NUEVAS REALIDADES PARA LA EDUCACIÓN EN INGENIERÍA: CURRÍCULO, TECNOLOGÍA, MEDIO AMBIENTE Y DESARROLLO
13 - 16 DE SEPTIEMBRE 2022 CARTAGENA DE INDIAS, COLOMBIA
Encuentro Internacional de Educación en Ingeniería ACOFI

Pedagogical strategy to promote ethics and profesional responsability in engineering curricula

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Abstract

During several decades, engineering was considered a morally and ethically neutral profession. Therefore, it was assumed that reflections about ethics and moral were not necessary. Consequently, questions have been outlined to include ethics in engineering curricula. These questions have been developed slowly in the last decades with the imperative need of designing an ethical framework to inform technical decisions that engineers make in project management. Associated with this issue, some curricular guidance have been found. The first one is based on the educational framework for curricular design named CDIO (conceive, design, implement, operate). CDIO initiative establishes that in the curriculum should be explicit, the promotion of ethics, social responsibility, integrity, professional behavior, staying current on the world of engineering, a commitment to work embracing equity, diversity, and teamwork.

The second guidance refers to the field of accreditation board – ABET. ABET declares that students are expected to know and be able to do some knowledge, skills, and behaviors associated to their progress in the program. In particular, an expected student outcome is related to the ability for recognizing ethical and professional responsibilities in engineering context and make informed judgments considering global, economic, environmental, and societal backgrounds.

Previous studies guide the "ought to" mode curricula related to ethics. Literature has acknowledged several challenges to carry out that mode: unsystematic implementation of ethics, the low weight given to this subject in the curriculum, the low familiarity with the theoretical knowledge in ethics, instructors' difficulties to structure a comprehensive, theoretical and practical framework, among others.

Considering this background, the School of Engineering at the Pontificia Universidad Javeriana (PUJ) has made curricular reflections for designing a pedagogical strategy focused on ethics and social responsibility. This strategy involves several milestones, such as: shared reflections between the faculty of Engineering and the Center of Teological Formation to design educational activities, a systematic "roadmap" to approach ethics issues in the program, the strengthening of ethics reflections in mandatory disciplinary courses, the inclusion of voluntary workshops to explore and identify values among students, the promotion of ethics and social and professional responsibilities in designing engineering projects, and the proposal of quantitative and qualitative measures to reflect about students' progress in the field of moral and ethics.

In this context, the paper introduces some literature considerations about ethics in engineering education. Then, it presents the conceptual and methodological framework that underlies the pedagogical strategy. After that, the designed strategy is described. Finally, some reflections about the implementation and future work are discussed.

Keywords: ethics; moral; engineering education, engineering curriculum; pedagogical strategy

Resumen

Durante varias décadas, la profesión de ingeniería fue considerada moral y éticamente neutra; por lo tanto, se supuso que las reflexiones sobre la ética y la moral no eran necesarias. En consecuencia, los cuestionamientos sobre cómo incorporar la ética en los currículos de ingeniería se han planteado, de manera lenta, en las últimas décadas, con la imperiosa necesidad de diseñar soportes éticos para informar las decisiones técnicas que toman los ingenieros en cada proyecto que gestionan. En relación con este llamado urgente a la acción, se han encontrado algunas orientaciones curriculares. La primera se basa en el marco educativo para el diseño curricular denominado CDIO (concebir, diseñar, implementar, operar). La iniciativa CDIO establece que en el currículo debe ser explícito el fomento de la ética, la responsabilidad social, la integridad, el comportamiento profesional, la actualización en el mundo de la ingeniería, el compromiso de trabajar con equidad, diversidad y trabajo en equipo. La segunda guía proviene del campo de la junta de acreditación - ABET. Aquí, ABET declara lo que se espera que los estudiantes sepan y puedan tener en términos de conocimientos, habilidades y comportamientos debido a su progreso a través del programa. En particular, un resultado estudiantil esperado está relacionado con la capacidad de reconocer responsabilidades éticas y profesionales en situaciones de ingeniería y emitir juicios informados, que deben considerar el impacto de las soluciones de ingeniería en contextos globales, económicos, ambientales y sociales.

