Case Studies About Moral Dilemas to Apply Ethical Theories in Engineering Education

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***Abstract*— The significance of incorporating ethics education in engineering programs has grown considerably in recent times, especially within domains such as computer science, software engineering, data science, and artificial intelligence. In response to this demand, a pedagogical activity was developed and executed to facilitate students in applying ethical theories to occupational and societal challenges while enhancing their critical thinking abilities. This activity involves students participating in a debate where they are assigned a moral stance to uphold and must utilize one of the ethical theories explored in class to bolster their case. This paper offers an in-depth account of the conception and execution of this educational activity, as well as the encouraging results observed. Furthermore, the paper showcases the scenario utilized in the activity, which outlines a professional conundrum in the realm of Computer Engineering. The findings of this educational activity indicate its efficacy as a teaching instrument for ethics in engineering programs, with potential applicability to other engineering fields. By integrating such pedagogical activities into engineering programs, educators can empower students with essential ethical values and skills to tackle intricate ethical issues in their professional and social spheres while also fostering critical thinking and encouraging dialogue among students.**

***Index Terms*— Computer ethics, critical thinking, ethics in engineering, didactical resource.**

I. Introduction

OVER the past few years, the impact of computers and computer networks on society has led to the emergence of a new class of ethical and social issues, which has been a concern since the early days of digital computing [1]. Today, the increasing use of information and communication technologies (ICT) has resulted in a range of moral, ethical, social, legal, and political issues that must be considered.

For example, the emergence of Brain-Computer Interfaces (BCIs), an innovation on the horizon, has brought forth several intricate questions across multiple dimensions: (1) moral ("If BCIs can enhance cognitive abilities and reduce human error, should they be implemented? Should their use be compulsory?"), (2) ethical ("Is it acceptable to delegate ethical decision-making to devices that interface with our brains, the workings of which we don't fully understand?"), (3) social ("Should we allow a significant portion of the workforce to be augmented by such technology?"), (4) political ("How do we address the economic and political ramifications for those who lose jobs due to increased efficiency?"), (5) legal ("What legal frameworks need to be established for regulating BCIs?"), (7) security ("How can we ensure the cybersecurity of our neural devices and associated infrastructure?"). These questions, along with even more complex ones, emerge with the introduction of new technologies like smartphones, drones, 3D printers, the Internet of Things, social networks, the web, facial recognition technologies, big data, and every application of (shallow) AI (artificial intelligence).

Nonetheless, the intricacy, abilities, and influence of these innovations are tied to exponential-like trends, such as those outlined by Moore's Law (the number of transistors per square inch in a processor doubles every 18 months), Metcalfe's Law (the potential utility of a network is proportional to the square of the number of nodes), and other similar observations that strongly imply that the trajectory of technological change is exponential. According to Kurzweil, the technological advancements we will experience during the 21st century will be equivalent to 20,000 years of progress at today's rate [2]. As a result, it is crucial to consider the technological singularity hypothesis: "The technological singularity—or simply the singularity—is a hypothetical point in time at which technological growth becomes uncontrollable and irreversible, resulting in unforeseeable changes to human civilization" [3].

Thus, it is evident that incorporating engineering ethics into the computer engineer's curriculum is crucial. While the technical competencies are essential, the development of the profession also requires transversal competencies such as team work, ethical analysis, and communication skills.

The inclusion of environmental, social, and ethical aspects of technology has been a part of some undergraduate computer science curricula for more than twenty years. This paper focuses on the study of ethics, which is an essential component of computer science education.

The term "computer ethics" was first coined in 1978 by Walter Maner, who noticed that ethical decisions become more complex when computers are involved. This led to a need for a distinct branch of ethics that dealt specifically with computers [4]. Maner's work generated significant interest in this new field in the late 1970s and 1980s within university circles. Deborah Johnson wrote the first textbook on computer ethics in the 1980s [5].

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The study of ethics was not introduced into computer science curricula until 1991. An ACM/IEEE joint committee was established, and they created a new curriculum for computer science that included computer ethics [6]. In the same year, the first conference on Computing and Values was founded by America's National Science Foundation in the USA. This multidisciplinary conference was organized by Terell Byrum and Walter Maner and brought together philosophers, scientists, computer engineers, business managers, and professionals [4].

