Professional and Ethical Deliberation

Educating Engineering Students in Responsible Wellbeing

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Abstract— **Engineering work involves constant deliberation, yet little effort is invested in most programs to provide a well-structured framework for engineering deliberation. The following paper presents how engineering students learn the virtue of professional and moral deliberation through various educational activities in the course *Ethics in Engineering* at the University of Puerto Rico in Mayaguez. In addition, it presents five levels of moral development that enable an assessment of students' degree of deliberative skills. The assessment results show that the activities designed for this course to improve UPRM students' deliberation skills achieved their objective. These activities could be used or modified elsewhere to suit the needs of other engineering courses and/or programs.**

Keywords— engineering ethics; engineering design; ethical deliberation; professional code of ethics; moral development

I. Introduction

As part of their career, engineers need to make complex decisions that include social, economic, environmental and ethical issues. However, a professional and ethical deliberation is often missing in the context of uncertain and complex engineering decisions. Deliberation is the process that carefully considers reasons to adopt a decision in the context of uncertainty. Engineering as a profession elaborates technical projects to adapt the milieu to reach personal and social wellbeing. Therefore, deliberation in engineering is the decision-making process that chooses the optimum means (e.g., instruments, process and materials) to achieve these technical projects after carefully considering all options, possible consequences and values behind these endeavors. Consequently, there is a need to purposely educate students in the virtue of deliberation.

II. Five Levels of Moral Development (LMD)

A. Five Levels of Moral Development (LMD) Oriented to Responsible Wellbeing

This paper presents five levels of moral development (LMD) that enable an assessment of engineering students' degree of deliberative skills. These proposed LMD are based on the work of Kohlberg [1], Harris *et al*. [2], Cruz and Frey [3] and the Revised Bloom Taxonomy [4] These levels, presented in a progressive sequence of skills, are: 1) Ethical Awareness, 2) Assessment, 3) Preventive, 4) Integration and 5) Value Realization. These levels include the three types of engineering ethics as explained by Harris *et al*.: prohibitive ethics, preventive ethics and aspirational ethics.

1) Ethical Awareness

Ethical Awareness refers to the ability to perceive ethical issues embedded in complex and concrete engineering situations. One example is the ability to see how technology is "value-laden". It is also the ability to distinguish an ethical issue from a legal issue. In addition, it is also the skill related to recognize a moral issue based on its "consequences".

This level is related to the "remembering" domain of the Revised Bloom Taxonomy [5]. There are some key verbs, based on the Revised Bloom Taxonomy, related to this level: remembering and recognizing.

2) Assessment

The skills linked to this level are related to the ability of agents to evaluate engineering processes, artifacts or systems by means of ethical principles, theories and values. It is the ability to consider several possible solutions to resolve a problematic scenario. The agent in this level applies different ethical approaches such as utilitarianism, deontology, and virtue ethics and uses these to accomplish moral reasoning and judgment in order to compare multiple alternatives to solve engineering problems. It is also the capacity of evaluating a case based on an engineering code of ethics or ethical principles such as non-maleficence (No-Harm), autonomy, justice and beneficence.

This level is related to the "understanding" domain of the Revised Bloom Taxonomy. Key verbs related to this level are: understanding, interpreting, comparing and explaining.

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3) *Preventive*

The agent with skills in this level is capable of examining a project in order to anticipate possible ethical/social conflicts and design counter measures to reduce possible ethical problems that might produce harmful consequences. It should take place early in the engineering project before a potential problem becomes deep-rooted in the project and extremely difficult to solve. An important skill in this level is to have moral imagination to articulate possible and creative solutions to prevent fully developed ethical-technical problems.

This level is related to the "applying", "analyzing" and "evaluating" domains of the Revised Bloom Taxonomy. Key verbs related to this level are: executing, implementing, differentiating, organizing, attributing, checking and critiquing.

4) *Integration*

It is the creation of a solution that integrates ethical considerations into an engineering activity. Ethics plays an essential role in the engineering practice, solution, design. It seeks explicitly and deliberatively to embody a series of intrinsic values and translate them into technical specifications that realize these values. As conflicts among technical specifications emerge, the agent relates the specifications' trade-offs to value-conflicts. The agent has the objective of satisfying the conflicting values and specifications through a deliberation process. This requires the ability to integrate the skills from previous levels: awareness, assessment and preventive skills.