Estas declaraciones previas guían el modo "deber ser" de los currículos de ingeniería relacionados con la ética. Sin embargo, la literatura ha reconocido varios desafíos para ponerlos en práctica: la implementación asistemática de la ética, el poco peso que se le da en el currículo, la poca familiaridad con el conocimiento teórico sobre el tema, la lucha de los profesores para estructurar un marco teórico y práctico integral, entre otros.

Considerando estos desafíos, la Facultad de Ingeniería de la Pontificia Universidad Javeriana (PUJ) ha realizado reflexiones curriculares al respecto. Como resultado se diseñó una estrategia pedagógica para promover la ética y la responsabilidad social. Esta estrategia involucra varios hitos, tales como: la reflexión conjunta entre los profesores de la Facultad de Ingeniería y los del Centro de Formación Teológica para diseñar las actividades educativas, la creación de una "hoja de ruta" sistemática para abordar los temas de ética a través del programa, el fortalecimiento de las reflexiones éticas en los cursos disciplinares obligatorios, la inclusión de talleres voluntarios para explorar e identificar valores entre los estudiantes, la promoción de la ética y la responsabilidad social y profesional en el diseño de proyectos de ingeniería, y la propuesta de medidas cuantitativas y cualitativas para reflexionar sobre la evolución de los estudiantes en el campo de la moral y la ética.

En este contexto, el artículo presenta algunas consideraciones de la literatura sobre la ética en la educación en ingeniería. Luego, presenta el marco conceptual y metodológico que fundamenta la estrategia pedagógica. Posteriormente se describe la estrategia diseñada. Finalmente, se discuten algunas reflexiones sobre la implementación y el trabajo futuro.

***Keywords**: ética, moral, educación en ingeniería, currículo de ingeniería, estrategia pedagógica*

1. The ethical context of engineering

In several decades, engineering was considered as morally and ethically neutral. However, in recent years there have been some questions about the role of engineering in society for its ethical and moral implications. Multiples cases involves falling of infrastructure, changes in software that measures control of emissions to evade economic sanctions, the use of artificial intelligence and big data to elaborate customers' profiles that invade their personal lives, the use of algorithms of facial recognition that cannot recognize people from specific social racial groups. These examples show the importance of engineers' professional responsibilities. In addition, in our classrooms, students face several challenges related to cheat, fraud, and their acknowledgment of intellectual property. All of these situations highlight the need of approaching ethical and moral issues in engineering education.

2. The engineering ethical challenge

Taking this context in mind, the School of Engineering at the PUJ has reflected about including ethics and moral in engineering curricula, in an explicit way. During the implementation, international frameworks were considered. The first one was the CDIO™ Iniciative, created by the Royal Institute of Technology (KTH) in Stockholm, Linköping University (LiU) in Linköping, and Chalmers University of Technology in Gothenburg, plus Massachusetts Institute of Technology in USA. This iniciative is defined as "an innovative educational framework for producing the next generation of engineers. The framework provides students with an education stressing engineering fundamentals set in the context of Conceiving — Designing — Implementing — Operating (CDIO) real-world systems and products." (CDIO, 2022). The second one refers to the proposal of student outcomes from the

Accreditation Board for Engineering and Technology (ABET) to measure and evaluate the improvement of several knowledge, skills, and attitudes that a student should learn during his/her engineering program's trajectory (ABET, 2022). Finally, we redesigned engineering programs curricula from content-based models of curriculum design to competence-based models. Therefore, the ability to take ethical and professional responsibilities in relation to engineering decisions and to evaluate impacts of those solutions became relevant for students' learning process.