In Europe, the Barcelona School of Informatics (Facultat d'Informàtica de Barcelona - FIB) at Universitat Politècnica de Catalunya (UPC) included courses on "Social Impact and Professional Ethics of Informatics" and "Informatics History" in their Informatics Engineering graduate program in 1991 [6], [7]. Another early initiative took place in 1995 when the Centre for Computing and Social Responsibility (CCSR) was founded at De Montfort University (United Kingdom) with Professors Simon Rogerson, Terry Ward Bynum, and Don Gotterbarn among the staff. Rogerson became Europe's first Professor in Computer Ethics in 1998 and contributed significantly to the historical debate on the impact of strategic, managerial, and ethical issues of ICT within organizations [8].

When it comes to introducing the study of ethics in ICT curricula, there are many different approaches. One such approach is to focus on the process of ethical decision-making, which places an emphasis on the process required to reach conclusions about ethical dilemmas [9], [10].

Other researchers focus on professional practice and suggest that ethics education should focus on practical applications, teaching students how to solve ethical problems both morally and technically. For this purpose, the use and teaching of codes of ethics are becoming increasingly important in ICT ethics education [11], [12]. Johnson proposes ethics education as a set of activities that provides students with basic knowledge about "codes of ethics and standards of behavior," develops their skills at interpreting and applying these codes and standards, and increases the likelihood that students will be prepared to handle ethical issues once they enter their professional lives [13]. Similarly, Samson suggests that codes of ethics provide valuable guidelines to achieve ethical behavior and to assess moral responsibility in the profession.

Another approach is to base the teaching strategy not only on ethics but also on the social implications that help students in ICT develop their ethical reasoning skills and an appreciation for the complex impact that technologies have on society [15]. This approach works by exposing students to as many cultural, social, legal, and ethical issues in the discipline of computing as possible to broaden their appreciation and understanding of complex issues. This approach is similar to the ones taken by Barceló at UPC and Gordon at the University of Hull [16].

Incorporating ethics into the research and development process itself is a crucial aspect of promoting ethical practices in the field of ICT. Spiekerman emphasizes the need to integrate computer science with philosophy and management to achieve this goal [17].

Patrignani explores how universities can prepare the next generation of computer professionals to be ethically grounded, using the concept of Slow Tech as a baseline for analysis. He argues that the ICT supply chain should consider social desirability, environmental sustainability, and ethical acceptability [18].

Other contributions provide surveys of the growing collection of topics in ICT ethics [19], [20]. These surveys show an increase in the number of publications in the area, indicating a trend toward growing awareness of the field's increasing importance. However, the distribution of topics remains broadly constant.

Teaching the ethics of ICT to engineers is challenging, despite the various experiences and recognized methods for integrating these subjects into the computer science curriculum. The rapid evolution of technology makes it even more difficult in computer science education.

Engineering education includes not only technical skills but also professional skills, particularly in computer science education. The ABET's EC 2000 criteria include a set of professional skills that involve process and awareness skills [21]. Process skills include communication, teamwork, understanding ethics and professionalism, while awareness skills include engineering within a global, economic, environmental, and societal context, and lifelong learning.

In the context of Spanish universities, during the process of adapting Spanish university degrees to the European Higher Education Area (EHEA), the so-called *White Books* [25] were edited for the various degrees existing at that time. They analyzed the characteristics of the corresponding or related studies in Europe, professional profiles and competences, and proposed a curriculum structure, among other aspects. These papers recommended specifically courses on ethical and social issues following the recommendations of both ACM/IEEE and ABET. Miñano et al. shows that integration of ethics courses in computer science degrees is greater than in other engineering degrees. In fact, in informatics engineering degrees, specific courses about social, ethical and legal issues are usually used to deal with the sustainability competencies [26].

Various methods are used in engineering schools to teach ethics, including codes of ethics, case problems, moral theory, problem-solving heuristics, humanistic readings, and service-learning [22], [23]. Bowden proposed an ethics course based on case problems, ethical theory, acting in the public interest, the study of codes of ethics, and the role of the professional society [24].

