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Assessing the Product Development & Design Courses within the MIT-Portugal Program

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Abstract

The Product Design and Development (PDD) course is part of the curriculum that Ph.D. and Advanced Study students in the Engineering Design and Advanced Manufacturing (EDAM) study as part of the MIT-Portugal program. The PDD course is taught by Portuguese faculty in collaboration with MIT faculty. The goal of this research was to assess the PDD course within the EDAM MIT-Portugal Program. The research participants included about 100 students who were divided into three groups: (1) Engineering Systems Division at MIT, (2) EDAM program, which included students from several universities in Portugal, and (3) Instituto Superior Técnico (IST) and and Faculdade de Engenharia da Universidade do Porto (FEUP). The MIT students studied a project-based semester-long PDD course. The EDAM students took an intensive modular course, taught in a condensed schedule with emphasis on project-based learning. The other group from Portugal took a more traditional, semester-long course. Research tools included pre- and post-questionnaires, with questions related to students' learning outcomes and perceptions. Questions included describing key PDD concepts and processes, ranking reasons for product success despite failing technical specifications, and identifying team and individual skills required for working on a product development project. Focus groups were carried out with EDAM faculty and students. The EDAM students were appreciative of the program and the efforts made by the faculty to provide an excellent experience. However, they noted that the workload during the teaching weeks is heavy and intensive, especially for the students who continue working in the industry during their study. The paper summarizes the research findings and its conclusions.

1. Introduction

The MIT-Portugal Program (MPP) is an initiative set in place by the Portuguese Government, including seven Portuguese Universities and the Massachusetts Institute of Technology after recognizing that Portugal was lagging behind in the world economy for the past years. The MPP was built with the objective of enhancing Portuguese higher education and bringing it closer to industrial needs [1]. The MPP includes four different focus areas: Biotechnology, Sustainable Energy Systems, Transportation Systems, and Engineering Design and Advanced Manufacturing (EDAM). This paper focuses on assessing one of the courses offered to graduate students in the EDAM program – the Product Design and Development (PDD) course. This course emphasizes project-based learning, as a means to deal with important issues attributed to the engineering profession. The engineering profession involves handling uncertainty, incomplete data, constant change in the working environment, and conflicting requirements from various stakeholders. Despite these challenges, lecture-based delivery is still the common practice in many universities and colleges [2].

1.A. Project-based Learning in Engineering Courses

Developments in student-centered approach, such as project-based learning, are just starting to make a dent in engineering education [3, 4]. There is a gap between Portuguese universities and industry with respect to product development and entrepreneurship. Teaching these topics is expected to promote students' thinking skills and ability to successfully launch new businesses [5]. Product development encompasses activities that are part of the product lifecycle, starting with a market need and ending in the production and sale of the product. According to [6], the product development process is the sequence of activities carried out by an enterprise to design, build, and commercialize a product.

2. Research goal and setting

The goal of this research was to assess the Product Design and Development course primarily within the EDAM focus area of the MIT-Portugal Program. The research included graduate students who were divided into three groups: (1) Engineering Systems Division at MIT, (2) EDAM program, which included students from three universities in Portugal, and (3) Instituto Superior Técnico (IST) and and Faculdade de Engenharia da Universidade do Porto (FEUP).

2.A. The Product Design and Development Courses

All three PDD courses used the textbook "Product Design and Development" (Ulrich & Eppinger, 2008) as a foundational resource, but some extra readings are sometimes proposed for some specific topics. The MIT graduate students studied a project-based semester-long PDD course. Within the EDAM curriculum, the PDD course is part of the Ph.D. and Advanced Study program. The EDAM PDD course focuses on teamwork, integration of interdisciplinary domain knowledge, with emphasis on system thinking in an industrial setting [7]. The EDAM course was taught by Portuguese faculty from IST, FEUP, and Universidade do Minho (UM), in collaboration with MIT faculty in a condensed schedule with emphasis on project-based learning. This program has a condensed structure with two one-week intensive lecturing periods interspersed with six weeks without lectures. The third research group – IST and FEUP – took two separate, more traditional, semester-long PDD courses.