In consequence, a new challenge for the redesigned curricula consists of exploring ethics, conceptually and methodologically, to establish a "route map" to manage ethics issues with students. In this sense, we have found that the field of ethics and moral is broad (Singhapakdi et al., 1994) and includes similarities such as both terms deal with the notion of right or wrong where ethics seems to be related to social and cultural standards, and moral seems to be related to individual beliefs, intentions, and actions. Hence, moral can be seen as the basis for ethics. Moral theories can be described in two types: deontological and teleological. The first one refers to actions that are good or bad under specific rules. The second one is associated with the evaluation of actions' consequences to determine their rightness. Other approaches explains that moral virtue are the main concept to try with moral and ethics issues, thus, dispositions to think, act, feel in a certain way in life make a good or bad person. The relativeness or absolutism that involves moral thoughts and actions has also been studied. For some people, there is no possible way to establish universal moral rules, whereas to other people at least one way is possible.

As mentioned above, ethics and moral are complex concepts. These concepts need to be fully understood for better discussions and reflections in our teaching-learning processes. Furthermore, several theories have showed how a person develops his/her moral reasoning. Some authors as Skinner, Freud, Piaget, and Kolhberg have presented their theories with different approaches. For instance, Skinner focuses on punishment and rewards; Freud pays attention to desires; Piaget highlights individual socio-cognitive and socio-emotional factors; and Kolhberg proposes a developmental construction of morally (Jambon and Smetana, 2015).

Diverse models and theories have influenced engineering education. In a recent research, Martin et al. (2021) points out that the goals for engineering ethics education can be grouped under 12 major categories, for instance, learning objectives related to moral sensibility, analysis, creativity, judgment, decision making, argumentation, knowledge, design, agency and action, situatedness, emotional development, character and virtue development. Nevertheless, there is not completely understanding if these goals help students to comprehend their responsibilities as future engineers.

Another aspect to consider ethics and moral in engineering education is related to the areas where these topics are taught: sustainability, health, safety, community engagement, humanitarian engineering, and value sensitive design, all of them related to the concept of "professional responsibility" (Martin et al., 2021). This shows the unbalanced form that engineering curricula approach ethics, which is associated to another challenge: the lack of expertise to teach these themes in an engineering subject, along with the disinterest showed by students (Bielefeldt and Canney, 2016).

Finally, the unbalanced tools or knowledge taught in engineering curricula are focused in technical training rather than social or human skills. This challenge is related to the unsystematic and non-

systemic implementation throughout curricula, including the lack of instruments to measure the attributes that students need to enhance (Canney and Bielefeldt, 2012).

3. The engineering ethical proposal

Considering the above-mentioned challenges, and the purpose of clarifying a systematic and systemic strategy to develop engineering ethics, a pedagogical curricular strategy was based on several milestones throughout engineering curricula in PUJ. This strategy aims to prepare students to engage in their professional context.

The strategy focuses on designing a systematic "roadmap" to approach ethics cornerstone issues in the program. This strategy involves various classes, the first one is a mandatory class in each engineering program where technical knowledge is taught in first semester. In this class, a test (Defining Issues Test – DIT) related to moral dilemmas (Rest, 1986; Mesa & Suárez, 2006) associated to the theory of moral development (about moral judgments) proposed by Kolhberg (1996) is applied and the overall results are presented to reflect about first-year students decision-making process. Results allow mapping students' thoughts and behaviors for subsequent comparison at the end of the program.

In the second semester, in an engineering design class, where students from all of the engineering programs gather in groups to solve real problems, different activities have been outlined (León & Suárez, 2013).

The first activity is a workshop called "Manifiesto Javeriano" (manifesto Javeriano). This workshop explores students' values as a community willing to behave in an honoring way according to their identified and selected values. Each student enrolled in the class clarifies his/her values and then they share their selection with peers to formulate a class manifesto.

The second activity is a workshop at the middle of the semester to discuss about social, economic, ethical, moral, and environmental impacts of the solutions they are designing. At the end of the semester, students present their solutions and professors inquiry about the analyzing method and how they decide the relevance of their technical designs. Reflections related to improve student's moral development are promoted. These reflections are strengthened in a third-semester class named "Theological Significance", where students and professors discuss about how their technical solutions should be considered in a systemic and broad sense.