This level is related to the "creating" domain of the Revised Bloom Taxonomy. Key verbs related to this level are: reorganizing, generating, planning, producing.

5) *Value realization*

Skills that belong to this level relate to the ability to recognize and take advantage of opportunities for promoting the personal and social well-being, e.g., enhance safety and health, improve the quality of the environment and better living conditions. The agent goes beyond the prescribed limits, or the minimal obligatory duties in a problem. The agent seeks to improve living conditions, personal, communal and social wellbeing based on values such as justice, respect, responsibility, trust and integrity.

This level is related to a domain that the authors call "creative synthesis", which does not appear in the Revised Bloom Taxonomy. The *status quo* is questioned and another world is envisioned.

A graphical representation of the relationship between LMD and Bloom's Taxonomy is presented in Figure 1.

III. Process of Educating Engineering Students in the Virtue of Deliberation

A series of major activities have been recently executed in UPRM's Engineering Ethics philosophy course (taught by the Philosophy Section of the Humanities Department), to gradually introduce engineering students in the virtue of deliberation.

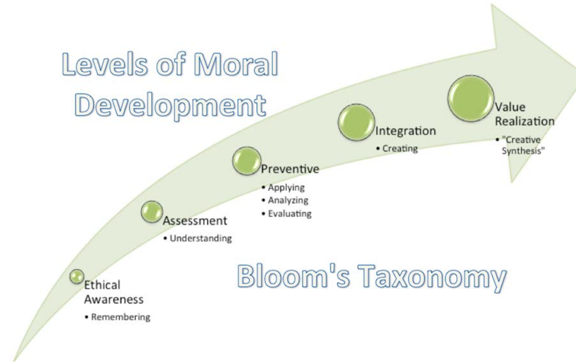

Fig. 1. Relationship between the LMD [2][3] and Bloom's Taxonomy [4]

A. *Engineering Code of Ethics and the Analysis of Cases*

The first major activity to educate students in the virtue of deliberation is the description, understanding and application of the Engineering Codes of Ethics to case studies. After a brief introduction to professional codes of ethics, two engineering codes were discussed in class. The National Society of Professional Engineering (NSPE) Code of Ethics [6] and the Code of Ethics of PR's professional society of engineers: "Colegio de Ingenieros y Agrimensores de Puerto Rico" (CIAPR) [7]. Both were used to analyze engineering cases, similar to those that appear in the NSPE Board of Ethical Review Cases [8].

B. *Ethical Theories and Ethical Principles*

After the discussion of cases based on engineering codes of ethics, there is a discussion of possible limitations of the codes in their application, which includes: possible conflict in the application of canons or norms and cases not covered by the canons or norms. Students are introduced to ethical theories and ethical principles to deal with the limitations and to enable students to deepen their LMD.

1) *Utilitarianism*

Utilitarianism is an ethical theory summarized by the Utilitarianism Principle: "the greatest good for the greatest number" [9], which is also formulated as "the greatest happiness for the greatest number" [10]. One of the elements retrieved from Utilitarianism, is the Harm Principle elaborated by Stuart Mill [11]: "avoid a harmful action". Cruz and Frey developed the Harm Test that operates as a pedagogical tool that helps in the implementation of the Harm Principle [12]. In a previous work we formulated the Harm Test in terms of this question: "Does this action do less harm than the alternative?" [13]. An open discussion allows students to evaluate the positive and negative aspects of this ethical approach. Among the limitations discussed are the difficulties of quantifying goods and the tendency to sacrifice the good of those falling outside the "majority" [14]. To overcome these limitations, a second ethical approach is discussed, Kantian Deontology.

2) *Deontology*

Kant's third formulation of the categorical imperative is the following: "act in such a way that you always treat humanity whether in your person or in another, always as an end and never simply as a means" [15]. According to Kant, the Golden Rule ("do not do to others that you do not want done to yourself") is derived from the third formulation of the categorical imperative [16]. The Golden Rule can also be partially formulated as a Reversibility Test formulated into the following question: "Would I think this is a good choice if I were among those affected by it?" Students understand this test with this formulation [17]: "put yourself in another's shoes".

After discussing Kant, inspired on William David Ross, *prima facie* principles [18], a deontology based on multiple principles, is introduced. The discussed principles are the following: non-maleficent, autonomy, justice and beneficence [19], [20].

