LEARNING THROUGH CHALLENGES: INTRODUCING SOFT SKILLS TO FRESHMAN ENGINEERING STUDENTS

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ABSTRACT

There are some skills that are easier to teach than others. Finding ways for introducing, teaching and evaluating non-technical or non-disciplinary skills is troublesome. As an outcome of a recent curriculum review our faculty concluded that “Introduction to Engineering” is a core course to introduce soft skills. Soft skills are acquired while students work in a number of projects that we have called them challenges. This paper describes the foundations and motivations behind the effort of last years at Pontificia Universidad Javeriana for designing a course that engages students through motivating experiences in order to teach them how to apply soft skills. A detail description of activities to introduce eight learning outcomes is presented.

KEYWORDS

Ethics, collaboration, teamwork, effective communication, CDIO Standards: 4.

INTRODUCTION

CDIO consortium recommends an introduction to engineering course in first year. The background of first year students is heterogeneous, so teachers’ efforts must take into account this circumstance and the gradual adaptation of students to their new way of thinking as future engineers. This first course has the very important two objectives of engaging students and motivating them to study engineering. It is taken in consideration the context of future real life problems, the different learning styles of students, the wide variety of personalities and the mentioned heterogeneous background.

The Introduction to Engineering course at Pontificia Universidad Javeriana demands 48 hours of student work during an academic period of 16 weeks. It has a weekly session with supervision of teacher of 2 hours and it requires from every student a weekly dedication of independent work of 4 additional hours or more on average. During the course the following topics are presented:

- Engineering and Design: Engineering context from its origins until today.
- The program: From now until the day of their degree.
- Future prospects: Beyond the grade.

The topic that demands more dedication is the first one in which the most significant learning experiences take place in course. In the development of Introduction to Engineering, we use an approach of four steps that we have called IDEA which consists of the following progressive activities:

1. Inspiring students
2. Designing challenges
3. Exercising roles
4. Assessing outcomes

In the following section we present details regarding the way we introduce eight *soft* skills through our IDEA approach in referred course.

FIRST STEP: INSPIRING STUDENTS

The students we receive today were born before the transition to new millennium. They take computers, the Internet and cellular mobile phones for granted. Capturing the attention of today's new generation of students is a difficult task for teachers. Teaching them how to be engineers the same way we were taught no longer makes sense.

Students want to be challenged. Students' motivation is directly related with their own interests, their new way of thinking and real context situations. They want to get deeply involved in projects that challenge their own limits and capacities. They want to be inspired. Indeed, we use the word challenges, to make reference to the projects that they undertake in class. These challenges make students get involved in finding new solutions and new answers to our quests which are not easily found using Internet. We strongly believe that this change in denominating projects as challenges brings huge impact in learning and motivation.

Treat students as engineers since the very beginning of first class: a first outcome in our experience. When their teacher treats students as engineers, the mood of relationship changes. From the first greeting for welcome class, students are treated as engineers. This form of relationship is manifested not only in the oral communication of the teacher toward students but also in emails, in the assessment of projects, and other class activities. Homework and class activities are now engineering projects and qualification standards are similar to the evaluation criteria in an invitation to submit technical proposals. As the academic year progresses, we have realized that students stop calling their teachers as professor and is at this time when the relationship becomes a peer relationship in which the professor is also called engineer. When this point is reached, we stop being teachers teaching engineering for being engineers giving engineering instruction. We strongly believe that this way, students learn to recognize engineering as a noble profession and to being an engineer as a pride worthwhile the training they begin to receive. It is our commitment that in future they will respect other engineers and professionals in society as we respect them since the very beginning in classroom.

SECOND STEP: DESIGNING CHALLENGES

The challenging approach is an important step to create conditions for students learning. The former demands the designing of challenges around motivating experiences. Explicitly, those challenges were conceived, planned and discussed so that soft skills are needed to fulfill the expectations in order to solve the problem.

Three of challenges are oriented to build artifacts to solve hypothetical problems and one is oriented to solve a real life problem. For the three challenges based on hypothetical problems, a new challenge is proposed every two weeks. The solution to the challenge of real life requires 4 weeks for its development. All the work around these challenges requires 10 weeks of the academic period; the remainder 6 weeks is devoted to topics on history of engineering, engineering design and future professional perspectives. Each challenge focuses in different electronic engineering areas: general-purpose design, robotics, automation processes and electrical energy consumption.