2.B. The Research Participants

The total of 116 graduate students who responded to the pre-questionnaire consisted of 50 MIT, 25 EDAM, and 41 IST & FEUP students. Figure 1 describes the distribution of these students by their prior academic degrees: B.A. and M.A. or higher.

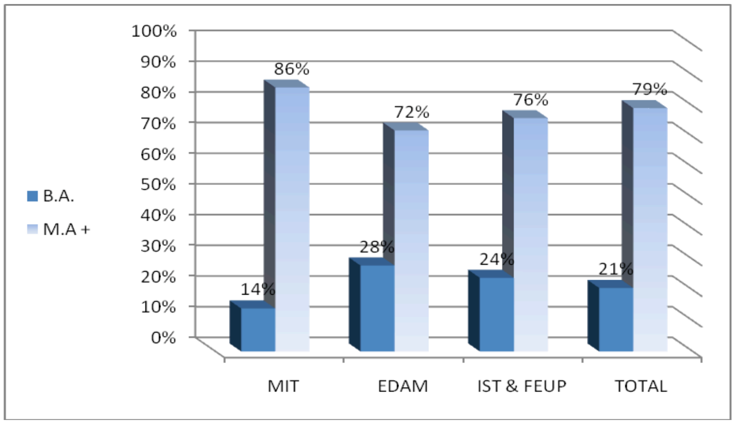

Figure 1. Graduate students' distribution by their prior academic degree

Comparing the students' distribution by prior academic degrees using Pearson Chi-Square, no significant differences were found between the three research groups. The students were asked to specify their area(s) of expertise and number of experience years in each of those areas. Many students indicated more than a single area of expertise.

Table 1 lists the students' number and percentage of the entire population by their declared areas of expertise, showing that engineering is the most prevalent expertise followed by management and manufacturing.

Table 1. Students' areas of expertise

Area of Expertise	N	Percent
Engineering	75	60%
Management	66	52%
Manufacturing	51	41%
Industrial Design	36	29%
Other	28	22%

Using Pearson Chi-Square, no significant differences were found between the three research groups with respect to distribution of work experience in any one of the areas, except for engineering.

Figure 2 presents the distribution of engineering work experience, showing that the vast majority of MIT graduate students have three or more years of engineering experience, while most of the Portuguese graduate students (EDAM and IST & FEUP), have less than three years. This difference was significant ($\chi^2 = 25.74$, $p<0.0001$).

Since the only difference found between graduate MIT and Portuguese students was the engineering work experience, we revisited the distribution of academic degrees. Examining MIT and Portuguese students with respect to their Master degree in engineering, we found a significant difference ($\chi^2 = 20.87$, $p<0.005$). There were significantly more MIT students holding a master degree in engineering (80%) than their peers: 40% in EDAM, and 61% in IST & FEUP.

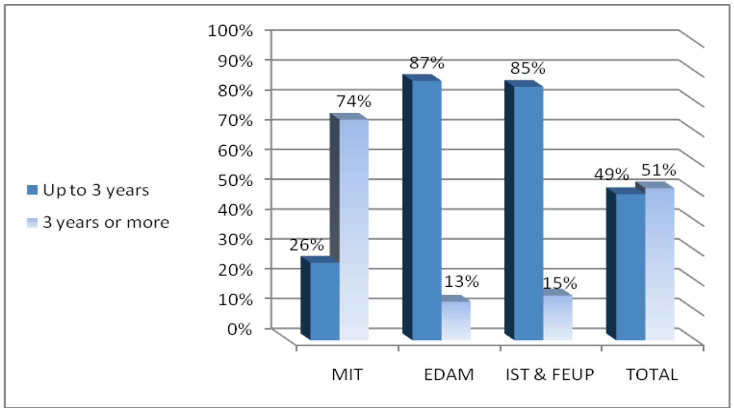

Figure 2. Graduate students' distribution by their engineering work experience

2.C. The Research Tools

Research tools included (1) pre- and post-questionnaires, administered to the students of all three research groups, and (2) focus groups for EDAM faculty and students. We focus on the analysis of several questions related to students' understanding and perceptions. Questions included describing key PDD concepts and processes, ranking reasons for product success despite failing technical specifications, and identifying team and individual skills required for working on a product development project. In the open-ended questions, students' responses from all three groups were analyzed and the extracted items were grouped into categories. These categories were primarily based on the courses textbook (Ulrich and Eppinger, 2008) with refinement based on items gleaned from the text written by the students.