Gotterbarn argues that computer science students need to be taught that ethical issues are relevant to their professional practice and how to recognize these issues, rather than just learning ethical theory and philosophical argumentation [24]. Johnson and Martin suggest that philosophers who have not had appropriate training in computer science cannot effectively teach computer science courses because they cannot appreciate key technical issues [13].

In summary, integrating ethics into the research and development process itself is essential for promoting ethical practices in the field of ICT. Various approaches are used to teach ethics in engineering schools, including codes of ethics, case problems, moral theory, problem-solving heuristics, humanistic readings, and service-learning. In addition,

teaching the relevance of ethical issues to computer science students is crucial, and educators should be trained in both philosophy and computer science.

II. Course, Didactical Resource and Methodology

A. Course Description

The case study presented in this paper is applied in two courses at different levels. The first course, "Fundamentals of business ethics and innovation" (FEEI), is mandatory for the Master's degree in Sustainability offered by the Sustainability Institute at UPC. FEEI is taught in English to a diverse audience of local and international students aged between 25 and 40 years old. The course covers two main topics related to ethics: 1) ethics applied in the field of engineering and legal frameworks for the development of professional activity in engineering, and 2) corporate social responsibility and ethics in companies and organizations.

The second course is an optional course taught in Catalan at the Barcelona School of Informatics at the Computer Engineering Degree. It is a course about Social and Environmental aspects of computing (ASMI). The students in this course are mainly local students aged between 20-21 years old, with 75% of them being male and the remaining being female.

The FEEI course is taught by one of the authors and the ASMI course is taught the other author. Both teachers are computer engineers.

We articulate the topic of ethics based on three pillars. First the fact that every moral/ethical decision need values. Ethics do not work without a set of values and priorities that each society/community/individual has. Our ethical decisions will vary very much with a different set of values and priorities. The second pillar are ethical theories. They are useful to provide a general framework to discuss about ethical dilemmas. Finally, the third pillar is deontology, which is useful in the practice of a computers science engineer.

The approach used to teach ethics in both courses includes two types of lectures: traditional expository lectures and practical lectures. In the traditional lectures, the basics of ethics, morality, and culture are covered as well as ethical theories and deontology.

In addition to the traditional lectures, practical lectures are also included in the courses. Three cases are presented to the students, with the first one focusing on identifying important moral values when reasoning about morals. This is followed by a role play case where students have to argue in favor or against certain moral issues. The second case usually involves a high-profile news story where technology is involved and understanding the nuances of the technology is important to identify a moral dilemma. Students use ethical theories to argue in favor or against certain moral issues in this role play. Finally, the last assignment is a case study where students apply codes of ethics to reason about professional practice.

We will focus on ethical theories lectures because the experiment and didactical resource provided in this paper is based on it. Ethical theories are presented as tools to make moral decisions, and a selection of ethical theories are analyzed by working on examples and short cases. The chosen theories include Kantianism, Rule and Act Utilitarianism, Social Contract, and Virtue Ethics.

The previous theories were chosen because they are very different and provide different approaches to study the morality of an action. On the one hand Kantianism and Social Contract evaluate an action as morally right only if they are done out of duty and in accordance with a universal moral law. While Kant proposes the categorical imperative as an attempt to create a universal moral law, Social contract states that people's moral obligations are derived from an implicit agreement among individuals to form the society in which they live. On the other hand, act Utilitarianism is a consequentialist theory, that focuses on outcomes to determine if an action is wrong or right. What brings the greatest happiness to the most people is the right action to take. Finally, virtue ethics focuses on the intentions of the agent when evaluating the morality of an action. This theory emphasizes the development of good character traits over time and believes that virtuous individuals will inherently make the right moral decisions.

This approach provides frameworks for identifying and reasoning about moral dilemmas involving the application of technology, specifically computers or computer software. Students are equipped to make moral decisions and present arguments in favor or against them. With these two types of lectures, the basics of philosophical thinking are provided, and students are encouraged to think critically and analytically about ethical issues related to the field of ICT.