3) Virtue Ethics

Virtue ethics states that human beings should realize necesarry actions that achieve good life or well-being [21]. Well-being is the ultimate end of human life [22] and the activities that achieve it are virtues. A discussion is organized around the meaning of well-being and its difference with the utilitarianism notion of happiness that is connected to pleasure.

For Aristotle, virtue is a disposition, a decisional state that is a mean or intermediate between two extremes or vices: excess or defect relative to the subject [23]. A virtuous person chooses a moderate position through which he/she becomes excelent. Then we discuss Aristotle's notion of prudent agent as a wise deliberator. It is the agent that possesses the practical wisdom that enables him/her "to see what is the right thing to do in the circunstances" [24]. Afterward, the class discusses virtue ethics' application to engineering [25].

Finally, in this section, we study, from the standpoint of virtue ethics, the Le Messurier case in order to see how this structural engineer avoided extreme positions that could end in a disaster. [26]-[28].

A Publicity Test partially encapsulates virtue ethics with two questions or tests: "Does my decision affirm my personal integrity and values that I hold as important?"; "Would I defend and sustain my decision in a public forum in front of people interested or affected by my decision?"

4) Summary of Theories by Means of Tests

These three ethical theories were summarized through the HARM Test, REVERSIBILITY Test and PUBLICITY Test. They are used in the examination of cases to introduce students in the ethical analysis, deliberation process and decision-making. These ethical theories, principles and the Aristotle concept of deliberation are applied by students in a particular exercise: to revise and write anew the CIAPR Code of Ethics.

A significant part of the semester is dedicated to the third major activity called "Value Sensitive Design". This major activity enables the clarification of the deliberative process, the role of values and ethics in design. Due to its complexity we will discuss it in next section.

IV. "Value Sensitive Design" Educational Activity

In this activity, we deepen the concept of "deliberation". *Deliberation is the act of carefully considering the pros and cons of different options before making a decision*. According to Aristotle, we deliberate about things, options, actions that are possible and that can be done in different manners [29]. In class, there is a discussion of how engineering design is precisely an object of deliberations. Two modules are presented in class related to deliberation, engineering projects and engineering design.

A. Engineering Projects and Deliberation

Engineering can be defined as a profession that elaborates projects to adapt the environment by means of techniques in order to produce a more humane life. In other words, engineering's end is to promote responsible well-being. To accomplish such goal it is necessary to deliberate, which is understood as an elaboration of engineering projects that are mature, reasonable, well-thought and responsible [30][31].

1) Components of the deliberation process

Following Diego Gracia, a Spanish bioethicist, the method of deliberation has three components: facts, values and duties [32].

a) Facts are data that describe problems that engineers seek to solve. They correspond to descriptive judgements that provide information including measured data, available technologies, materials, personal, professional and communal qualities.

b) Values correspond to value judgments. A judgement estimates something as appreciated and good or as bad and disliked. Engineering projects embody values in facts.

Here, we introduce a distinction between intrinsic values and instrumental values. Intrinsic values have value in themselves. Instrumental values are values that enable us to obtain other values. Example of the first one is health. Example of instrumental values are medicines or artifacts that enable us to reach or maintain our health. Normally, values have two poles: positive values and negative values or anti-values.

c) Duties correspond to prescriptive judgments that compel us to do what is right and to avoid what is wrong. In terms of values, duties are the realization of values and the rejection of what is an anti-value [33].

2) Values and duties conflicts:

There is a need to deliberate when there is a conflict of two or more values or a conflict of two or more duties. Such conflicts are ethical problems. Normally, a conflict of duties manifests a conflict of values.

3) Steps in the method of deliberation

a) Step 1: Clarify facts. Facts need to be clarified in order to understand the problem.

b) Step 2: Uncovering the values in conflicts and discovering extreme solutions. Once the facts are clarified, values in conflicts need to be uncovered. In addition, the agent needs to formulate the extreme solutions (following Aristotle notion of vice as an extreme) that normally, in a value-conflict situation, favor one value and lacerate or damage the others.

c) Step 3: Elaborating intermediate solutions. In this step, the agent elaborates intermediate states (different from the extremes) that seek to save all values at stake. Here the agent must be creative in the elaboration of different alternatives. Then each intermediate alternative must be analyzed to gauge advantages and disadvantages: consequence analysis.

