# LOCAL CO-EDUCATION IN INDUSTRIAL DESIGN AND PRODUCT DEVELOPMENT: A REAL CASE SIMULATION – FIVE TEAMS, FIVE COMPANIES

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**ABSTRACT**
The present work aims at identifying how an effective project-based learning approach, focused on meeting real product development needs of local companies, can be implemented. The main issue is determining how project-based learning can be successfully employed to ensure students acquire the skills and knowledge required by companies. Towards this end, we propose a model for co-education, materialized and validated in a final-year industrial design degree course, with student groups working in cooperation with local SMEs. The proposed approach differs from others in the literature in 3 key features: it is prescriptive, it considers the final result (not just the process), and it involves local companies throughout the development stages. The developed work represents a contribution to an improved understanding of project-based learning and co-education.

*Keywords: Co-education, project-based learning, industrial collaboration, industrial design, product development*

## 1 INTRODUCTION

The concept of co-education originated and is often associated with mixing genres within the same institution [1, 2]. However, this concept has evolved to a wider concept of collaboration; in the context of this paper, co-education means education involving all those that have a stake in the learning process (students, teachers, and companies). Through this approach, companies take an active role in ensuring the correct guidance for the education of their future collaborators, providing their unique and informed perspective on goals, concepts, methods, and tools. The main driver behind co-education essentially embodies the main goal of teaching institutions: to adequately prepare students for the job market. If achieved, companies will benefit from having better prepared students, with a minimized adaptation stage. Also, students will typically exhibit improved performance during early training periods, and more rapidly achieve their true potential. However, practical implementation of effective co-education approaches is not trivial, as discussed by several authors [3, 4, 5, 6, 7].

Project-based learning is a standard teaching method where students develop competences in independent thinking and responsibility, as well as explore adequate social behaviours for team work. The origin of this concept date to the 17th and 18th centuries and was aimed at professional training, to ensure students could link theory and practice [3]. In the early 20$^{th}$ century, the American progressive movement has redefined the concept to a wider scope, where the fundamental characteristic of the project method became a constructive activity with intentional action [7]. Nowadays, this approach is applied throughout the world in many degrees at different educational levels, and degrees in product design and development often feature several project-based courses [8].

There are a few premises to project-based learning [4, 5, 6]. The first is that students perceive a personal significance in the work, and believe it can have practical application. The second is that the project fulfils an educational purpose which can be assimilated in an empiric way. Other premises include self-evaluation and faculty feedback, and setting adequate learning objectives.

Traditionally, the basis of project-based learning in product development courses is very focused on the process and not the final result [4, 6]. However, in Portugal (and probably elsewhere, although we have not been able to include this aspect in our study), one typically finds many supposedly project-based courses where faculty simply launches a proposal and evaluates the final result, with little concern about the learning process. In our co-education model, we explicitly want to consider both the process and the final result, since the final result is a part of the process and we have found from personal experience that this will motivate students to achieve a better final output. This includes ensuring the technical and commercial viability of the product.

In general, project-based learning approaches are traditionally described only in terms of guidelines, and there is very little work describing exactly how to achieve them effectively. They are more descriptive than prescriptive. The proposed co-educational model establishes specific tasks, support techniques that can be used to implement them, and identifies the output each phase should produce.

Another concept widely employed in Europe is Cooperative Learning [5]. This concept resorts to small groups of students, working together to maximize individual and group learning. However, it is still a process based only on student-faculty interaction and without a prescriptive process.

At a higher education level, and particularly in the final stages of the educational program, it is very important to establish a relationship between the higher education institutions and the surrounding community and local companies. In Portugal, many degrees claim this proximity and interaction in their programs, and emphasize in their goals the important of technology and knowledge transfer to society. However, this is rarely implemented in practical terms in the respective courses. The proposed model proposes a practical way to achieve this level of interaction with companies.

