DESIGN METHODOLOGY COURSES IN THE MECHANICAL ENGINEERING DEPARTMENT OF ESCOLA POLITÉCNICA – USP

Authors:

Paulo Carlos Kaminski, Polytechnic School of the University of São Paulo, pckamins@usp.br
Marcelo Massarani, Polytechnic School of the University of São Paulo, massara@usp.br

Abstract *— Design methodology courses help the development of skills to approach and solve badly defined problems, common in every day work of design and operational engineers. This ability and knowledge to work with diffuse and non-structured problems is highly desirable. This paper shows how teaching of design methodology is treated in the Mechanical Engineering habilitation of Escola Politécnica - USP. There are two disciplines about this subject: Design Methodology I in fifth semester and Design Methodology II in seventh semester. The first one shows the basic concepts of design and students develop a project of a new product. The second one deals with the project management, and it is based on teamwork in groups with about fifteen to twenty students. They are submitted to several common difficulties in design process, for example: lack of information, unclear authority, open problems and others. The observed result was the increase of important skills for design engineers: communication, people management, problem definitions, analysis, solution synthesis and research*

Index Terms *— Course Plan, Design Methodology, Project Management .*

Engineering courses at Polytechnic School of University of São Paulo have been restructured into a new curricular structure, whose first group graduated in the period from first semester of 1999 and final of 2003. In the last two years, 2003 and 2004, a new reflection process has begun, concerned about what is expected from the future engineer (2015), how the School must organize itself and what actions must be done to form this future engineer. This program is called "POLI 2015". In the current system, the high school student is submitted to a vestibular test for Engineering without a specialization defined, applying for one of the total 750 vacancies offered by the School. Table 1 shows the candidates/vacancy ratio since the last restructuring process was implemented and exposes that the interest for the School has been high and has fluctuated around 10 candidates per vacancy, which means that only one candidate in ten gets the right to attend the course. However, when compared with other careers such as Medicine, Law and Business Administration, the candidate/vacancy ratio has been declining dramatically.

YEAR	CANDIDATE/VACANCY RATIO
1999	8,8
2000	10,5
2001	11,0
2002	11,2
2003	9,8
2004	9,4

TABLE 1
ENGINEERING CANDIDATE/VACANCY RATIO

The choice of Engineering specialization occurs in two phases: the first one is for a Grand Area in the end of the first year of the course and the second one is for the final specification in the end of the second year. There are four Grand Areas: Civil, Mechanical, Chemical and Electrical. The Mechanical Grand Area includes specializations in Mechanical, Mechatronic, Naval and Industrial Engineering. Specifically in Mechanical Engineering, besides the curricular restructuring, instruments to create a flexible and multidisciplinary curriculum were introduced. In order to get the integration of different topics, there are "integration disciplines" (Kimmel et all, 2003) [5] which develop, manage and promote activities that enclose topics of other disciplines of the same semester. There is this kind of discipline in all semesters with specific objectives. In the last five years, the real integration was more related to the integration disciplines' professors than to the topics involved. Therefore, there is a gap between what is planned and the reality, with relevant differences among disciplines offered since the introduction of these disciplines in the curriculum of the course.

Two integration disciplines are Project Methodology I and II, offered in fifth and seventh semesters respectively and focused on general product development. Project Methodology I is concerned about product design, a more specific topic, and Project Methodology II has the focus on project management, a more generic and systemic issue.

The last Mechanical Engineering curricular structure had only Project Methodology discipline in seventh semester, without focus on integration and content equivalent to the actual Project Methodology I, that means, product design. Project management, presented in Project Methodology II, was not included in the last curricular structure.

PROJECT METHODOLOGY I

2.1 Objective

Project Methodology I objectives can be classified in knowledge and skills. Other disciplines occurring in the same semester are:

- Solid Mechanics I
- Materials for Mechanical Construction
- Fluid Mechanics II
- Thermodynamics I
- Vibrations
- Mechanism Project

The knowledge presented by these disciplines is:

- Introduction to engineering project and product development
- Project spiral and production and consumption cycle
- Value analysis in projects and techniques for new ideas generation
- Feasibility analysis
- Basic project, including: stability, sensibility and compatibility analysis.