All projects, before assignment, have different documents to illustrate the necessity and the problem in a detailed form: A context defined with a letter of requirement, a document that illustrates the defined problem with its constraint, limits and grading criteria. In a separated sheet students will find different role assignments for each project. Following we describe the different challenges we have designed for them to solve while they develop soft-skills.

1. Egg protection:

Description: This challenge is widely known in science and engineering contests. In the most recognized search engines, results exceed centenaries links. The experiment either done in an informal contest or in an academic environment consist in designing a device to throw an egg from a considerable height in order to avoid breaking it when impact against the floor.

Pontificia Universidad Javeriana is an educational institution with great social responsibility, which is located in Colombia where poverty level is over 40%. We believe that the experience must be worthy to be lived as long as it generates in students ethical questions regarding the fact of throwing an egg that it could have been the food of a person in need.

Students are given the specifications described below and are asked not to make any test until having the confidence that the conceived device is effective. It is said to students that the day of the test, only eggs brought by teacher will be used. To be fully coherent with the Jesuit education given at Universidad Javeriana and the purpose of the test, the eggs are prepared beforehand. We removed the white and yolk, and filled it with a solution that recreates the original weight without suffering any damage in the shell. This is information that students ignore before deciding to do or not the test, which stimulates a whole rich discussion regarding ethical issues involved and the use of dummies devices in controlled engineering testing.

Specifications:

- To prevent the egg from breaking from 20 meters free fall without using a system type parachute to slow down the falling.
- The designed device should not be larger than a cube of side 10 cm size.
- Solution must be delivered in a week.

Context: To give context to the test, it is told students that a company has requested services to Universidad Javeriana to design a transportation package that will protect fertilized eggs of a bird of the Colombian Amazon in danger of extinction.

Skills that are developed: Students work in acquiring teamwork, oral and written communication, lifelong learning and mainly the development of an ethical behavior in a social context situation.

2. Bristelbot race:

Description: Robotics is a subject of much interest in electronic engineering students. With this test, we show that to implement a robot, students neither need sophisticated infrastructure nor a deep understanding of the subject. It is then proposed the construction of a mobile robot which locomotion is based on a principle of vibration caused by a toothbrush that uses a small cellular phone vibrator.

There are several internet sources where its construction is shown. What students cannot find by using Internet is how to make it move in a straight-line direction. We found an interesting challenge to make a proposal to build a bristelbot in which improvements will be made to maintain the direction of movement in a straight-line, while students try to optimize the speed of locomotion.

Specification: Build a bristelbot that is able to take a tour in a straight line along a PVC pipe in the shortest time possible.

Context: For this challenge, the problem was contextualized in a service company that inspects the state of ducts and pipes using miniature cameras. The robot that is able to do it in the shortest time, wins the contract.

Skills that are developed: Teamwork, oral and written communication, lifelong learning and mainly developing of competitiveness, taking into considerations their consequences.

3. Timer device:

Description: Measuring time is one of the oldest challenges that has confronted the man before the origins of modern engineering. Electronics has responded to this challenge in an effective and efficient manner compared to other solutions with mechanical, hydraulic, pneumatic and electrical principles. This challenge consists of conceiving a device to measure a span of one minute to power a device without using any electronic device.

Context: To give context to the problem beyond measuring a time lapse, they are asked to design an accurate, small, low cost device that will be used to trigger a timer in a disposable film camera.

Skills that are developed: Cooperation, teamwork, oral and written communication, lifelong learning and decision making by using selection matrix tool.

4. Energy saving:

Description: This final challenge is to achieve a reduction in energy consumption in each of the students' homes in a time span of a month. This challenge must be demonstrated by verifiable evidence. To this end, students are required to photograph the energy counter and send a copy of last bill of electricity with the average consumption of the previous three months registered. This challenge doesn't have hypothetical context because indeed the proposal already has its own context in energy and money saving, and environment impact.

Skills that are developed: Teamwork, oral and written communication, lifelong learning.

THIRD STEP: EXERCISING ROLES

Four roles are assigned to solve every challenge; each student must assume different roles which are different in each project. Challenges are given to groups of four members.

a. **Technical report**. Each group presents a technical report following a given format. It must include objectives, list of materials, development procedures, material costs, duration of the process, testing protocol and responses to given questions.
b. **Oral presentation**. Before the final presentation of the product, a group member gives an executive (3 min.) oral presentation about the product, its characteristics and test results. It must be supported with digital material.
c. **Log book**. A member of the group is in charge of documenting every step of the brainstorming, selection, conception, design, implementation and testing of the project. The log transcripts must be included in the technical report.
d. **3D Models**. As a result of the conception step, a member of the group must create a 3D model using free software like Google Sketchup ® and has to be included in the technical report.