## 2 CO-EDUCATION MODEL

Based on years of experience in teaching a project course in the final semester of an undergraduate degree in industrial design, we have developed a model for co-education that has been implemented and validated, featuring excellent output in terms of project results, and which has received excellent feedback from both students and companies. The model encompasses time spent by student teams in the academic setting, with interactions among teams that foster brainstorming and peer-learning, and considerable time spent at companies, which enables practical validation and technical development.

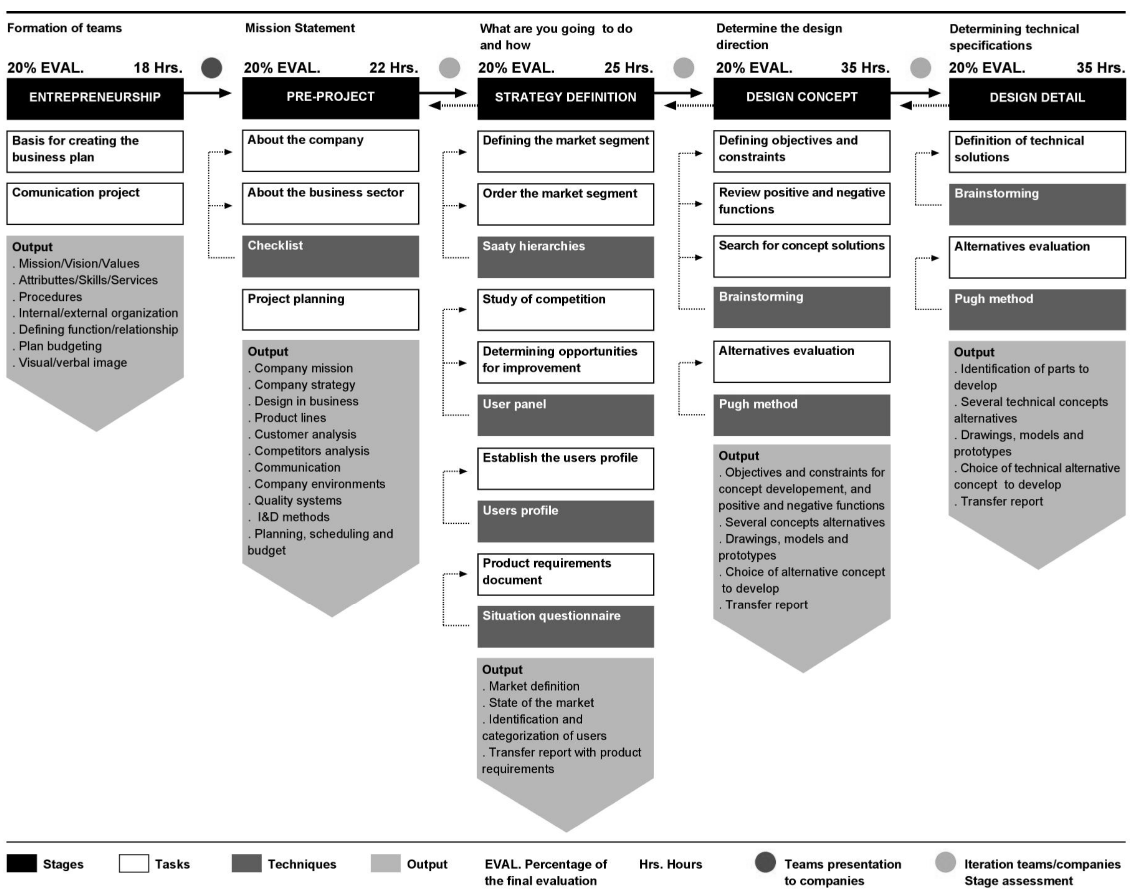


*Figure 1. Co-education model proposed*

A co-education model with 5 development stages (see Figure 1) was created based on the user-centred design process proposed by Page et al. [9].
The first stage, *Entrepreneurship*, concerns the creation of the student teams, and included also the tasks of formulating a business and communication plan. Each student team must establish a virtual design consulting company, which sets a framework for all interactions with the case-study companies.
The second stage, *Pre-Project*, consisted on the detailed formulation of the project, with the tasks of studying and analyzing the partner company and its sector of activity. For this purpose, a checklist was employed [10], where the company's mission and strategy, its design management, current products, main customers and competitors, communication and image strategy, environmental awareness and practices, and R&D methods were assessed. In addition, the project to be developed was planned.
The third stage, *Definition of Strategy*, enables teams and companies to define the market segment, based on the Saaty hierarchies' technique [11], which is essentially a decision making method based on evaluation of different market segments and predefined criteria, such as market size, spending, ease of access, satisfaction, and commercial network. Student teams studied the competition and identified improvement opportunities, using the user panel technique [12], a method for assessing the perceptions of a group of people with respect to competition products. Subsequently, they set a user profile [13], through a detailed report of potential users, their characteristics, limitations and capabilities concerning the use of the product. This document includes information such as age, sex, nationality, education level, previous experience with similar products, native language, possible disabilities and handicaps, occupation, motivation for usage, product-related particular characteristics, and any other relevant unspecified physical features. Finally, this stage must define the requirements of the product to be developed, which was done using a situation questionnaire [13], which aims at compiling all information related to the product that is being developed or redesigned. This should contain also information about product placement, usage environmental, potential modifications, technical limitations, available resources, criteria for concept selection, and history of existing solutions.
