# POLITICAL ACTION AND IMPLICIT KNOWLEDGE IN ENGINEERING EDUCATION: A CASE OF STUDY.

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## ABSTRACT

The educational act is a political act, where information and data are just a fraction of what should be taught. Indeed, there has been much literature on the subject of promoting creativity, teamwork, management, communications, and ethics (so called "soft-skills") in engineering curricula. This knowledge might be as important as technical knowledge. Some authors report experiences where this issue has been approached by incorporating specific courses on these subjects in the curriculum. This strategy belittles the role of the implicit curriculum in addition to explicit curriculum. The Multimedia Engineering program at Universidad San Buenaventura - Cali, a blend between engineering, design and the creative arts, is a program where these skills play a particularly important role. First, in the sense that creativity is a fundamental component in arts, and second, in the sense that the program's graduates will be responsible for the future uses of technology, and as such they should be aware of their role of promoters of social change. Through a case-study in the development of a robotic-art installation, we suggest that teamwork, ethics, and emotional knowledge are better "taught" through an implicit curriculum and that "soft-skills" may not be that soft. Structural changes in the educational act, including physical spaces, number of students per teacher and class duration may be needed to implement pedagogical models that incorporate these skills.

*Keywords: Engineering education, teamwork, heterarchy, political duties, collaborative programming*

## 1 INTRODUCTION

There is a well-documented need for incorporating so called "soft skills" such as interdisciplinary teamwork, management, communications, ethics, problem solving and creativity in engineering curricula. Their importance is such, that they are now called "21st Century skills". Moore and Voltmer [1] state that "the increase in "required" technical material has resulted in the neglect of creativity and imagination in many programs" and that "emerging engineers must recognize their role, not merely as developers of new technological systems, but also as educated, informed, and ethical servants of society with a higher purpose". Scheer et al. [2] state that pedagogical models that incorporate these aspects have been difficult to implement, and suggest Design-Thinking as a framework where they can be "learnt". Nearly all engineering programs state that their ultimate purpose is to serve to mankind by the use of applied scientific and technical knowledge. Many works deal with incorporating sustainability issues in engineering curricula, though these changes may be slow [3]. The promotion of civic values in engineering is addressed by Liu [4] by using service-oriented real-world projects in class. The approach from Liu is a good example of service-learning in software engineering. Apart from social commitment, new curricula should allow students to develop non-technical competences, and let them unfold their personality [2]. Pair programming has been shown to increase not only quality but confidence in the students own work [5]. Felder [6] argues that "even more important than providing exercises in creativity is making students feel secure about participating in them. Most of us learn early that being wrong is unacceptable and looking foolish is even worse, and these lessons are reinforced throughout our lives". Therefore, interaction in the classroom acts in emotional ways in students, but this is rarely taken into account when designing engineering curricula.

The Multimedia Engineering program at Universidad San Buenaventura - Cali is a new undergraduate program that shares elements from computer science, electronic engineering, creative arts and design. The program aims at creative uses of technology, specifically in their potential for transforming society. Therefore, the incorporation of the aforementioned skills is necessary. Curriculum-wise, computer science/engineering is very different from the creative arts. Engineering curricula have a strong science (mainly mathematics and physics) basis, followed by applied engineering (often called "professional") courses. Some programs also have courses focused on management and entrepreneurship. While many programs include elective courses on social sciences and ethics (especially in confessional universities), their impact in a graduate's professional life is questionable and students often regard them as non-relevant. Teamwork is occasionally used in final projects of engineering courses, but entire courses devoted to team-projects are seldom.

Development methodologies from the creative arts and design field are also different. If not a major component, most multimedia engineering projects involve programming at some point of their development and therefore software engineering methodologies may be used as a model. While some software development models are more flexible than others, they differ from methodologies in the creative arts and design. Users may become spectators, and functional requirements may become expressive requirements (communicate an idea), or end requirements (e.g. "promote bicycle use in urban areas"). In the arts and design fields, conceptual basis has a more balanced relation with technical development.