The discipline must provide the development of the following skills:

- Team working
- Oral and written professional communication
- General research development, not only with academic purposes.

2.2 Program

The program of the discipline was composed by expositive classes for presentation of its theory and a team project involving Feasibility Analysis and Basic Project of a product. The book used as a support material for expositive classes is KAMINSKI (2002)[4]. The topics of production and consumption cycle, feasibility analysis and basic project follow ASIMOV (1962) [1]orientation and were implemented by Prof. Omar Madureira (class notes 1989) [6] in Polytechnic School Mechanical Engineering course in 80's. On the other hand, Project Spiral, very relevant topic of the discipline, has been successfully used in Naval Engineering (EVANS, 1959) [2].

Project teams are composed by five to eight undergraduates and their themes varies each year: in 2001, it was the development of a domestic ventilator, in 2002, an automotive cooling system, in 2003, a toy with movements controlled by the child and in 2004, a medical/hospital device for domiciliary usage. Themes have been chosen considering real projects developed by professors in partnership with industrial sectors for promoting better discussions and quality evaluations of the alternatives proposed by the students. Its important to emphasize that the ideal scenario is a discipline with a small number of teams composed for up to five students. However, this is not feasible due to the high average of 90 students per class in the discipline, composing an average of 12 teams per class. The 2004 theme will be shown as an example of how project themes are presented to the student.

The project theme will be a **medical/hospital device** with the following characteristics:

- Domiciliary usage
- Power provided by the user or companion
- Sales in the whole national territory

The main project characteristic is the absence of a defined structure, that means, an open problem, which is generally uncomfortable to be managed by students used to solving well defined structured problems, that most of times have a single solution.

In the Feasibility Analysis, students are stimulated to begin with a real market or society need that must be identified and justified with collected information.

Another recommendation for the development of the project is the most of the research must be done by visiting companies and interviewing professionals related to the product to be designed.

Project follow up is done in specific classes in which each team presents to the professors all progresses obtained and difficulties faced to receive orientations for next steps.

Additionally, two "panels" for making all teams understand what each one is doing in their project. In the panel, each team must prepare a poster with maximum size equivalent to an A1 paper sheet and must present the project in five minutes. (Figures 1 and 2)