The fourth stage, *Design Concept*, consisted on defining a design direction, by setting objectives and specifications, analyzing positive and negative functions, and developing alternative concepts. For this purpose, the Brainstorming technique was employed [14, 15, 16], where teams and companies generated a large number of product concepts, with the course faculty acting as facilitator and moderator. Subsequently, concept evaluation was performed using the Pugh Method [17], which enables selecting the best alternative (in this case, solution concept), by formulating evaluation criteria (e.g. safety, ease of usage, technical, price, aesthetics, durability, manufacturability, reliability), and the relative importance of each criterion (%). All comparison is made to a reference product, usually one which is well established in the market.
The fifth (and final) stage, *Design Detail*, was related to establishing the technical specifications for the concept selected in the previous stage, creating technical options and evaluating them. Again, Brainstorming was used for generating several possible technical solutions (e.g. parts, features, joints, materials, finishes, dimensions), and the Pugh Method was used for selecting among these.
The time available for the entire process was 135 hours, divided as follows: Entrepreneurship 18h, Pre-Project 22h, Strategy Definition 25h, Design Concept 35h, and Design Detail 35h. Approximately 70% of the allocated project time was spent in the in-house studio and 30% in the case-study companies' facilities.

## 3 A REAL CASE SIMULATION - FIVE TEAMS, FIVE COMPANIES

The methodology espoused in the previous section was implemented in a real case simulation, during one semester. In this period, they had to perform all stages of the model, develop the project, and present the final result to the faculty and the partner company with which they cooperated.

### 3.1 Characterization of stakeholders: facilitator, teams and companies

The simulation was conducted within the scope project course of the Industrial Design degree at the Polytechnic Institute of Cavado and Ave (IPCA). This project course takes place during the second semester of the final-year (third year). IPCA is located in Barcelos, in the north part of Portugal. The region is characterized has having a diverse range of industries and companies (e.g. textiles and clothing, ceramics, furniture, medical devices, cutlery, metal working).

### 3.2 Student teams

The first stage of the proposed model consists of a very brief approach to entrepreneurship, where the student teams have to simulate the creation of a virtual company. In total, 5 teams of 5 elements each were created. Thus, each team has simulated the creation of small design consultancy start-ups, and positioned themselves as if this was a real enterprise. Namely, teams had to decide on a company name, mission and vision, values, objectives, skills, and had to define an organization flowchart with a division of function and responsibility among the team members. Some of the teams have decided to apply a rotation scheme to all team members, to enable everyone to take each role within their virtual enterprise during the project. This was allowed, since it enables them to evaluate how they fit in each role, and possibly help them make some decisions for how to set themselves later on when they graduate and go seek a job. Although a detailed description of the virtual companies is outside the scope of this paper, teams were: team A: "*DIP – Developing Industrial Production"*; team B: "*DARE by a design mind"*; team C: "*SEMENTE* consulting, design and development"; team D: "*O Negative"*; and team E: "*N2 Nitrogen"*.

