from the qualitative point of view the systematic design was used, seeking to explain the action from a general level. conceptual, discovering categories or patterns in a set of qualitative data [12], for the documentary analysis of the study plan, 86 documents were analyzed: Institutional Educational Project -PEI, Development Plan, Educational Program Projects -PEP, study plans of Engineering: Civil, Administrative, Environmental, Petroleum, Mechanical, Electrical, Control, Geological, Chemical, Industrial, Mining and Metallurgical, Information Systems and Technologies and Software, as well as course designs.

Similarly, two surveys were applied, a questionnaire for 175 students from different engineering careers of the Faculty of Mines of the National University. Colombia, Medellin Campus, which was previously validated using the cognitive interview methodology -EC [21], an evaluation device consisting of two semi-structured questionnaires applied in a controlled environment to ten engineering students, to detect problems in the questions, possible answers and have knowledge about how the questionnaire is working. And for the questionnaire applied to 41 engineering professors, the face validity was used [12] to assess the content validity through the analysis of four expert engineering professors to evaluate the sufficiency, clarity, coherence and relevance of the questionnaire [22] with the help of four expert teaching engineers. Both questionnaires with informed consent.

3. Results

3.1 Review of curriculum documents

In the documentary analysis of institutional policy such as the PEI and the Development plan, there is an orientation towards comprehensive training with an ethical and humanistic basis, according to the institutional policy, values are promoted, respect for human rights, thought conscious,

having as its ultimate goal, the construction of the country towards a collective well-being.

In the review of the PEP, it is found that, in the training objectives of the program and the professional profile, an ethical component is integrated in most of them, such as training professionals on an ethical and humanistic basis, with critical awareness, to act responsibly, which, in the same way, agrees with the institutional policy. Contents directed towards ethics are not observed in the components of foundation, disciplinary training and it is not specified in the component of free choice.

Similarly, reviewing the engineering curricula, it is found that in the foundation components and disciplinary training, most do not identify any subject with a degree in relation to ethical and humanistic training. And, in terms of course design formats, it is found that values training is specified in only a few courses, with content aimed at teamwork, a sense of responsibility and commitment.

3.2 Perception of engineering professors

Regarding the identification of problems generated by the lack of ethics in engineering, as can be seen in Fig. 1, 12% of the professors reported not having identified any cases, another 12% few cases, and 39% some cases. While the majority, 37% responded that they have identified many cases of problems arising from the lack of ethics in engineering.

As for whether the engineer must adjust to the job offers of the environment or maintain an ethical position in his exercise above the job possibilities, as Fig. 2 shows, the majority of respondents 90%, express that they must maintain their ethical position, although they have to sacrifice job offers, 2.4% say that they must adjust to the job offers of the medium even if they have to sacrifice their ethical position, and 7.3% present ambiguous positions to the two exposed.

When professors refer to other ways of teaching ethics in engineering, they suggest teaching "by example" what has been called "invisible pedagogy". Also through interdisciplinary work, incorporate aspects of the ethics of self-care from the referential framework of engineering, promote reflections on ethics in the development of the entire training process, not as an appendix to comprehensive training but as a central aspect of the training itself, propose discussions about the ethical sense in academic, administrative, and personal processes and teach the consequences of not acting ethically.

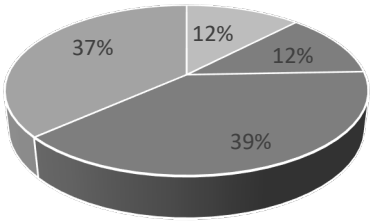

Figure 1. Identification of problems of ethics in engineering
Source: the authors

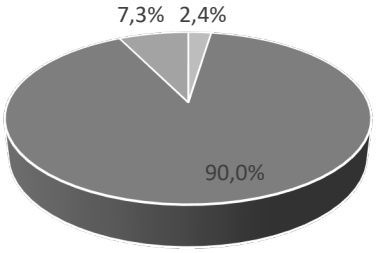

Figure 2. Maintaining an ethical posture or adjusting to the job offer
Source: the authors