d) Step 4: Chosing an optimal solution. Then, the agent chooses a preliminary or hypothetical optimal solution among the possible intermediate ones. The criteria for the choice of the optimal solution are the following: it protects as much as possible the conflicting values; it puts instrumental values at the service of intrinsic values. Perhaps the optimal solution could be a hybrid or a combination of the intermediate solutions. It is conceivable that the agent discovers that one of the extreme solutions is the solution that causes the less harm. This is a typical case of problem mitigation.

e) Step 5: Testing the optimal solution. Once the hypothetical optimal value is chosen, this must be verified by a series of tests. Among the tests, there are the HARM, REVERSIBILITY and PUBLICITY tests already explained. HARM Test helps to see if our option causes no harm or less harm than others. REVERSIBILITY enable us to include all possible stakeholders involved in the conflict. PUBLICITY verifies if all our values are preserved. In addition, the Publicity Test enables the agent to verify if she/he is capable of sustaining publicly her/his position.

Another test to be used is the TIME Test: would I have chosen the same preliminary optimal solution if I had more time to deliberate? A LEGAL Test follows the question: Is it the proposed solution legal? Then, there is a CODE Test: does this option complies with an engineering code of ethics?

If the optimal solution does not fulfill the tests, then another possible intermediate solution should be elaborated.

B. Engineering Design Process and Deliberation

This part is a continuation of a work that began in 2002 at UPRM as published in [34]. We present in this paper an innovative evolution in terms of a professional deliberation inspired in what is called “Value Sensitive Design”.

Following a classic text on the subject, engineering design has been defined as “a thoughtful process for generating plans or schemes for devices, systems, or processes that attain given objectives while adhering to specified constrains” [35]. There are many descriptions of the design process that includes multiple steps, phases or moments [36], [37], [38], [39], [40], [41], [42], [43]. In all models, it is clear that there are a series of iterations with feedbacks from one phase to others. For instance, data, information and restrictions in one phase influences posterior phases, forcing designers to return to previous phases to modify them. Our intention here is not to develop a full ultimate model, but to use one as heuristics, i.e., as a tool to better understand the integration of ethics into the engineering process and to enable students to understand and use it.

In our course, we distinguish three phases or moments in the engineering design process: (1) problem identification, (2) invention or development of a concrete solution (e.g., prototype, blueprint, process or algorithm) and (3) the manufacturing process. We integrated in the design process manufacture or construction in order to explain students how this third phase influences and transforms other phases in the design process. In addition, including the manufacturing phase enables us to include ethical issues that pertain to that moment, e.g., safety in manufacture, material choices and environmental impact. A graphical representation is presented in the figure below.

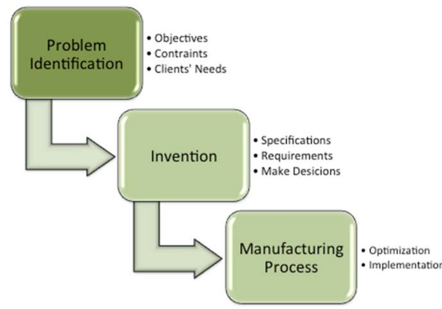

Fig. 2. Phases in the Engineering Design Process.

1) Phase One: problem identification

Students learn that in this phase engineers analyze and formulate the problem and envision possible initial solutions. Here designers explicitly formulate the objectives, the constraints and the clients’ needs and desires [44]. Creativity should enable engineers to overcome the tendency to be fixed in one solution [45], [46].

2) Phase Two: invention or development of a concrete solution

Here, engineers pass from an initial idea for a solution to a concrete solution. The concrete solution could be a blueprint, an artifact or device, a prototype, a process or an algorithm. This second moment includes the formulation of a list of specifications and requirements. These specifications need to be optimized considering economic cost, time, safety, materials, sustainability, environmental protection and public welfare. As in the first phase, engineers should not be fixated with one solution and must be creative by developing multiple possible solutions.

Here the designer confronts the reality that not all specifications can be optimized independently of each other. There is a trade-off between specifications and other considerations. Consequently, engineers have to make decisions that are seldom purely technical. Design choices could have consequences at a personal, social and environmental levels.

3) Phase Three: manufacture or construction

This phase deals with the manufacture or construction specifications developed in the second step, which depend on the nature of the final product. It could be the construction of one complex system, e.g., a building, an airport or a bridge. Or it could be the mass production of an artifact or device, e.g., vehicles, computers, etc. This phase is related to the optimization of resources, production costs, time, safety of the manufacturing process and material choices. In this phase engineers encounter trade-offs among cost, time production, security testing of the product, security of employees and the environmental protection, materials used to construct the device or system. Considering manufacturing in the design process forces designers to consider sustainability issues and the disposal of the product at the end of its life. All of these apply well known concepts such as "design for manufacturing (DFM)", "design for assembly (DFA)" and "design for sustainability" [47].