Questionnaires Findings

One of the first questions in the post-questionnaire asked for describing the product the team developed. Examples of products the MIT teams developed as part of the PDD course were A battery integrated carry-on bag for heavy business travelers, a medicine dispenser with two compartments, remote keyless door opener, a task management system for blind people living with others, rechargeable briefcase, and a rack for storing cans and bottles before taking them in for a refund.

Examples of products the Portuguese teams developed were "baby bottle anywhere", a portable device to easily carry bags, solar energy supported baggage, exploitation of solar energy for glacier refrigeration, a cane with sensors for the blind, orange Juicer for children, a Web platform for storing medical data, a trash compactor, a social network for elderly people, "Soapy Soap" - a soap with a surprise inside to help parents with kids hygiene.

To analyze changes in students' responses before and after the PDD course, we compared responses to several questions. One of the questions called for ranking critical success factors for a "good" product. Table 2 lists the pre and post average ranking on a 1-5 scale of the entire student population. The score of the post is consistently higher than that of the pre. The highest ranking items in both the pre and the post are fulfillment of (1) the product's intended function and (2) critical customer need. Trend, portability, fair price, and ease of use increased the most (0.7, 0.6, 0.5 and 0.5, respectively). These factors increased the most due to the fact that in the post-questionnaire, the students had to relate these factors to the product they had developed in the PDD course.

Table 2. Students' ranking of a product's critical success factors

	PRE N = 109		POST N = 75	
	Mean	S. D.	Mean	S. D.
The product is easy to use	3.8	1.3	4.3	1.0
The product is attractive	3.2	1.5	3.6	1.2
The product is trendy	2.2	1.3	2.9	1.3
The product is novel	2.7	1.5	3.1	1.5
The product's price seems fair	3.5	1.5	4.0	1.1
The product is portable	2.2	1.4	2.8	1.4
The product fulfills its intended function	4.6	0.9	4.6	0.9
The product fulfills a critical customer need	4.3	1.3	4.5	1.0

The next question called for ranking reasons for product success despite failing technical specifications. The pre and post responses for MIT, EDAM, and IST & FEUP are presented in Figure 3,
Figure **4**, and Figure 5, respectively.

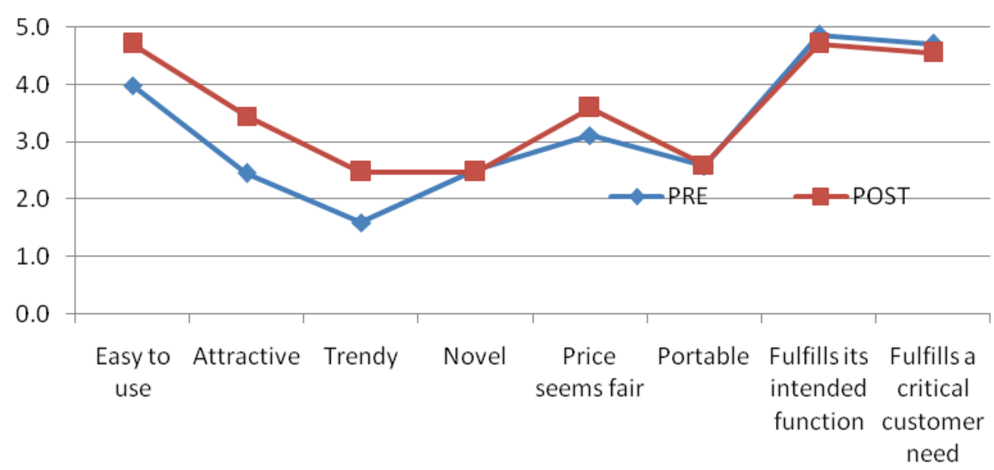

Figure 3. Reasons for product success despite failing technical specifications: MIT graduate students' responses ($N_{pre} = 47$, $N_{post} = 27$)