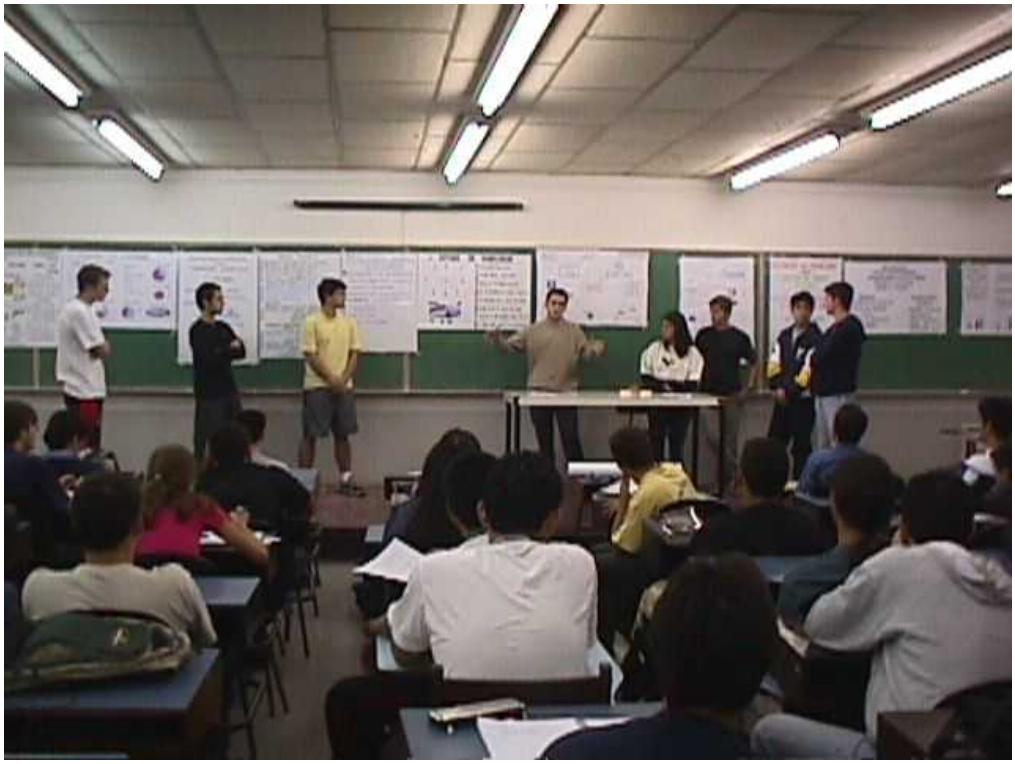

FIGURE 1
PANEL PRESENTATION IN THE DISCIPLINE PROJECT METHODOLOGY I.

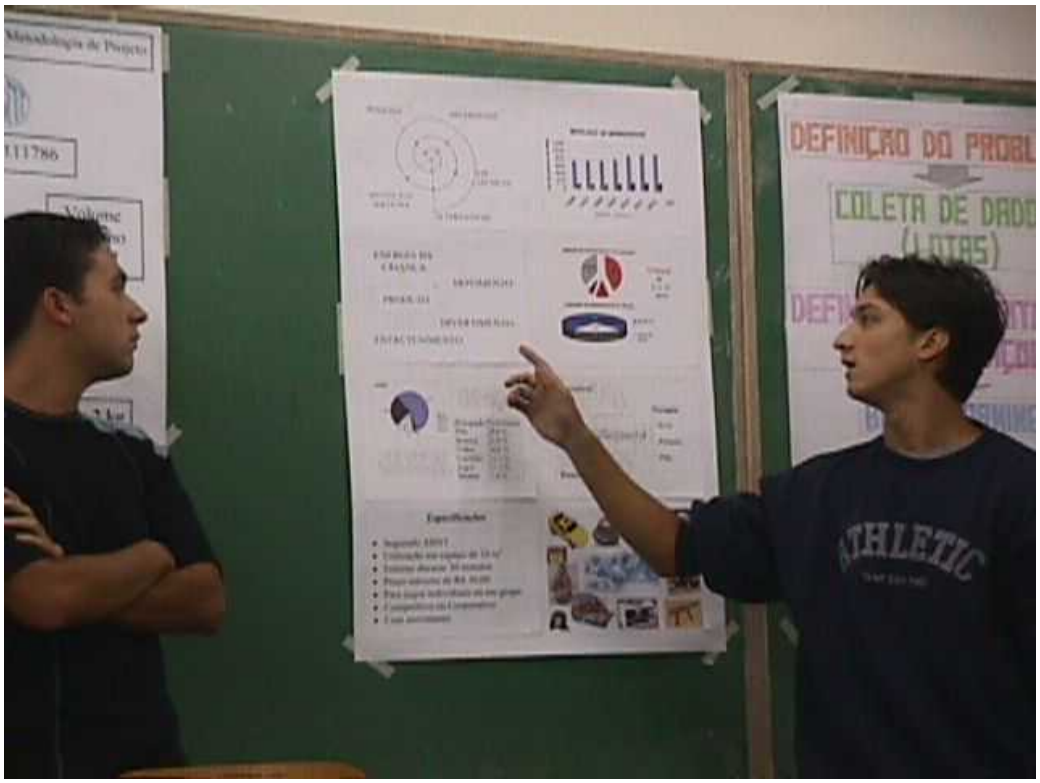

FIGURE 2
POSTER PRESENTED IN THE PANEL OF THE DISCIPLINE PROJECT METHODOLOGY I.