C. Integrating Ethics in All Phases of the Design Process

This section explains how ethics is integrated in the engineering design process. The articulation between ethics and design depends on the phase of the design process.

1) Ethical Issues in Phase One: problem identification

The ethical issues that appear in the problem identification phase are directly related to the stakeholders. Engineers must make an effort to identify and list those who are directly interested, e.g., clients, users, work-team, companies, public agencies, etc. In addition, those directly or indirectly, positively or negatively affected by the design, e.g., surrounding neighbors, peers, professional societies or society at large should be considered [48].

Then agents (in this case, students) must identify the values (intrinsic and instrumental) that clients bring when they ask for engineers' services. In addition, agents must make an effort to find out other values that clients do not envision initially, especially those that, directly or indirectly, have a level of impact in those affected.

Engineering students are asked to identify possible value-conflicts. Examples of conflicts are: environment protection versus economic return or gain; time efficiency versus product costs; etc. Once a conflict of values is found, the process to solve it requires the same method of deliberation explained before: a) discovering extreme solutions, b) elaborating intermediate solutions, c) choosing a preliminary optimal solution and d) testing the optimal solution.

2) Ethical Issues in Phase Two: development of a concrete solution

The ethical issues that emerge in this phase are related to trade-offs between technical specifications and conflicts between stakeholders' requirements and possible consequences to people who are affected, to the public welfare and to the environment. A designer could find, among other possibilities, the following trade-offs: safety versus cost and available technology; project's time frame versus quality control testing, health and safety; materials cost versus environmental impacts and sustainability, etc. What is relevant here is to uncover the values that are behind a technical specification. Agents must translate technical specifications to values in order to find what value-conflicts are behind technical trade-offs.

Examples of some relations between technical specifications and values are the following: time or performance are related to the value of efficiency; cost is related to economic value; materials are related to security, environment protection, and economic return; low energy consumption could be related to environmental protection and efficiency.

Once a translation is done from technical specifications to values, the value-conflicts will emerge, for example: security versus economic value; efficiency (in terms of energy consumption) versus user's autonomy; etc. Once a conflict of values is found, the process to solve it follows the same *method of deliberation* explained before.

3) Ethical Issues in Phase Three: manufacture or construction

This phase considers manufacturing specifications, metric descriptions, prototype details, and subsystems' descriptions originated in the second phase [49]. Cost reduction and production speed are among the goals of this phase. Frequently, these goals could diverge from the values of product safety, manufacturing process safety and environmental protection. The discussion in class is directed toward the need for ethical deliberation and prudential choices to solve the conflict of values.

V. Assessment Process

The assessment activities presented in this section were developed to determine the impact of this course in each student's LMD through the process of deliberation. A total of five activities were designed and implemented during the fall semester were 29 students were enrolled. Each student had to submit a written response for each activity individually or as a group, as explained below.

In a particular assessment activity, students received a score that corresponds to the LMD reached in that activity, according to an evaluation of their written responses. To quantify their responses a value of points was established for each level: level 1 (Ethical Awareness) - 1pt, level 2 (Assessment) - 2pts, level 3 (Preventive Skills) - 3 pts, level 4 (Integration) - 4 pts and level 5 (Value Realization) - 5 pts. It is important to clarify that these scores were not used for course grading (only for assessment purposes). In this section, we describe the assessment activities implemented, present their quantitative results, and provide samples of students' formulations for each activity according to the LMD. These formulations were used to code the level that their responses corresponded to.

A. Baseline Case

At the beginning of the semester, before any material was discussed, students were assigned a brief case to analyze. Students' responses established the LMD of each student at the beginning of the semester. This provided a baseline from which to monitor their progress in the stages of moral development throughout the course.

1) Case Description

"A bridge will be built in a municipality. This bridge will connect the top of two mountains. A poor rural community lives in the valley that connects both mountains. This means that the bridge will pass over several houses of this community. The mayor of that municipality summons

Engineer X to design the bridge and to construct it. What should engineer X do?"