FOURTH STEP: ASSESSING EXPECTED OUTCOMES AND GRADING CRITERIA

Grading criteria and expected outcome is explicit; each one of the four roles has different percentage of the final grade. Also the conditions and ways to measure the artifact functionality are previously given.

a. **Context**: An organization has a problem to solve, a letter of requirement is delivered and transformed in a definition of a problem.
b. **Defined problem**: The problem is defined and the specification of problem is given. It includes limits, constraints, performance criteria and technical variables are explicit. Every problem has deadline, specifications and resource limitations.
c. **Grading criteria**: Which is separated in five tasks: Results of the challenge, Technical report, Oral presentation, Log book, and 3D Models

INTRODUCING SOFT SKILLS

For teachers, is common to complain about some skills that students should have, especially communication and teamwork. It is very difficult to teach them, and even more difficult to put this topics in context. Typically, the demand or requirement of these soft skills are explicit in more advanced courses, including the expectation of excellent student performance in referred tasks. We have decided that the Introduction of Engineering course must involve those soft-skills, and taught them in a proper engineering context. Next we present how we introduced these skills in the electronic engineering course for freshman students.

1. Teamwork

As it was mentioned before, each student must assume different roles and it is different in each project. The idea is that students gain experience doing different tasks in each project, and find the proper role according with group necessity. All tasks, including artifact functionality is a group responsibility; although tech report, oral presentations and written log is assigned to a selected member, grading is given for the whole group. In order to make students gain experience in different engineering tasks, each role and the members of the group are changed between projects. At the beginning, we let the group interact and try to function accordingly to the required tasks; after the second challenge, teamwork theory is introduced based in D. Keirsey work (Kersey, 1984). Specifically, a reflection of different roles in a team is provided in class. The main idea of introducing Keirsey´s Theories is to provide information about what the different roles in a group are and how to create teams that could function better. According to Keirsey, a combination of different aspects of personality produce a typical role in a group; there are some roles that shouldn´t work together in the same team and there are roles that complements at its best. With a previous survey, teachers can organize group members according to Keirsey´s theory.

2. Written communication

Another common concern in engineering students and graduates is the typical low performance in written communication. We have introduced, in this course, a methodology based in XML. XML (Extensible Markup Language) is a language used to structure information in a document or in general in any text file. We strongly believe that with adoption of XML, written communication abilities are improved. As a result of the use of this tool in teaching, students have written more concrete and shorter sentences, better structured paragraphs and text sequence is better articulated. For a teacher, is easily identified the narration sequence, because the main ideas are explicit.

We have introduced an innovative application of XML format that supports the organization of ideas to teach how to prepare a tech report. Students are asked to present an essay related to a common topic which must follow the next format.

```
<?xml version="1.0" ?>
<!—Structure for a simple original essay (without references), -->
<!—must be used as a template-->
<!—all ideas must be original and not copied from other sources-->

<document type ="Instructive">
<title></title>
<autor></autor>
<paragraph type="introductory">
<idea type="general"></idea>
<idea type="support"></idea>
<idea type="support"></idea>
<idea type="Thesis"></idea>
</paragraph >

<!—Following is copied many times as body paragraphs the essay has-->
<paragraph type="body">
<idea type="main"></idea>
<idea tipo="support"></idea>
<idea tipo="support"></idea>
<idea tipo="support"></idea>
</paragraph >

<!—closing paragraph-->
<paragraph type="closing">
<idea tipo="support"></idea>
<idea tipo="support"></idea>
<idea tipo="support"></idea>
</paragraph >
```

Figure 1. Essay XML Format

Table 1 Essay rubrics

Essay Rubrics				
Essay Title	It´s not titled, or title is similar to "essay for introduction to engineering"	Title is similar to "how to foment the study of electronic engineering in Colombia"	Title is not specific or is not interesting	Title is attractive, interesting and specific: it invites the reader to continue reading it
Thesis				
Essay thesis	Thesis is not a statement, it doesn´t express a clear and categorical idea; it is ambiguous or confuse	Thesis express an ambiguous or confuse idea, but is expressed as a statement	Thesis express a clear idea, is a statement; but is not interesting or is not related with the title	Thesis is a categorical, convincing (or persuasive) and interesting statement; it also is related with the title
Unity of the essay	One or none main idea of the paragraphs supports or argue the thesis	Only two main ideas of the paragraph support or argue the thesis	Only three main ideas of the paragraph support or argue the thesis	Each main ideas of the paragraph support or argue the thesis
Paragraph structure and clearness				
For first Paragraph				
Unity of the paragraph	None specific ideas are related with the thesis or general idea of the paragraph	Only one idea is related with the thesis or main idea of the paragraph	The Two specific ideas are related only with the thesis or with the general idea	Both specific ideas are related with thesis and general idea
Clarity of ideas	None or only one idea is clear and grammatically correct	Only two ideas are clear and grammatically correct	Only three ideas are clear and grammatically correct	All four ideas are clear and grammatically correct
For all paragraphs				
Unity of the paragraph	None idea supports or argues the main idea	Only one idea supports or argues the main idea	Only two ideas support or argues the main idea	All supporting ideas support or argues the main idea
Clarity of ideas	None or only one idea is clear and grammatically correct	Only two ideas are clear and grammatically correct	Only three ideas are clear and grammatically correct	All four ideas are clear and grammatically correct