These types of assignments can be an interesting didactic resource for teachers who work on the ethics topic in engineering degrees. Technical knowledge cannot be separated from reflection on its impact or how it affects society. No technology is neutral, and the pros are often presented as benefits for society when arguing in favor of its introduction. However, negative side effects may appear when the new technology is being used. Therefore, engineers must have a critical spirit about new inventions and how they will affect society. To do so, philosophy, sociology, and history are good tools, as proposed in the framework of CTS (Science, Technology, and Society). This approach encourages students to think critically and analytically about ethical issues and to develop a broader understanding of their professional responsibilities beyond technical competencies.

The key aspects underlying the course are:

1. The practical lectures and case studies included in the course to help students apply ethical theories in real-world scenarios.

2. The importance of incorporating ethical reflection into engineering education and recognizing the societal impact of technology.

3. The use of philosophy, sociology, and history as tools to help engineers develop a critical and ethical perspective on technology and its impact on society.

B. Didactical Resource

Here is an example of a case study presented to the students in winter 2022. The case title is "Crowdfunding the war in Ukraine with Cryptocurrencies". Since the start of the invasion

of Ukraine by the Russian army, a lot of reactions have ensued: From the almost unanimous condemnation of the UN to logistical aid to the Ukrainian defense forces not in the form of humanitarian supplies but also war vehicles, weapons, and ammunition.

The MAD (Mutually Assured Destruction) doctrine was introduced during the Cold War in the late 1950s and early 1960s. It was a strategy developed by the United States and Soviet Union to deter nuclear war by ensuring that both countries would be completely destroyed in the event of a nuclear attack. The MAD doctrine advises that countries with nuclear weapons should not engage directly.

Hence NATO and EU countries have started to apply unprecedented economic sanctions, like the exclusion of Russian banks from the SWIFT international banking communications, the ban of imports and exports from and to Russia (not including oil and gas by the time being), and the direct seizing of actives owned by Russian oligarchs in western countries, in-cluding Switzerland and Monaco. Media associated with the Russian government (like Russia Today) have been canceled on platforms like Youtube, Twitter, and Facebook in several countries. And this is just the tip of the iceberg of the cyber-war that arguably was already ongoing.

Cryptocurrencies can be used to avoid censorship and control over financial transactions. Since they are decentralized and use blockchain technology, transactions cannot be easily traced or controlled by governments or financial institutions. This makes them attractive to individuals and organizations that want to operate outside of traditional financial systems. However, it also raises concerns about the potential for illicit activities, such as money laundering or financing of illegal activities.

In this scenario, thousands of citizens worldwide started donating cryptocurrencies (Bitcoin and Ether) to wallets owned by the Ukrainian government. This constitutes an unprecedented fact in history: the crowdfunding of a war effort in a country by foreign citizens. The Ukrainian government has decided to take ad-vantage of this situation and promised the airdrop of tokens to the Ethereum wal-lets that had donated until a given deadline. This caused a significant increase in donations, including hundreds of thousands of micro-donations not motivated by solidarity but as speculation.

C. Methodology

We use the role play technique when debating about ethical issues using ethical theories. This method allows students to argue in favor or against certain moral issues from a specific perspective, point of view or moral framework.

First, the students were grouped randomly in several groups. Each group had to prepare arguments in favor or against the actions described in the case. Each group was tasked to develop arguments in favor or against the case and using only arguments consistent with one or two specific ethical theories. The ethical theories we used where Kantianism, Virtue ethics, Social Contract Theory and Utilitarism. And for each theory one group had to give arguments in favor and another against it.

During the role play, students were encouraged to think critically and develop their own moral reasoning skills. They had to understand the underlying principles of each ethical theory and apply them to the case. This required not only a solid understanding of the theories themselves but also the ability to analyze and evaluate the actions taken in the case from different ethical perspectives. In addition to preparing arguments, each group had to anticipate the objections and counterarguments that could be made by the opposing group.