### 3.3 Case-study companies

A set of local SMEs were approached by the students and invited to cooperate in this course. The co-development model, the project framework, and the course logistics were described to the companies from the start, to ensure they knew what to expect and also what was expected of them.

Company A: *"Doctorgimo Medical Equipment",* is a veterinary equipment supplier, with a product list that includes laboratory equipment, infusion, and surgery, among others.

Company B: *FAMO Office Furniture Industry* is currently the second largest office furniture company in Portugal, and the highest ranking in terms of exporting in the Iberian market.

Company C: *Sifinox Urban Furniture* offers services in civil metal construction and is currently restructuring its business model, through a strong investment in development of new products (domestic equipment for exterior spaces) with the purpose of creating a new brand.

Company D: *2 Ideas Urban and Recreational Equipment* is a micro-company dedicated to editing and commercializing urban furniture and recreational equipment.

Company E: *Belo Inox Cutlery* is a cutlery company with over 50 years of experience and where all manufacturing and commercialization is done indoors. However, they feature a handicap; namely, all design is subcontracted outside the company.

### 3.4 Project example: system of clinical cages for animals (Company A)

As an example, we describe the problem identified in cooperation with Company A and the solution developed by the respective student team. Company A had a diversified line of medical products and equipment for veterinary clinics and hospitals. However, they felt their product portfolio should expand to include animal cages and had been unable to develop an adequate solution. The product should be focused on the Iberian market and solve the typical functional, aesthetics and productive flaws in these products. A preliminary analysis showed that existing products were all made of stainless steel or polypropylene, with 3 to 4 individual animal spaces, and standard accessories (wheels, grid panels). The target animals were defined as domestic, of variable races, of both sexes, and of small to medium size. Specifications were defined by categories: animal physiognomy, safety, maintenance, usage, materials selection, fabrication requirements, user interfaces, and wear.

Six concepts were initially designed. These typically included employing a single module, with the possibility to attach multiple copies of this module, according to number of animals and available size. Also, they feature the possibility to remove an individual module from the main structure to facilitate transporting the animal. Internal space dividers were identified as a way to increase the number of cage typologies for different animal sizes. The key innovations of the different concepts were evaluated against a reference cage commercialized by the company, based on the relative importance of each requirement: adaptability to multiple animal sizes, enabling the animal to move, safety, stability and weight of the overall structure and each module, easy sanitation, easy assembly, easy transportation of animals, production costs, and the possibility to couple external devices to the modules (e.g. feeding equipment). A final solution was designed (as shown in Figure 2), based on two different structural elements, which interconnect and enable a medium or large global structure. Different technical alternatives were developed for grid panels, locking mechanism, and wheels.

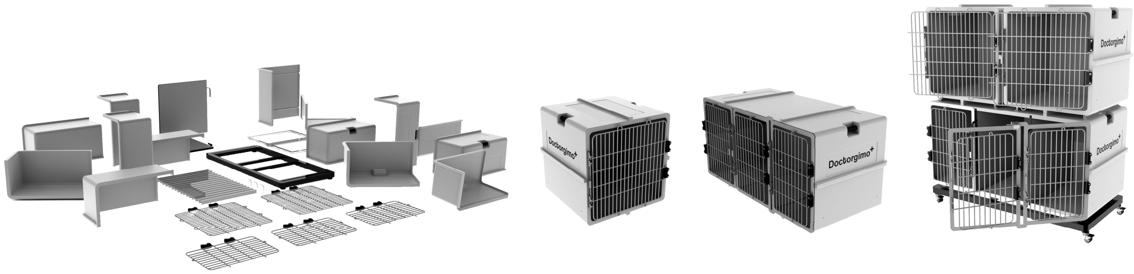

*Figure 2. System for animal cages clinics*

# 4 ASSESSMENT AND EVALUATION

According to the Bologna educational model, which has been implemented in Portugal for the past few years, evaluation should be done throughout the courses rather than simply at the end. Following this principle, each student team was evaluated at every stage of the proposed co-education model. All grades are quantitative and assigned in a scale of 0 to 20. The evaluation of each stage represented 20% of the final grade. Thus, the final course grade (overall evaluation) is calculated as the average grade for each of the 5 stages (in each stage pondered from the performance in the different tasks of that stage). For example, for the Entrepreneur stage, 75% of the grade was for the business plan while 25% for the communication project. This fine detail of grade distribution must be set by the faculty depending on specific characteristics of the lectures and the students' background from other courses.