XML is based in html format, each sentence is framed between opening tags (<tags>) and closing tags (</tags>) We explain that each paragraph with this guide should have a main idea and three supporting ideas. For a teacher, is very easy to find which is the main idea and assess if the following ideas effectively supports it. Additionally, a rubric is given to the class and the essays are assigned to a different student for him to assess it. The purpose of this co-evaluation, is that each students assumes an evaluation role which give them better context in order to understand the purpose of this tool, see table 1 for essay rubrics used.

3. Oral communication

As a complement of the final presentation of the project, the student with the presenter role has to give an oral presentation of 3 minutes maximum. It has to be aided with multimedia. First presentations are recorded and feedback is given in next class; later in the course, students are asked to give feedback in a survey for each new presenter, this survey is an adaptation of Peer Evaluation for Oral presentations (Lannon, 2011).

Table 2 Oral presentation rubrics

Content	poor	regular	Good	Excellent
The definition of purpose of presentation was				
Evidence (or arguments) of statements was				
Use of visual aids was				
Content presented to audience was				
Organization and clearness				
Sequence of subjects presented was				
Use of transitions during presentation was				
Synthesis before presenting conclusions was				
Clarity in the final message was				
Presentation Style				
Level of confidence and security shown in the subject was				
Level of dominion of the presentation and audience was				
Level of enthusiasm was				
Pronuntiation was				
Use of gestures, tone, volume and rhythm was				
Visual contact with audience was				
The concrete management and convincing of questions was				
Personal presentation was				

4. Decision making

As previously mentioned, at the same time challenges are developed, students do the reading and studying of the textbook (Grech, 2001) The book emphasizes in a proposal of design methodology that involve the next basics steps: problem definition, study and proposal of solution criteria, proposing a weighting criteria, looking for numerous and different alternatives for solving the problem and finally the discernment of the best solution through a tool called selection matrix.

For students to gain experience in using the selection matrix tool they are asked to apply it to one of the challenges that has been proposed to assess. For this exercise to be more complex, non-linear relationships are used to evaluate the specifications of built artifacts. All information is provided and finally by a matrix operation, students should determine the order in which the best projects supplied the specifications imposed.

This exercise requires a basic knowledge of linear algebra that helps to reinforce and apply concepts in a meaningful way in a real context. Information gathering, definition of criteria, weighting criteria vector, defining entries to matrix of results and solving matrix are important valued elements in the final grade of the challenge.

5. Ethics

The objective in the introduction of this skill is to present a real ethical dilemma in order to make considerations about that every decision has an ethical implication, and ethics are intimately related with a responsible, autonomous and free decision. This skill is also introduced in the first challenge as described above (see egg protection section).

We consider that although is easier to give study cases and debate about the ethical decision, these aren´t directly related to their own experience and could easily turn in the so called political correct answer. That´s why we conduct an activity immersed in the first challenge where own decisions will affect overall grades. Students have to make an ethical decision according with the known performance of their artifact. Specifically, after oral presentation, each group must decide if they are going to present (and test in the presence of the teacher) their product. They should know if it functions correctly and won´t fail on the final test. If they decide not to test the artifact, a grade of 3.5/5.0 is given –no questions asked-; indeed, we celebrate the ethical decision of not deliver the product, if they are not sure about its proper functioning. On the other hand, if they decide to test it and the product fails the test, the score is the lowest (0/5.0) and each other group that decided to test their own artifact also are scored with the lowest grade. If all artifacts function, the grade is the maximum for the whole class (excluding groups with didn't present the test).