Second, a spokesperson from each group articulates the arguments they have identified. The professor records these on the chalkboard. Ultimately, students vote on the arguments they deem most compelling or persuasive based on their personal values. To conclude, we analyzed the ethical theories upon which the most voted arguments are based.

III. Results

In this section we are going to discuss the findings of the case study. The groups that work using the Kantianism provided with arguments in favor and against the donations using cryptocurrencies. The most voted argument in favor of the dotation was that if roles were reversed one would welcome the help. The second most voted argument was that the action springs from good intentions (not treating others as means to an end). Students identified three arguments to rebate the previous ones. The arguments are:1) Is it not self-interest? Isn't the action done out of fear and using the Ukrainian land as a shield for the West?, 2) Good intentions should not lead to providing weapons, 3) This donation could backfire and make wars more gruesome (like Napoleonic wars after the French revolution, when all the people of the state got involved in the war effort) and it would certainly benefit and incentivize the weapons industry.

The groups using the utilitarian morals agreed that they had to minimize suffering. Those in favor of the donation argued that in the long term, stopping an authoritarian tyrant with a record of invading countries is necessary to prevent suffering. Ukrainians will suffer more under the Puttin's yolk than if they surrender.

Those against the crowdfunding argued that in the short term the best bet to stop suffering is to stop the war. Crowdfunding Ukrainian's defense only makes it worse, and what will come later is unknown. These two points are in heavy dispute with a slight majority on the side in favor.

The groups using the social contract theory in favor of the crowdfunding explained that the donation is an example of participatory democracy (vote with wallet). They also base their arguments using the United Nations Charter Preamble (first paragraph) that states: "We the people of the United Nations Determined to save succeeding generations from the scourge of war, which twice in our lifetime has brought untold sorrow to mankind, and to reaffirm faith in fundamental human rights, in the dignity and worth of the human person, in the equal rights of men and women and of nations large and small…".

The groups that argued against the crowdfunding stated that a social contract for believers in the Christian religion states that you shall not kill.

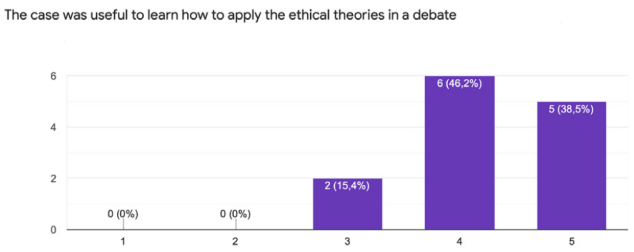

Fig. 1. Answers to the first question.

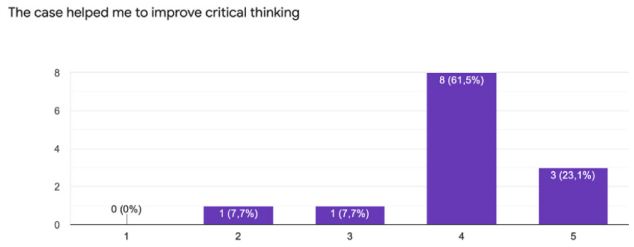

Fig. 2. Answers to the second question.

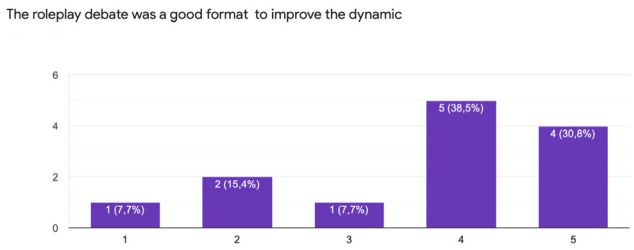

Fig. 3. Responses to the third question.

An anonymous survey was conducted among the students of the FEEI course to gather their opinion about the case. They were presented with 4 questions to answer in the Likert scale from 1 to 5, being 1 not in agreement with the statement and 5 in total agreement with the statement. 13 students of 21 answered the questionnaire.

Question 1:

The students agreed that the case was useful to learn how-to apply ethical theories in a debate. Only 15'4% of the respondents positioned themselves neutral, while the 84,6% were in agreement and 38,5% completely in agreement.