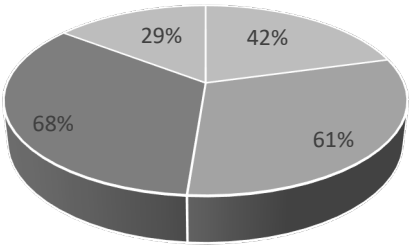

Figure 3. Moral dilemmas should be taught
Source: the authors

Regarding whether it is important that scientific and technical knowledge be integrated into ethical training in future engineers. Otherwise, Fig. 3 allows to see that many teachers with 68%, believe that decision making should be taught in the face of moral dilemmas in engineering, 61%, are also in favor of teaching ethics in engineering through the case study, 42% think that the engineering code of ethics should be taught, and 29% suggest other strategies.

Regarding knowledge about engineering courses in which engineering ethics education is taught, as can be seen in Fig. 4, a 47.5% respond that they do not know and 52.5% say that they do know one or some courses where ethics education is taught in the same.

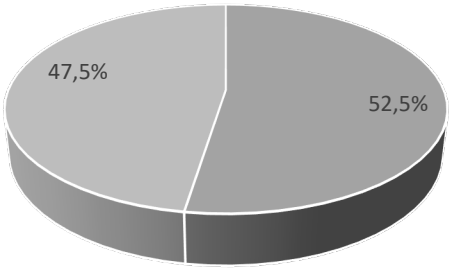

Figure 4. Ethics in engineering is taught in the courses
Source: the authors

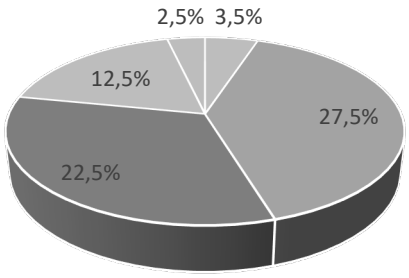

Figure 5. Inclusion of ethics in classes
Source: the authors

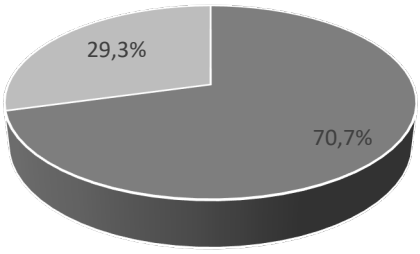

Figure 6. Spaces for ethical debate in universities
Source: the authors

Now, delving into the question, about whether you yourself as a teacher have included topics related to ethics in engineering, as Fig. 5 shows, 27.5% answer that many times, 22.5% rarely, the 12.5% sometimes, 35% answer that always, and 2.5% never.

When asked if enough spaces for debate are promoted in the university in relation to the current problems of ethics in engineering, 70.7% say no, and 29.3% say yes, Fig. 6 allows see him.

Regarding the methodological proposals of professors to teach ethics in engineering, they suggest carrying out chairs, diplomas and permanent campaigns of ethics in engineering. Also, implement case studies with a humanistic vision, hold discussion and participation spaces in which the four principles of the "Declaration of Ethical Principles of Engineers" are worked on, also work with moral dilemmas, teach ethics by example, with fundamental theoretical support and praxis, including subjects dedicated to professional ethics, hold events where ethics is the central theme, with reflection on ethics in the university itself and its forms of relationship with the external world, with communities, companies , businessmen, the state and other actors, taking courses designed for this purpose, and through impact studies of engineering projects.

3.3 Perception of engineering students

98.8% of the students consider it important to teach ethics in engineering along with other scientific and technical knowledge, because it should be part of the profession, because of the role of engineering in society and because of the primacy of human values. Only 0.2% consider that they are indifferent.