Students tend to always present the test, even with the big risk assumed. The ethical dilemma requires for them to think about the impact in other groups if they fail, so they have to discuss –prior to the final test- if they made all the trials required and are totally certain about the wanted outcomes. After the test (usually one or two of the groups fails), the debate about ethics begins, we ask them to answer some questions in an online forum. Some questions are asked in order to feed the discussion; for instance, someone who decided to present the test could be absolutely sure about his correct artifact performance, because all the trials were correct; though the day of the final test, it failed; was unethical the decision to present the test? What should have been done? Other question are related to justice, was just or unjust the grades of the other groups who actually passed the test, knowing that the criteria, specifications and rules were totally clear? Is there an alternative decision for the teacher? Is righteous and ethical to let them present the test again? If so, in what conditions should be tested again? The subsequent actions depends on the considerations of the group.

6. Competitiveness

Competitiveness is the ability to deliver a product or service more efficiently and effectively than others. The concept of competitiveness is important as long as students understand that pursuing excellence in their projects and themselves is necessary to provide better service to society. In the future, the work environment will expect them to be competitive.

The result of final grades is designed in such a way that at the end of the challenge only one team can stand out among others. As in all other projects, it is recognized and valued the effort made by the development of the technical report, three-dimensional graphics, project blog, and delivery of oral presentation. Nevertheless, it is clear that the large percentage of the final grade is weighted more heavily as the final result of the competition. Particularly, the rules of the competition follow similar procedures than races; with points awarded according to the time spent in complete the task.

The idea of competition excites students since the beginning. Along the development of projects, communication takes place mainly between every team and teacher. The environment previous to competition shows anxiety and tension between students. In some cases discussions may arise. At the end, a wrap-up meeting is made to give feedback and reflect about the situations occurred during the competence.

At the end of this experience, teachers highlight the following formative apprenticeships:

- Respect for other competitors. Fair play in projects, fair play in life.
- Pursue excellence, not perfection.
- Following established clear rules
- Managing frustration. learning from mistakes.
- The concept of ideas protection and patents

7. ***Cooperation***.

Future engineers may be involved in a competitive environment or maybe they won't. In any case, we wanted to introduce the concept of cooperation to contrast the previous experience. At the end, development of science and engineering is a cooperative endeavor of mankind.

Cooperation is the voluntarily arrangement in which two or more entities engage in a mutually beneficial exchange instead of competing. In the real world, teams in sports, business and industry generally cooperates in small teams to compete and win against others. Our society has become a highly competitive environment in which we recognize that we cannot take a stand on the sidelines. The main difference of this proposal compared to most educational practices is that most of these experiences, the cooperation between different working groups is rarely encouraged. This practice comes from the need to understand the effect of a global cooperation beyond the interest of the team.

From our personal experience in the industry we have seen in workplace that finding differences between departments in an organization is common. Understanding the role that every team, every department and every division has in the development in behalf of a more general common goal is an important concept that we wanted to bring to the classroom.

The way to assess this cooperation effort has been through the grades that all members share and that differs from those achieved by other teams. For assessment purposes in the experience of general cooperation, the weight in the final grade is not the result of the achievement gotten but instead it is the result of real and effective contributions to others. Explicitly, during the final test, if all proposed artifact solves the challenge, all students will receive a generous grade bonus. The final big goal here is making other teams' designs much better than the one that it is proposed and presented by every group in the oral presentation.

The values that stand out from this experience are:
- Promote empathetic listening.
- Communicate clearly and calmly.
- Treat others equitably.
- Encourage their peers to get better results.

CONCLUSIONS

Treating students as engineers from the beginning is an important first step to create conditions for students' learning, so it is important to generate motivating and challenging experiences where soft skills are needed to fulfill the expectations and solve the problem.

Introducing writing should be focused in how to generate good ideas, not in the grammar. We have observed that students struggle with the redaction and tend to forget the idea that they want to communicate. Is true that the final result of the XML tool is not a complete essay, but the ideas are clearly determined and easier to understand.

Cooperation has been essential part of the work that all students do in the teamwork they belong to, in order to solve each challenge. At the end of the cooperative challenge, the results of all teams usually were better than they had originally discussed in plenary.

At the end of the competitive challenge, it is important to have a wrap-up meeting to give feedback in order to get the most of this experience. This last feedback is so important that without it the challenge and the experience gained wouldn't have been just a game. Students learn in this way to handle the implications of the pursuit of excellence from the classroom.

We usually let students who failed in the ethical challenge, retry the test; this is done just for not foster the frustration and interrelation problems within the group. However, the practice of provide an ethical dilemma encourage the empathic thinking and provides a real situation where there aren´t obvious responses.

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