Curriculum wise, the blend between engineering, creative arts and design is a challenge, but also an opportunity to reshape the way engineering students relate to technology. In 2013, the GTA (*Grupo de tecnología para las artes*) group worked in a robotic-art collaboration. The fact that it was an art project with a strong engineering component, makes it a good illustration of pedagogical dilemmas in multimedia engineering. In the following, we will use it as a case study for analyzing the importance of non-technical knowledge in engineering education and its implementation in the curriculum.

## 2 THE SYMBIOSIS PROJECT

The Symbiosis project was a 5-month collaboration between *Precarius Tecnologicus* and the GTA group. The GTA is led by one of the authors of this text and integrated by 6 multimedia engineering students, four of which participated in the project. The aim of the installation was to build a set of vegetal-robotic organisms that would illustrate and question the symbiosis between nature and technology. Robots would provide the locomotion for a plant in its need of water and light. The project had a schedule with encompassed a research stage (roughly one month), a prototyping stage (one month), a development stage (programming and building, two months), and a testing and set-up stage. The group would meet most of the time in the artist's studio on a weekly basis, though in the final stage of the project several day-long sessions were needed in order to meet the deadline. After the art exhibition, the students held a 20-hour workshop on robotics to 18 peers. The group held two wrap-up meetings in which the project was evaluated.

### 2.1 Results

After the design stage, the group decided to make a series of hexapods with a Raspberry Pi brain and 18 servomotors that would live in a constrained space. The insects would carry the plant in their back and take it to a watering place. For their spatial awareness, a custom computer-vision application would be programmed, which would send the robots position data (acquired by a camera on top of the pen) via Wifi. While solar energy was considered for powering the robots, requirements of both the Raspberry Pi and the servomotors demanded for batteries.

The project revealed interesting aspects about both technical and non-technical skills in engineering. It was a real-world project, and therefore with little tolerance to failure. Students devoted an approximate of 8 hours per week to the project in its beginnings, but near the deadline their dedication more than tripled. The collaboration was mostly extracurricular, and therefore the students would not be graded. Despite this fact, students showed an unprecedented commitment with the work being done. In the wrap-up meetings, all participants stated that the project was the most enriching experience along their studies and that they had learned more by working in the project than in a standard course. As it was a project outside the curriculum and the total hours that students dedicated to the project was not counted, a proof of this statement cannot be provided.

Interdisciplinary work with the arts was important in several senses. The participants were able to spontaneously assume their roles or tasks according to their experience or interests. The work, as a real-world art project, had both a technical and documentation requirement, providing a good example of students' future professional life. The scope of the project was broad enough so that all participants had to learn from each other, promoting respect towards other students' opinions.

From a technical point of view, several issues arose. Students agreed that they had very often chose difficult solutions when problems appeared during the project. In a few cases where ready-made solutions were available the group decided to program their own solutions (e.g. programmed vs. ready-made computer vision software, RaspberryPi vs. Arduino boards). This fact led the group to devote more time to technical aspects, than to conceptual aspects, and was eventually a mistake. The group agreed on the fact that the initial design was not achievable in the time that was proposed, and changed servo-motor locomotion with geared motors. While this can be accounted for a lack of research, the authors state that engineering students often have technical goals instead of conceptual goals. Their projects are often conceived in terms of the tools that they involve, rather than in the message they convey, or their overall functionality. This may be so because both students and teachers have been trained in out-of-context situations where they have to implement a tool or use a technique for the sake of learning it and not with a particular purpose.

From a non-technical point of view, the relationship between students and teacher was much more symmetric than in a standard engineering course. While the teacher did play a leading role in the group, students were free to choose many solutions to problems and eventually inverted the knowledge flow as they “taught the teacher” about tools they had learnt. Close to the deadline, the group had to work in several day-long sessions, which enhanced the cohesion of the group. In this sense, space was also important. Day-long and night-long session could not be held in the installations of the university, as there were not any permanent spaces where the group could leave their hardware for several days. A workshop on robotics was conducted, as one of the project goals was also to transmit to peers what had been learned during the process. During the workshop, the students of the group assumed the role of instructors. Assistants to the workshop were both teachers and students from other engineering programs. The workshop was not only a good way of replicating what was learnt, but also a way of building-up self-confidence in students.