Teams are supposed to prepare a preliminary project report containing the Feasibility Analysis. In the end of the semester, the Basic Project is prepared, also including a more detailed Feasibility Analysis. Grades consider the following issues: presentation, problem definition, development methodology, quality of alternatives presented and general presentation.

Final evaluation is composed by grades attributed to each presentation, panels and reports. Besides, there are two written tests.

Results

It can be observed that the proposed activities are coherent with objectives of the discipline. The following issues must be emphasized:

A sensible improvement in oral and written presentation occurs in the second panel and in basic project.

The project proposal without a clear definition makes students uncomfortable because they are used to solving well - defined problems and following pre-determined structures (Hubka and Eder, 2003) [3].

Topics integration occurs in two ways: by the contact with professors of other disciplines as consultants and by examples used by professors about projects under development in the semester.

This discipline intends to, with available resources, form a graduated student with more project knowledge and skills. This is a great need of the industry in Brazil and internationally, which can be confirmed by NICOLAI (1998) [7], that analyzes the profile of the engineers desired by industries in USA. In this research, the author opposes the education philosophy focused on forming a "scientist" and "designer" engineer. Engineering schools have been forming bad engineers that are good researchers. Lots of professors in these schools are researchers that, although graduated in Engineering, have low experience with industry, consultancy firms, etc. This causes a no valorization of project activities and product development in these institutions. On the other hand, industries need engineers able to solving open problems and with project development skills. This discipline intends to reduce the distortion existent in the formation of Engineering students.

PROJECT METHODOLOGY II

Project Methodology II is offered in the seventh semester of Mechanical Engineering course and has the objectives described above. Other disciplines occurring in the same semester are:

- Machine elements II
- Thermodynamics II
- Mechanical quantities measurement
- Mass and heat transfers
- Control and applications
- Thermodynamics of compressible fluids and applications
- Fluid-mechanical automation
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The knowledge presented by these disciplines is:

- Project optimization.
- Project management. Planning and Organization.
- Quality in Projects. Quality systems in projects. Quality guarantee in projects.
- Forecasting and reliability analysis. Maintainability in project. Safety quantification.
- Project and environment. Ergonomics.
- Industrial property.

The discipline must provide the development of the following skills:

- Time management.
- Human and other resources management
- Research skills

3.2 Program

Discipline program includes expositive classes for presentation of theory and a project of an enterprise.

The expositive classes are supported by PMBOK (2000) [8], provided to the students in the beginning of the discipline. More than fifteen students compose each team. The project scope must involve a real identified need and the results required are proportional to the number of people in the team, demanding organization and management of the team. Then, students must deal with real team working problems during the discipline, simulating real cases in their professional market.

Project follow up is done in specific classes in which each team individually presents to the professors all progresses obtained and difficulties faced to receive orientations for next steps. Besides, two free presentations, the first one with fifteen minutes and the second one with thirty minutes, are done by each team to the rest of the class.

Students must prepare a preliminary report with the project progress and a final one with the complete project.

Evaluation is composed by grades for project follow up activities, reports and two written tests.

3.3 Results

There is an initial difficulty in the team organization with fifteen students or more that occurs in the first two weeks. After this period, the group develops tools for internal communication (all teams use “e-groups”) and tools for project integration.

Another difficulty is the establishment of leaderships and hierarchies for team organization. All kinds of organization can be observed, from some with "positions and responsibilities" definition to informal ones. There is an odd leadership position avoided by students, sometimes the less adapted to leadership is nominated team leader, which harms the reach of project objectives. The best results were observed in groups that defined clearly the responsibilities of each element.

CONCLUSIONS

The main contributions of Project Methodology I and II in Mechanical Engineering course is the involvement of subjective needs that must be converted in a well defined engineering problem.

Engineering students generally receive clearly defined problems during their basic disciplines and instructions for development of experiments in labs. An open problem is more similar to professional reality. Sometimes, the information available is not enough or there is an excess of information. Dealing with this kind of problem creates an initial difficulty to students and provides benefits that will be noticed in their way to face problems.

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