Of the 98.8%, as can be seen in Fig. 7, 6.33% did not answer, other 39.65% of the students, they consider that ethics should be implicit in their training as engineers, mainly because it is part of the professional career, since subjects such as these provide them with elements of judgment in your professional life. They consider that a professional must have integrity, not only have good technical knowledge, but also could make fair decisions on economic benefits or other interests that do not harm the social and environmental dimensions. In this sense, ethics is essential for decision-making in professional practice.

On the other hand, continuing with Fig. 7, a 35.63% of the students think that ethics education should be included in engineering, due to the role of the engineer in society. Responsibility with society must be promoted in training, putting safety first, and for this it is necessary to teach how to do the right thing, not to be part of the culture of illegality, and to respect the laws of the country and professional standards. Well, your actions have an impact on others, therefore, you must be aware, to contribute to the common good, build a better country.

And 18.39% refer that ethical education in engineering should be given, because before any technical or scientific knowledge, one cannot forget that one is human and a person, therefore, the duty to act with human values. It is important that people develop as human beings, engineers cannot be disconnected from the humanitarian. Ethics is as important as technical and scientific knowledge. Before being professionals, you must learn to be people with great ethical and moral value, that makes "good engineers", the students also think.

Otherwise, 68% of the students report that, since the beginning of their professional career, they have not seen a subject that has the term ethics implicit in its title. And 32% say yes.

In another way, 74.1% of the students affirm that they have seen subjects, which, although they do not have the term ethics implicit in their title, have addressed problems of ethics in engineering, while 25.9% he says no.

However, Without the figure implying a proportion that completes 100% taking into account that different options were allowed to be chosen, and as can be seen in Fig. 8, a 42.3% of students report that they have already been taught ethics through ethical dilemmas, 40.9% with studies of case, 32.9% with keynote presentations, 30.2% with debates, 28.9% with virtual courses, 15.4% with group workshops and 10.1% with continuing education courses.

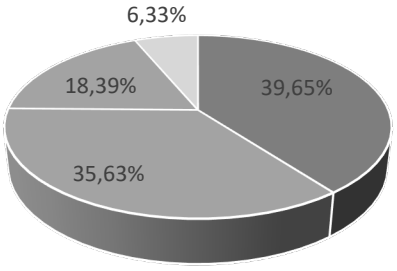

Figure 7. Why include ethics in engineering
Source: the authors

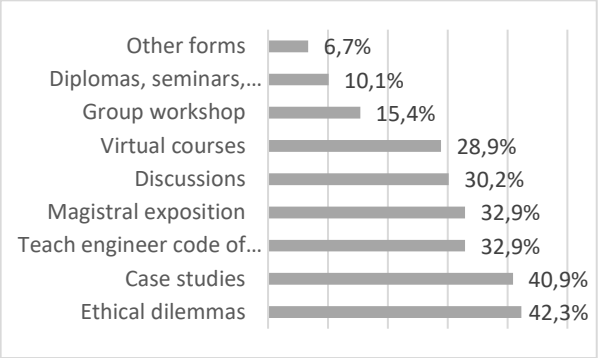

Figure 8. How ethics has been taught to students
Source: the authors

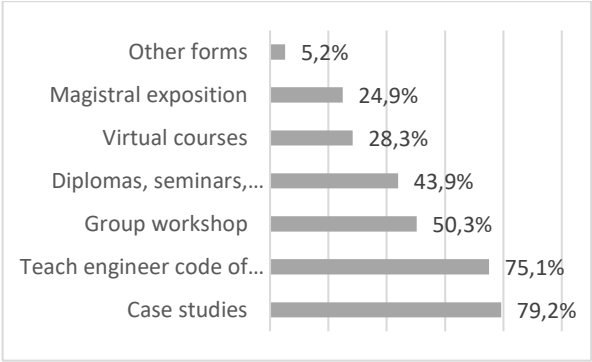

Figure 9. How they would like to see ethics taught to students
Source: the authors

When they mention other forms (6,7%), they comment that group presentations, webinars, debates, social research, and volunteering have been carried out.