2) Results of this activity

The average LMD obtained in this activity was 1.72. This low score was expected since it was conducted at the beginning of the semester. Figure 3 presents the histogram of students' responses for this activity. Further statistical analysis shows that three students were considered outliers: one with 4 and two with 5 of LMD. As expected, most students were in levels "0" (not even Ethical Awareness), "1" and "2". Table I provides examples of students' formulations and corresponding score based on the LMD.

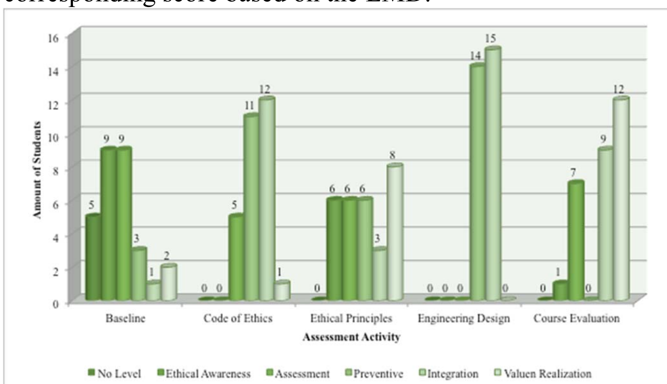

Fig. 3. Histogram of students' responses for each activity

TABLE I. EXAMPLES OF STUDENTS' FORMULATIONS AND THE CORRESPONDING LMD ASIGNED

Level & Points	Students Formulations
0	• "There is no moral obligation with the community. Consider only the economic factor."
1	• "Recognize that this bridge construction is a problem and that the safety of the community is important."
2	• "Discuss hazards and difficulties, and present alternatives to prevent the bridge construction. If this is not possible, avoid harm to the affected community."
3	• "Minimize the damage, and consider the positive or negative impact. Generate the greatest good and develop a prevention plan. Anticipate and avoid risks."
4	• "Consider that ecosystems or endangered species are not affected. Consult with the affected people and, in case of damage, seek other alternatives. Consider building the bridge for the same purpose, but not necessarily above the poor community. Construction of eco-friendly bridge, use of materials safe for the environment, produce or consume green energy, and cause minimal damage."
5	• "Provide and prioritize moral values within society. Evaluate the benefits and risks to the community. Engineer considers talking with nearby residents and with the Mayor with the objective of realizing the well-being of the community."

B. Analysis of Cases Using a Code of Ethics

This assessment activity was assigned immediately after the Engineering Codes of Ethics were discussed. Two cases were given to students. Each student was asked to analyze each case using the CIAPR and the NSPE codes of ethics. The following is an example of the cases assigned.

1) Case of Electrical System Design for a Small Hospital:

"An Engineer A works in the design of an electrical system for a small hospital. In the design, Engineer A has two options to meet the demand for hot water: (a) reuse the heat of air conditioners' cooling towers supplemented by solar water heaters or (b) electric heaters. Both are robust designs that meet the hospital's planned needs. However, the former consumes less electricity or none at all. The client that subcontracts Engineers A, who is the administrator of the hospital reconstruction project does not believe in solar energy and has repeatedly told the Engineer that he/she wants 'uninterrupted' hot water".

Engineer A's uncle owns a hardware store chain and supplies electric heaters. He has told Engineer A that if electric heaters are selected, the Engineer will receive a 10% commission on the sale. Engineer A opts for electric heaters in the design and proposes the one that the uncle sells."

Students were asked to evaluate the decision of Engineer A using CIAPR and NSPE code of ethics. In addition, students were asked to explain what would they do if they were in the same position of Engineer A.

2) Assessment of this activity

The average LMD in this activity was 3.31. This average corresponds to the third level: Preventive Skills. This value was expected since most Engineering Codes of Ethics are centered on preventing damage or harmful consequences. There were no outliers (refer to Figure 3). A sample of elements found in students' written work and used to assign LMD is presented in Table II.

TABLE II. EXAMPLES OF ELEMENTS FOUND AND USED TO ASSIGN LMD LEVEL

Level & Points	Elements found and Used to Assign LMD
2	• Evaluation of the case based on the principles of beneficence and non-maleficence.
3	• Prevent situations that generate possible ethical problems, such as conflicts of interest. • Prevent possible ethical problems through customer orientation. • Avoid accepting agreements that promote conflicts of interest. If it is required, approach relevant authorities.
4	• Propose and develop a new design and / or solution that avoids possible risks in the future. • Selection of solutions that promote energy saving, economy and environmental preservation.
5	• Develop solutions that fulfill the codes of ethics. Provides value to the parties involved and aims to promote their well-being.