After these activities, other interventions have been defined. In the second class of Engineering Design (in fifth semester) and in the class of Faith and Commitment of the Engineer (in sixth semester), a similar scheme is presented between ethical, moral, and technical focus of engineering design. This step of the route map is focused in the design of engineering solutions to vulnerable communities or non-profit organizations.

At the end of the engineering curricula, in the final design project (tipically named "thesis") we have planned an intervention to evaluate how future engineers can face their ethical issues in their professional careers. This intervention includes a new application of the DIT (post-test) and the assessment of ethical impacts of their engineering solutions. The assessment is associated to the applied test at the beginning of the program to identify students' improvement in moral development.

In summary, the pedagogical strategy aims to build reflections about engineering decisions and ethical impacts in professional context of our students for overcoming the afore-mentioned challenges. For implementing the strategy, we worked with experts, designed measures, formulated a systematic way to teach this topic, allowed students to discuss ethical issues in technical classes, and promoted several learning objectives. In the first semester of 2022, the first step of the implementation process was performed. Figure 1 presents a summary of the proposal.

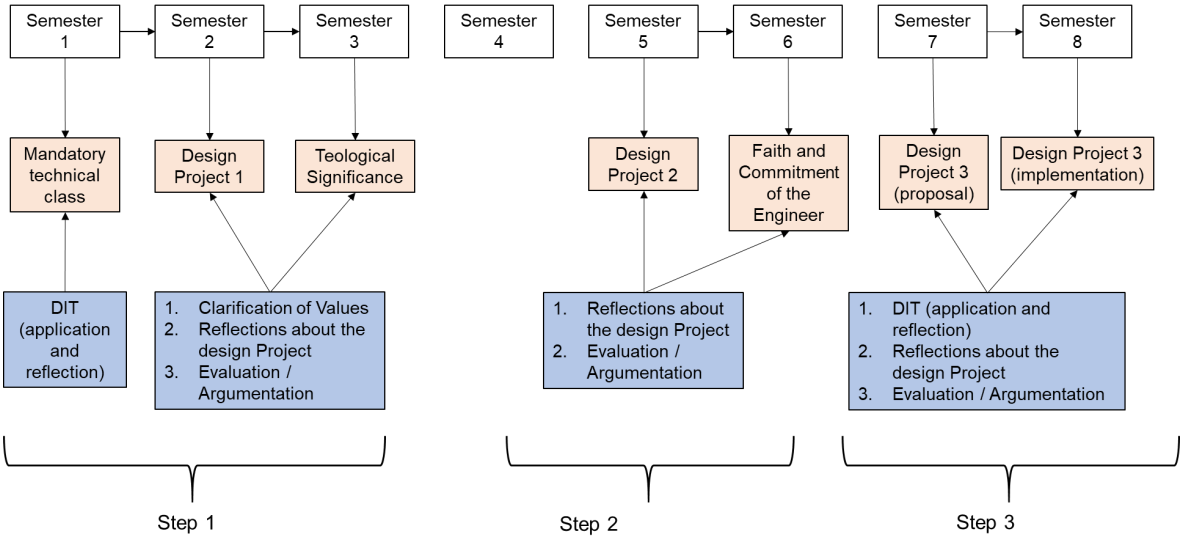

Figure 1: Pedagogical Strategy Proposal to Promote Ethics in Engineering Curricula.

4. Final reflections

Having explored the challenges associated to approaching engineering ethical education, we presented a pedagogical strategy to promote ethics in engineering curricula at PUJ. We implemented step 1 in the first semester of 2022. In doing so, we have found that these activities allow students reflecting about ethics and moral, considering implications of their designs and their decision-making process. The next step is to carry out the rest of the proposal and evaluate the improvement of ethical reflections in our engineering students.

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