## 3 DISCUSSION

Education, from its different physical and virtual scenarios provides explicit and implicit languages, tools and elements, which act as variables in the teaching and learning process. Explicit language refers to formal instructions by the teacher about how work has to be done, specific knowledge about the subject that is being taught, and its purpose. Implicit language refers to the mechanism by which intangible habits and attitudes are learnt from the teacher. For example, a teacher may be used to solve problems with daring and novel approaches, however, his attitude towards problem solving is probably learned by students implicitly, and not by telling students to “please be daring”. Personal attitudes from the teacher may be passed on to students via an implicit way. Also, the nature of the interaction between the two may generate new attitudes. As an illustration, the teacher may not be fearful himself, but he may build-up a fearful attitude in his students because of an authoritarian form of interaction. Explicit contents (mostly technical in the engineering case), as well as implicit contents transmitted by a symbolic meta-language, complement themselves to conform knowledge. The Symbiosis project was an opportunity to examine both of these aspects. There was a great deal of explicit knowledge into play (robotics, electronics, computer vision, biology). However, as the group did not have experience in all of these fields, the process was not a standard unidirectional teacher-to-student learning process, but rather a process where knowledge was jointly constructed. From a pedagogical point of view, the learning *process* was therefore as important as the *contents* being learnt. The management of these implicit channels demands also a big responsibility, as it may be more prone to convey moral, political, ethical and emotional knowledge than the explicit channel. We state that however they are called, multidisciplinary teamwork, creativity, communication skills, etc. are learnt in non-explicit ways, and that greater awareness of this fact (mainly by the teacher) is necessary to achieve effective learning experiences. *Learning experiences* are indeed a good metaphor about where new curricula may point, as they stress the fact that learning is a holistic process. Some successful case studies [7][8], suggest that structural changes in the classroom are a good start. Indeed, the Symbiosis project held important structural differences with standard classroom interaction: open spaces where team-members could both interact among each other or work individually; permanent spaces that the team felt as “their-own”, accessible at nearly any time; a low students-per-instructor rate. Structural aspects of classroom dynamics may be studied through social network analysis, of which case studies are provided in [9]. Interaction structures in the classroom should hold more similarities with real-world cases. Students and teachers are singular, therefore, interaction structures should respect these singularities by being more symmetrical (while conserving the role of the teacher of orienting problem solving). Dialogue and respect for the peer's opinion are essential in classroom communication. As stated by Dewey "every experience enacted and undergone modifies the one who acts and undergoes, while this modification affects, whether we wish it or not, the quality of subsequent experiences" [10]. We suggest that more symmetrical structures in the classroom may extend to other scopes, ultimately fostering democratic values in society. In this sense, intervening curricula is a political action.

Traditional pedagogical models are hierarchical. These models are centered in decisions coming from the teachers. An engineering curriculum that changes this structure, makes the student visible as a political subject, in the sense that it constructs a heterarchy. This concept has been defined previously in anthropology and can be extrapolated to sociological and pedagogical areas. According to Crumley: "Heterarchy may be defined as the relation of elements to one another when they are unranked or when they possess the potential for being ranked in a number of different ways [11]". These new structures are can be thought of as knowledge interaction networks where "value is amplified when there is organized dissonance about what is valuable. We do better when more of us with varied voices ask this question from different standpoints of what is worthy" [12].

## 4 CONCLUSIONS

Many authors have stressed the need of incorporating non-technical skills such as multidisciplinary teamwork, ethics, communication, creativity and curiosity in engineering curricula. These skills are particularly relevant for a multimedia engineering program, as it is a blend between engineering, design, and the creative arts. Effective learning experiences must balance them with technical skills. A case-study on an interdisciplinary robotic-art installation showed that students find these experiences more enriching both technically and emotionally than standard courses. Furthermore, we suggest that these skills are more prone to be experienced implicitly than explicitly, through interaction with peers and teachers in real-world collaborative projects. Both implicit and explicit strategies should be thus incorporated in pedagogical models. I this sense, structural changes that modify interaction patterns inside the classroom may be needed for achieving effective learning.

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