## 4.1 Evaluation results

The results for the self-assessment of the teams and the company evaluation of their work are shown in Figure 3. In both cases, the assessment is performed for each stage, each technique, and each task. Average results for the 5 teams are also shown for each of those. For perspicuity sake, and since there were no negative grades, all results are shown in a scale from 10 to 20 (passing grade is 10).

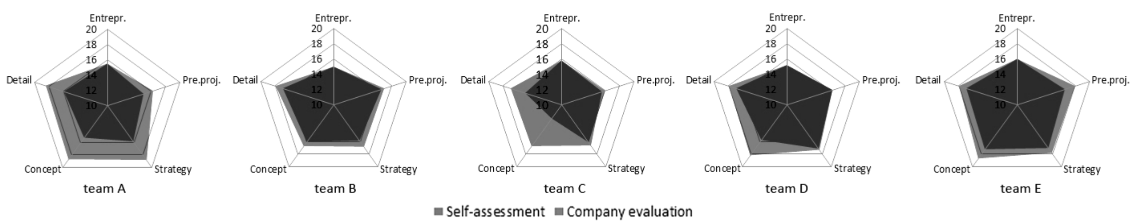


*Figure 3. Comparison of team self-assessment and company evaluation results for each stage. For team C, it is noticeable how the self-assessment grades exceed the company evaluation for two of the stages*

## 4.2 Analysis and discussion

It is clear from the analysis of Figure 3 that the team's self-assessment and the companies' evaluation regarding the team performance are quite homogeneous along the entire process. Regarding the team's self-assessment, there are small exceptions to this, such as in the Communication Project task, or the Product Requirements Document task. It was found by the faculty that this self-assessment is highly influenced by the team's ability to work as a cohesive group, where the functions of each member were clearly defined for that task, as well as how those functions related to the entire process.

The evaluations performed by the companies vary more noticeably across the grading range. Results are in general very good, having surpassed the faculty's expectation, and in fact, grades by companies are almost invariantly higher than the teams' self-assessments. Despite this, some particular aspects were pointed out as relatively negative by the companies. This often stems from the different perspectives concerning the same task, but once validated by the faculty, it can be an excellent mechanism for pointing out to student teams their main opportunities for improvement.

## 5 CONCLUDING REMARKS

In all cases, student teams achieved the objectives set in the beginning of the project. At the end, we believe there are two main outputs. First, students have gained a useful perspective on practical solving problems and daily operation of real companies, which is very difficult to obtain in academic settings. Second, each team has produced a new product (or family of products), as solution to the challenge proposed by companies. We find this approach to project-based learning, with the added feature of involving real companies, enable students to not only learn new skills but apply them in an empiric and meaningful way. The participation of all stakeholders of the co-education process was found to increase motivation and consequently foster better learning outcomes. It also helps students relate knowledge from different courses in an integrated manner (which they usually have considerable difficulty with), and forces them to practice communication and presentation skills.

There are three key features of this model. It is prescriptive, and does not limit itself to describing the stages or phases, but identifies specific tasks and support techniques that can be used to implement and validate each step of the process. It focuses not only on the process but, to a smaller extent, also on the outcome, increasing the scope of co-education and project-based learning. Finally, it enables students to interact strongly with companies, with the multiple advantages previously discussed in the text. This model was not designed to be employed in all project-based courses along the degree, and in fact, is only proposed for the final semester of formal education.

The participation of companies has also raised awareness to the potential benefits of having industrial designers working development of new products, which enables them to rise along the product value chain, and potentially create their own brands or reach new markets.

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