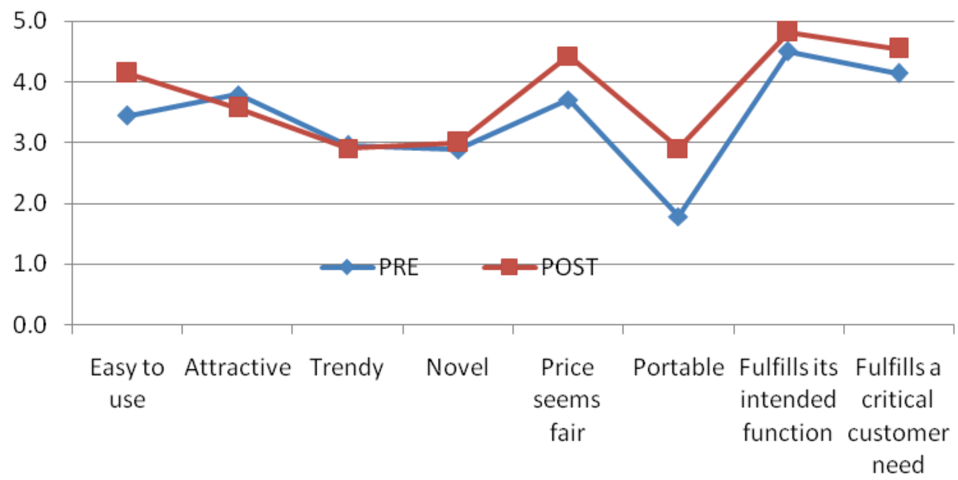

Figure 4. Reasons for product success despite failing technical specifications: EDAM graduate students' responses ($N_{pre} = 27$, $N_{post} = 21$)

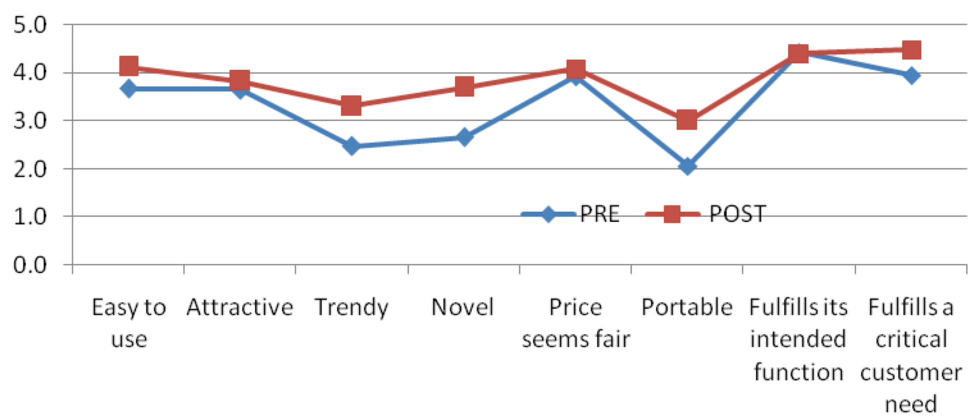

Figure 5. Reasons for product success despite failing technical specifications: IST & FEUP graduate students' responses ($N_{pre} = 35$, $N_{post} = 26$)

Examining the responses, we see that overall, the ranking in the post-questionnaire is higher than that in the pre-questionnaire for all three groups. The highest ranking items for the three groups were "Fulfills its intended function" and "Fulfills a critical need", both ranking above 4. These are followed by ease of use and fair price. "Trendy" and "Novel" are low-ranking items. Statistical analysis of the relative differences from pre to post revealed no significant difference between the three groups for any one of the items. Based on this and the similarity of ranking we conclude that the three groups had similar notion regarding reasons for product success despite technical failures.