C. Re-Writing the CIAPR Code of Ethics based on Ethical Theories and Principles.

1) Description of the activity

In this activity, the students must revise and write anew the CIAPR Code of Ethics using Utilitarianism, Kant's Deontology and Aristotelian Virtue Ethics. In addition, they had to use the principles of Non-maleficence, Autonomy, Justice, and Beneficence. As opposed to previous activities, this activity was conducted in groups composed of three students. Each group had to be diverse in terms of gender and engineering fields or other majors, i.e., no group can be composed only of students that belonged to the same field and gender.

Students were asked to maintain the code's structure: a preamble (that they might transform), canons and norms (named by some codes "rules of practices") inside each canon. Students were able to do one of the following: (i) maintain canons and norms as they currently are; (ii) eliminate norms or whole canons; (iii) transform existing ones; or (iv) add new canons and new norms. Finally, they had to justify whether they maintained, transformed, eliminated or added canons and norms using ethical theories and principles.

2) Assessment of this activity

The average LMD in this activity was 3.03. This average corresponds to the third level: Preventive Skills. However, there were more scores on the fifth level, when compared to the previous activity (with only one student). Something interesting to notice is the fact that in the previous activity there were only 5 students in the second level and in this activity there were 12 students in the first and second level. Further analysis needs to be conducted to provide an explanation of this behavior. There were no outliers. (Refer to Figure 3) A sample of elements found in students' written work and used to assign LMD is presented in Table III.

TABLE III. EXAMPLES OF ELEMENTS FOUND AND USED TO ASSIGN LMD LEVEL

Level & Points	Elements found and Used to Assign LMD
1	• Students lack of knowledge of principles and theories. • Limitation to decision making based on laws, norms or "what should be correct". • Acknowledge the existence of ethical problems.
2	• Act based on norms, principles, laws and codes of ethics, without degrading any moral value. • Minimize damage and do actions that are allowed.
3	• Prevent endangering safety and damage to the environment, health or welfare. • Minimize damages, avoid discrimination and social injustice. • Maintain a cooperative and team-working behavior worthy of the profession.
4	• Watch for safety and protect various aspects (values) related to well-being. • Ensure the value of healthy coexistence and acceptance of diversity.
5	• Promote the welfare of humankind and protect the public interest. • Aspire to the progress of humanity through inclusive processes for all members of society. • Conserve the environment, and have as an end the service to humanity and to future generations.

D. Engineering Design

This assessment activity was provided immediately after the "Value Sensitive Design" activity. The same group of students that re-wrote the CIAPR Code of Ethics were asked to evaluate an engineering design case based on the deliberative method previously explained. First, they had to identify in which phase of the design process was the project described in the case. Then, they had to clarify the facts, identify the conflict of values, create intermediate solutions, chose a preliminary optimal solution and test it. The case presented to students was in an open-ended format. The following is an example of a case presented.

1) Example of a case assigned to be analyzed

"*You are an engineer working in a company that provides 5000 jobs in Puerto Rico. Most of these jobs are located in a town where the company is installed. Puerto Rico is in a period of economic crisis and this town is one of the poorest, with the highest percentage of unemployment in the island. Currently, the company produces a low-cost cell phone, which uses a 'non-polluting' battery also produced in the same plant. The product has been marketed worldwide very well, partly because of the news that the battery is a new generation that does not pollute the environment.*

However, a week ago a technician of the company discovered, after some tests, that the battery is at least as polluting as the battery used in a similar device produced by a competitor whose production plant is located in another country. The head of the plant calls you, a member of a team of designers. In that meeting, he communicates the bad news to you about the contamination that produces the battery. He informs you that he has decided not to inform the public yet and that, for now, the company will continue its sales and the same publicity campaign of the cell phone with the battery. The boss, knowing that you are a person who follows 'high ethical standards', asks you and your team for some time. He says that he knows about the existence of a new material that could be used to build a new battery that would not contaminate or contaminate much less. He heard about it from another engineer who has just arrived from a technical conference in Europe. The boss reminds you that 5000 jobs in Puerto Rico, in a place with many economic problems, depend on you being 'patient' and he asks you to 'trust the boss'."