Now, regarding whether the students consider that the university generates enough spaces for debate regarding ethics in engineering, 73.8% consider that it does not, and 26.2% consider that it does.

Regarding the methodologies with which they would like to learn ethics in engineering, as Fig. 9 shows, most of the students state that the one they like the most is the case study (79.2%), followed by the teaching of the code of ethics of the engineer (75.1%) and work with group workshops (50.3%), virtual courses (28,3%) and magistral exposition (24,9%).

Regarding other forms, Fig. 10 shows that 5,2% the students affirm that it can be dealing with ethical issues in any subject of the career, for example, in a welding course, which could be thought to have nothing to do with ethics, there was an experience of teaching be ethical in the trade, in relation to the exercise of said activity. Also, through conversations, invite engineers to talk about their experiences in the field in relation to ethical decisions, also in forums and in professional practices.

Otherwise, 36.8% of students, report that ethics education in engineering needs to be further strengthened, 23 % of the students consider that ethics is not taught in some way throughout the curriculum. engineering, 9.8 % of the students think that there are no gaps regarding the training of ethics in engineering, 5.2 % consider that the education of ethics in engineering should be a compulsory subject and 25.3 % did not respond.

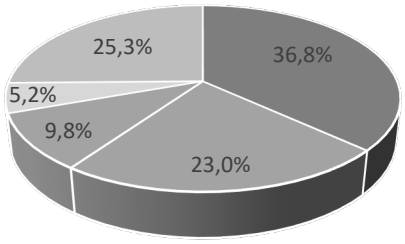

Figure 10. What do students think about ethics education?
Source: the authors

Of the 36.8% of the students, who think that it is necessary to improve the education of ethics in engineering, they consider that in this regard, there is a lot of work to be done, to train skills that are fundamental for the professional life where they will occupy positions managers or will be team leaders. There are few subjects that are seen in relation to ethical training, the fundamental and disciplinary components do not have specific contents of ethics in engineering, but these are contemplated within the component of free choice, which means that the decision to take courses on ethics depends entirely on the student and this does not normally happen since the general tendency is to understand engineering training as an exclusively technical training. It is important that ethics be part of the foundational component of academic programs.

The pedagogy of ethics in engineering cannot be subject to an option that the teacher may or may not take, which, in fact, if it were not for the human quality of the teachers, this topic would be forgotten on many occasions. Ethics in engineering should be a key piece in the programs, since there is not enough exposure to the subject, ethics must be emphasized at all times by university professors and show the advantages that it brings, and also show the mistakes that corruption and lack of ethics brings, it would be interesting to be able to carry out the exercise of ethics in engineering in a practical way.

On the other hand, 23% of the students consider that being an ethical professional is not taught throughout the curriculum, and they consider it important that they include some subject that does teach it, or that it is addressed in an integral way in all courses.

Some refer, that in many cases the subject is not touched to avoid discussions and controversies. The engineer today does not want to enter into ethical dilemmas in the academy because sharing personal points of view can be counterproductive, that is why he dedicates himself to discussing only technical problems, thus believing that if the problem is solved technically, it is already solved in his own right. totality, ignoring the areas of knowledge with a human approach.

Added to this is that students are not interested in ethics, and teachers do not encourage interest in ethics, there is a lack of interest in this subject on the part of most teachers. If a student is not interested in dealing with the subject, they will never deal with it in their entire university career, even though there are such good and necessary courses in the

university as the chair of ethics. On the other hand, some perceive that most of their classmates and teachers are only interested in graduating people who memorize procedures, looking for a place in the industry without caring if it is ethical or not.

Additionally, they argue that there is a culture of being more alive than others even if that means stepping over the other. With the simple fact that there are still people copying works, they already started badly, and it is even common to find certain teachers resorting to activities that students may consider unethical.