The post-questionnaire included the following question: "*List the activities that occurred in the development of the product your team carried out.*"

Following is the list of ten categories which emerged as a result of the item analysis and validation by two experts, arranged by the product lifecycle phases.

1. Social interactions – PDD-related team management, face-to-face or electronically-mediated meetings
2. Planning and brainstorming – including mission statement
3. Concept development – including generation, selection & testing
4. Market research – survey, interview of needs, questionnaires, competitors research
5. Analysis & design – Project and product analysis, benchmarking, architecture, design
6. Prototyping
7. Prototype testing – including experts or users survey
8. Product modifications & manufacturing
9. Business plan & IP – including marketing, patent, and risk
10. Presentations

Table 3. Number of product development items listed by students in the post questionnaire

Research Group	N Items	N Students	Items/Student
MIT	218	26	8.38
EDAM	146	17	8.59
IST & FEUP	157	21	7.48
Total	**521**	**64**	**8.14**

Table 3, which presents the number of product development items listed by students in the post questionnaire, shows that overall students provided detailed responses. MIT and EDAM students listed on average a higher number of items that the IST & FEUP students.

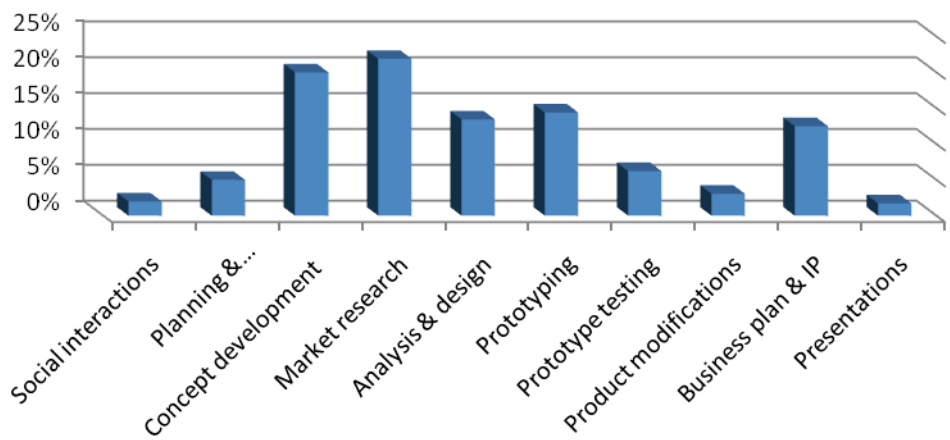

Figure 6. Distribution of product development categories listed by students in the post questionnaire

Examining **Figure 6**, we found out that the two highest ranking categories students listed were market research and concept development. These were followed by prototyping, analysis & design, and business plan & IP.

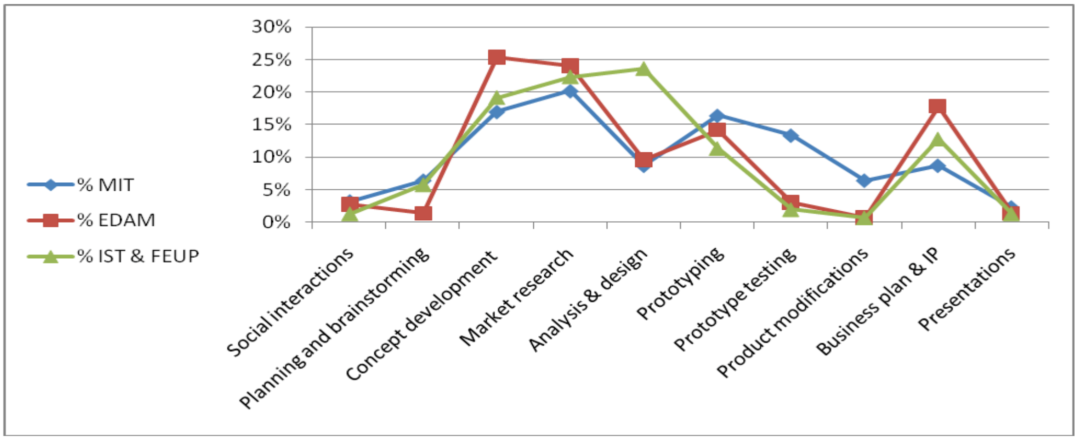

Figure 7. Distribution of product development categories in the post questionnaire by research group