Once the case was presented, students were asked to discuss the case in their assigned groups and seek to answer the question: What would you propose to your boss?

2) Assessment of this activity

The average LMD in this activity was 3.51. Results show that almost half of the class population (14) was in the third level (Preventive Skills) and a little more than a half (15) were in the fourth level (Integration). This shows progress when compared to previous activities (refer to Figure 3). There were no outliers. Table IV provides samples of students' responses.

E. Final activity: Personal Evaluation of the Course

This final assessment activity was part of the final exam. Students were informed that any answer was assumed to be valid and they would receive all the points in this part of the test. The questions were given a week in advance to give them enough time to elaborate their responses. This was an individual activity that consisted of a two-part question:

TABLE IV. EXAMPLES OF STUDENTS' FORMULATIONS AND THE CORRESPONDING LMD ASIGNED

Level & Points	Students Formulations
3	• "Stop the promotion of the existing product, this to consider the welfare of employees and prevent publishing misleading material" • "Be responsible with customers and the company." • "Provide an incentive for customers with the contaminating product."
4	• "Development of a product that does not cause damage to the environment." • "Avoid lacerating the values of environmental protection and development and well-being of the community." • "Create an efficient and eco-friendly product." • "Consider aspects such as communication and constant information, monitoring of processes and consideration of factors such as time, all to improve the existing design."

1) Open questions in the final exam

Would you recommend this course to a classmate? For what reasons? Mention and explain how do you think this course has changed the way you look at engineering and how it applies. Provide examples.

2) Assessment of this activity

The average LMD in this activity was 3.83. This average is closer to the fourth level (Integration). Notice that the majority of students were in levels fourth and fifth (refer to Figure 3). This shows progress compared to previous activities. There were no outliers. A sample of students' responses categorized according to each LMD is presented in the table below.

TABLE V. EXAMPLES OF STUDENTS' FORMULATIONS AND THE CORRESPONDING LMD ASIGNED

Level & Points	Students Formulations
1	• "Recognizes the aspects that the engineering profession entails and possible situations that may arise."
2	• "Knowledge of the existence of ethics codes that govern the profession, method of deliberation and factors that can cause damage."
4	• "Use of techniques and skills learned in the development of solutions or design. Deliberate properly when making decisions, and prioritize safety and well-being." • "Deliberate appropriately, proposing solutions that take into account multiple values (both intrinsic and instrumental)."
5	• "Aim to improve the society in which we live. Prioritize social opinion, welfare, safety and the environment." • "Improve human well-being and achieve a more dignified life." • "Projects must meet the personal values of the engineer and society." • "Importance of deliberation in the profession and daily life." • "The principal purpose of the engineering is serve for the well-being of society. Contribute to the social and environmental well-being."

Table VI shows many statistics variables for the group of 29 students: Average, Q1 (first quantile), Q2 (second quantile or median), Q3 (third quantile). With respect to the average, there is a progression of LMD in terms of educational activities, except in the third activity where the average worsened. However, the second activity and the third obtained the same median. This is due to the fact that a group of students improved to the fifth level (compare Q3) and another group worsen (compare Q1).

TABLE VI. GENERAL STATISTICS OF ASSESSMENT ACTIVITIES

Statistics	Level of Moral Development / Activity				
	First Activity	Second Activity	Third Activity	Fourth Activity	Fifth Activity
Average	1.72	3.31	3.03	3.51	3.83
Q1	1	3	2	3	2
Q2 Median	2	3	3	4	4
Q3	2	4	5	4	5

VI. CONCLUSIONS AND IMPLICATIONS

When comparing the results of the initial assessment activity and the final (fifth) activity there is a significant improvement in all statistical variables. In the first activity there were five "0"s (students who were not even at the first level), the average was 1.72 and the median was 2. In the final activity in the final exam the average was 3.83, the median was 4 and Q3 improved from 2 to 5. These educational and assessment activities enable us to identify a progress in terms of the LMD when comparing activities from the beginning and the end of the semester. These quantitative results agree with the professor's experience in the classroom where a significant qualitative progress was observed in the students' discussions, arguments and commitment to professional and ethical deliberation as the semester moved ahead.

Engineering work involves constant deliberation, yet little effort is invested in most programs to provide a well-structured framework for engineering deliberation. The assessment results show that the activities designed for this course to improve UPRM students' deliberation skills achieved their objective. These activities could be used or modified elsewhere to suit the needs of other engineering courses and/or programs.

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