Question 2:

In the second question the 84'6% is still in agreement with the statement about the case helping with improving critical thinking. While we find a single student who slightly disagrees.

Question 3:

69'3% of students liked the roleplay format to improve the dynamic of the class. While 23'9 did not like the roleplay, specifically a student disliked it completely. We can only guess that the particular student is the same one who manifested in classroom that he/she would have liked to choose a side to his/her predisposition.

Question 4:

A single student disagreed with the statement about the roleplay debate being a good format for critical thinking.

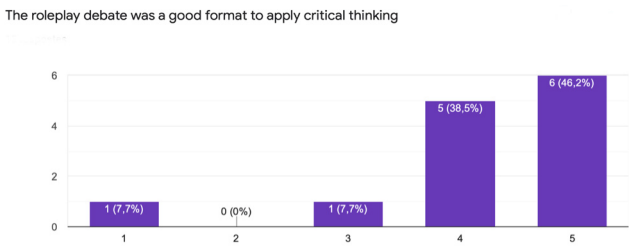

Fig. 4. Answers to question 4.

IV. Discussion

The authors consider that the first and second questions were crucial to the success of the learning activity. The goal of the activity was to facilitate the application of ethical theories in a debate and to enhance critical thinking skills. Based on the results of the survey, the authors conclude that the learning activity was a success and they plan to continue using this approach in the future.

However, the questions 3 and 4 about the format of the debate provide us with a bit of insight, that should be taken with a grain of salt since can be jus our own version of confirmation bias, but aligns with our speculations. Looking at Fig 3 and 4 we see a student strongly disagreeing with the statements and the opinions of the rest of the class. We can only guess/speculate that the particular student is the same on both questions, and was the same person who manifested in classroom that would have liked to choose a side to his/her predisposition. In this case the authors feel that the discomfort was exactly what the student needed to learn critical thinking skills and as teachers we have to accept the disagreement of the student with our ways.

During personal conversations with the authors, some students expressed their discomfort with the length and interruptions of the debate. They felt that the debate, which lasted for two hours, was cut short at times and that the professor interventions summarizing the points and writing the arguments on the blackboard at some moments interrupted the flow of the debate. To address this issue, the authors plan to consider other strategies for summarizing arguments, such as using a computer to document the arguments as the debate progresses, and providing a recap at the end of the debate or during low points.

Some students expressed their discomfort with the intensity and realism of the case study, but appreciated that it provided a more nuanced and less academic experience. They were grateful for the opportunity to develop their critical thinking skills and build more nuanced opinions on the topic. The authors believe that such discomfort is necessary for learning and plan to continue using such case studies in the future.

As educators, it is important to create an environment where students feel comfortable expressing their opinions, even if they disagree with the majority. Encouraging diverse perspectives and facilitating healthy debate can help students develop their critical thinking skills and improve their ability to analyze complex ethical issues.

Finally, we recognize that the case we presented was intense and dealt with real-world issues. However, we believe that this

is important for students to confront the complexity and gravity of ethical issues that they may encounter in their professional careers. By doing so, they can gain a deeper understanding of the impact of their work on society and develop nuanced opinions on how to approach these issues.

V. Conclusion

Incorporating ethics into the engineering curriculum is crucial. It is not only about teaching technical skills, but also about preparing students for their future roles as professionals who will have an impact on society. Ethics is a fundamental aspect of professional engineering practice and it should be treated as such in the curriculum.

Furthermore, the use of cryptocurrencies in the case study also highlights the importance of staying up-to-date with the latest technological advancements and their potential ethical implications.

It is important for future engineers to understand the potential ethical dilemmas that may arise with the adoption of new technologies, and to have the skills and knowledge to make informed decisions and contribute to ethical development. In conclusion, we believe that the use of roleplay debates in teaching engineering ethics is a valuable strategy that can be replicated in other contexts. It allows students to apply ethical theories in a practical way and improves their critical thinking skills. Incorporating ethics into the engineering curriculum is essential for preparing future engineers to make responsible decisions and contribute positively to society.

On next semesters we will continue to select cases that challenge our students to think critically and develop their ethical reasoning skills.

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