Comparing the distribution of categories by the three research groups, we see that overall the pattern is similar, but there are some interesting differences. MIT students were more inclined to handle later product lifecycle phases, such as prototyping, prototype testing and modification, than their Portuguese peers. EDAM students were more focused on early stages of concept development and market research, as well as later stages of business plan and IP. Analysis & Design was highest for IST & FEUP students.

3. Perceptions of Students and Faculty

Students and faculty perceptions were gathered from two sources. The post-questionnaire contained a question in which students were asked to list advantages and disadvantages of the project-based learning approach (for MIT graduates) and of the EDAM program (for EDAM graduates) in respect to their PDD courses. The second source was focus groups with EDAM students and faculty. Examples of MIT and EDAM students' responses are provided below.

4.A. MIT Students' Perceptions

MIT students provided several insights into the contribution of project-based learning to their career. One student said:"*I think that project-based is the best way to learn in PDD class as it leads students to think on how to apply the knowledge in the project. Lecture-only approach will not be beneficial if we don't have to work on any project in class*." Advantages listed by another student included: "*Apply the classroom directly to the project*. [We gained] *real hands on experience and outside the normal job description. Liked getting hands dirty, and going out to field*." Yet another student provided additional benefits: "[We] g*o through a complete cycle of development; Hands on experiences with each activity and their importance*."

The combination of teacher- and student-centered approaches was well received: "*Frontal lecture-only approach was useful when we learn something new such as concept generation or selection methods. On the other hand, project-based learning approach made us to stay active throughout the entire semester. Also the experience that we learned from our project gave us a very clear connection to the knowledge that we learned from lectures.*"

Main disadvantages students noted included: (1) "*There was a huge learning curve that took a lot time for the project...* [We] *wanted to learn material better, but* [were] *focused too much on project.*" (2) "[We] *spend too much time on the actual prototyping phase. Does it add to the learning experiences? Only skim through each phase so no deep learning experiences*." (3) "*Some products will fail, not all of tools presented in the class get used…*" (4) "*Different time schedule (difficult to manage sometimes) - Some team member commitment - Differences in expectation.*"

4.B. EDAM Students' Perceptions

EDAM students were more articulate, intertwining the positive and negative aspects of the condensed program. One wrote that for students who keep their day job this format is the best but highly demanding: "*The intensive lecturing periods are the best for those (like me) that have a job during the EDAM program. But the Saturday with classes is very difficult to manage because we are all week out of house and we have a family and children to take care. By the other side the full-term lecturing allow us to organize very well all the work, because in the intensive lecturing periods we have to[o] much work to deliver at the same time… [Need] a well organize schedule between courses for deliver assignments.*"

Other students commented on reading materials: (1) "*I think this method is quite good even though sometimes I have a hard time keeping up with the pace when there are a lot of things to read and prepare. Nonetheless that's something I have to improve and not something the program has to change. What I dislike in this method… if there's a good chance that the persons on the class already heard about a given subject, it's preferable to give a case study approach…*" (2) "*Given the intensive nature of the lecturing periods, volume of information can be overwhelming during classes, and there is little time to think about subjects between sessions. The weeks between lecturing periods allow us to schedule research according to individual study methods and timings. This second semester some readings were sent to students prior to lecturing period. That was positive, since we were introduced to subjects in advance. But, in some cases, limited time didn´t enable full discussion of subjects during classes. Homework and assignments scheduling during lecturing periods must be properly coordinated between different courses in order to enable students to properly carry out such tasks. An effort was noticed on this second semester and this issue has improved with regards to the first semester*."