An example of these unethical activities of professors, which are perceived in the academy, is what is known as scientific fraud committed by some professors, perhaps due to the pressure and desire to publish, even publishing in the so-called predatory journals initially called by Jeffrey Beall [24], there is talk of undeserved contributions, ghosts or fees, people who are included in a publication without deserving it, just for the fact of receiving a favor, being one of the most critical points in scientific publications [25] .

Secondly, 9,8 % of the students who think that there are no gaps regarding the education of ethics in engineering, refer that they have not seen some content, but they hope to see it, to others it seems that it is even evaluated in some chairs or he sees something of it in every subject.

And 5.2% of the students think that one of the gaps in their programs is the lack of a compulsory subject on ethics in engineering, despite being such an important issue when going out into the world of work. Therefore, the possibility that this topic will reach all students, or a large part of engineering students is very low, so the efforts they make will be insufficient. Some subjects that deal with the ethics of engineering are recognized, "it is very good", but since it is not compulsory, it does not reach everyone.

They think that the university should teach a compulsory subject from the beginning, to instill respect and responsibility with the profession, a course that explicitly focuses on ethics in engineering and cases where it has been corrupted, a course that explores the human dimension of the person and that allows changing the paradigms that are learned from today's society.

4. Discussion and Conclusions

Seeking to improve the ethical training of engineers, and to make it easier for engineering to continue contributing positively to the development of communities, different didactic strategies are identified that can contribute to the adequate training of ethics in engineering, taking into account how it has been taught. and listening to the suggestions of students and teachers about how it should be done, thus seeking to propose different forms of educational innovation for the teaching of ethics in engineering.

In the first step, it is necessary to address the curriculum, manifested in the study plans, Institutional Educational Projects -PEI and in the Methodological Structures of the courses or Syllabus. Ethics should be included as an important factor in the training of engineers in the curriculum, it should not be done as a subject of free choice, but as a compulsory transversal and disciplinary subject that bears its own name. Determine then what curricular elements require adjustment for an adequate education of ethics in engineering, in order to provide society with a professional committed to citizen values and principles. Considering that in engineering not only technical knowledge matters, but also the ethical position always before said knowledge.

Otherwise, ethics should be included in extracurricular spaces on an ongoing basis, promote talks, discussions, continuing education courses that have ethics as the main theme, involving already trained engineers, businessmen, people from the community.

Now, as proposals to teach ethics in engineering, the first thing is that it must be done from practice, including case studies, planning of moral dilemmas, of specific problems applied to engineering according to their realities. Bearing in mind that engineers face continuous ethical dilemmas in their daily lives that require permanent reflection on moral acts in everyday life, which promote the application of human values. Its objective is to generate skills in future engineers to be able to make good decisions.

The case studies, moral dilemmas and problem posing must include how to adjust to a job offer, teach the code of ethics but applied to specific cases of reality, for which the various sanctions that occur daily for Councils of Engineers such as COPNIA in Colombia. These practical exercises, case studies and dilemmas should always encourage reflection on what should be, should encourage discussion of the best ethical sense, showing the consequences of not acting ethically.

On the other hand, it is also one of the main activities necessary to strengthen ethical education in engineering, it is to generate awareness, not only in engineering students but also in teachers and for this, training is important, since ethics in engineering It is not an individual issue, but teachers must also join the ethical debate inside and outside the classroom, the teacher must set an example in his actions, he must always show the ethical in what he teaches and shows, behaviors that are known as "pedagogy invisible". The professor of any subject must teach ethics, in each course, in each activity.

Finally, in order to begin with the development of the ethics curriculum in engineering, it is proposed to start first with the various continuing education strategies such as seminars, diplomas, talks and different events, which promote the practical didactics of teaching ethics in engineering. engineering, through case studies, moral dilemmas and problem statements, taken from the Professional Engineering Councils or from the same engineers who live in everyday life, having to face ethical decisions in situations as professionals.

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