A Ph.D. student discussed acquired skills and project-based learning even though this was not directly asked: "*The intensive lectures are a good opportunity to develop our skills to plan, organize and study the materials before the lessons… I can be more effective and focused in my work…The students need to express their thoughts more effectively, perhaps with more visual thinking. The role of concurrent development of the projects (or thesis) is an excellent way to learn new knowledge (project based learning)…*"

4.C. Perceptions of EDAM Faculty

During November 2008, EDAM Faculty from three universities, IST, FEUP, and UM, met the author in Portugal. They were asked to comment on advantages and disadvantages of the EDAM program's intermittent lecture structure, and to compare it with the typical full-term lecturing structure they teach in other programs. Some of their responses, quoted below, indicate that this unique format has the advantage of getting commitment from faculty as well as students. Faculty

D noted: "*I find this lecturing scheme very good for me. I did not get relieved from my previous lecturing duties in my "normal" courses* [at the university]*, so the intensive lecturing of EDAM minimizes the disturbance with the other… three different courses besides EDAM. This political compromise of going from one university to the next to teach the several week lectures turned out to be very good in terms of commitment from faculty, since we need to move with the students when the lectures do not take place at our home institution, so we* [faculty] *also spend time that is totally devoted to the course we are teaching, with minimum interruption from other issues – it's a 'mini-sabbatical', if you wish to call it that…*"

Faculty G added the students' perspective: "*I think that the one intense week has the advantage of the students being completely concentrated in the program, and not disperse with their company problems. The fact that they are away from their job place is also very important for their success in the program. This is not common in the Portuguese system… but after a period students will find great advantages in this system…*"

Another advantage of the non-consecutive learning pattern was pointed out by faculty L: "… *It allows re-discussion of the topics of the first lecturing period after a reflection on it or its implementation, define more structured assignments, promote team working during the assignments... and it minimizes faculty* [schedule] *conflicts.*"

Linking academia with industry was raised as an advantage by faculty T: "*...the main advantage is the bridge between industry and university. The time used during the semester is very concentrated in two hard weeks. It is difficult for the students from the industry to get all the assignments on time. PhD students are more invested in the learning but they* [the professors] *try to combine them* [full time students with those who have jobs in industry] *together. The contact between the students and the faculty is very short and sometimes* [it] *is not easy to understand clearly what the real work of the students is.*"

The main concerns EDAM faculty mentioned related to overload and compensation for the time and effort they invest. As faculty O. noted: "*They (the faculty) are doing everything as before, but in addition... they also teach PDD in collaboration with other faculty because it is* [an] *interdisciplinary program and requires more expertise. The load is much higher for EDAM than for a regular program but they aren't getting extra salary or credit for teaching in the program. They also can't get time for research*."

Faculty O also pointed out that the students put much more effort than the professors expected and that there are differences between MIT and EDAM assessment culture. He stated: "*PDD students have a project with some collaboration with the industry. So, the very last assignment was graded by all the professors who teach the course. The Portuguese professors grade on a twenty scale and they do not have inflation in grades... They gave more analytical assignments and they were more structured. The MIT professors gave higher scores. Therefore, they ended up doing an average between the two cultures. I think that faculty* [from both countries] *would like to explore the idea of getting criteria and setting a standard assessment scale*."

4. Summary

This study had assessed the PDD course within the MIT-Portugal Program. The findings indicate that the PDD course has a positive impact on the students. The project-based learning approach that follows the MIT PDD course example has been instrumental in successfully incorporating hands-on activities into the formerly teacher-centered Portuguese approach. In a focus group session with the EDAM students, they were appreciative of the program and the efforts made by the faculty to provide an excellent experience. However, both the students and the faculty noted that the workload during the teaching weeks is heavy and intensive, especially for the students who continue working in the industry during their study, and for the faculty who teaches additional more traditional courses.

Acknowledgement

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