Abstract - This paper reports some ongoing experiences related to the product design teaching and learning processes in the Production Engineering undergraduate course at Federal University of Juiz de Fora, Brazil. The main topic of the discipline is a project assigned to the student’s teams in the beginning of the semester in which they have to design and build a small electric powered vehicle. In the end of the semester the teams compete in a race. The other topics are related to the more theoretical aspect of the product design and link an overview of design methodologies with some electronic, mechanical and structural concepts. There are also some tasks related to product dissection and investigation among with rapid design exercises as a mean to keep the interest and link these tasks to the design theories. Finally there is some discussion over the results from the student’s perspective and some directions on what must be reworked to improve the teaching and learning process.

Index Terms – product design, design methodologies, practical engineering knowledge, team work.

INTRODUCTION

The Production engineering course at the Federal University of Juiz de Fora is challenging with the aspects and difficulties of a new course implantation. It started in the first semester of 2000 and there are only two graduated classes until now. The characteristics of the Production Engineering course are orientated by the Brazilian Association of Production Engineering (ABEPRO) guidelines. These are folded in diverse sub areas like production management, operations research, quality management, product management, among others. The product engineering topic is inserted in the product management sub area with other topics like market research, design methodologies, product planning and marketing.

The discipline focused in this paper is the Product Engineering I with four theoretical credits and two practical laboratory credits. It is inserted in the sixth semester of the course. The more close contents related to the discipline are the Graphic Expression studied in the first and second semesters, Materials Engineering and Electricity and Energy in the fifth semester and Ergonomics and Materials Strength in the same semester. There is also a direct link with Product Engineering II and Manufacturing Processes in the following semester.

In that sense, the topics worked in the discipline are focused on basic design concepts, design methodologies, team work and product prototyping. These reported in this paper are being worked for about two years and are being improved every semester. According to the political and pedagogical project [4] and the course discipline structure distributed along its five years, it was identified the necessity to consider a more technical and engineering approach in some disciplines in order to have an effective balance with the administrative and management topics. This means that the students must construct the ability to design artifacts and technical processes from an approach that consider the technical, management and social aspects of the product. It means too that the Product Engineering discipline has an integrating role in the course curriculum.

In association with those aspects, one must consider the role of the laboratory in the engineering education. According to Feisel & Rosa [3], there are three basic types of engineering labs: the research, the development and the educational.

In the experiences reported here, the practical activities can be developed in a laboratory that has the characteristics of development and educational in the same time. This is due to the nature of the discipline contents. The students must develop diverse concepts for a product and test those ideas in the same time that they need to perform some practical experiences to understand the behavior of some devices incorporated in a product.

From this scenery this paper reports the ongoing experiences that try to link some practical tasks related to the small electric car project with the theoretical contents of the design process and basic concepts of electronics, mechanics, structure and materials engineering.

DESIGN METHODOLOGIES AND TECHNOLOGICAL TOPICS

The theoretical concepts of design methodologies that are approached in the discipline intends to give to the students an initial and broad sense of the nature of the design process itself along with a more detailed study of the main steps of it. These are the identification of customer needs, establishing the scope of the project, listing the basic specifications from the user’s statements and necessities, decomposing the problem and generating solution concepts for each sub problem, select and synthesizing a concept to be developed, refine the specifications and detailing the product. Those contents are based on the Ulrich and Eppinger book named Product Design and Development [5].

They are presented to the students in expositive classes with the use of common resources like the blackboard, overhead projector and so on. Although those traditional
media, the contents are also linked to the small car project and to the rapid design and product design investigation exercises. This association acts as a very strong mean of stimulation for the knowledge construction of those more theoretical concepts.

Along with those design process contents there is introduced the topics related to the simple machines, basic electronics, structural systems and materials. Those topics don’t need to be deeply stressed in the discipline because there are other disciplines on the course focused on each one. The strategy is at least to link it with the hands on task of design a product that must fit its objectives, that is win the race at the end of the semester.

An example of how the technical topics can interact with the project being developed is the one related to the structural systems. For a Production Engineering course there is no need to learn how to calculate and dimensioning complex structures like is the case for the civil engineer. But they need to know the contents related to Materials Strength that is worked on a specific discipline in the same semester. In this way, a broader strategy is at least to link it with the hands on task of design a product that must fit its objectives, that is win the race at the end of the semester.

The topics related to the electronic basic concepts like the use of the LDR to control the small car are worked in a similar way. One of the intentions is to bring the contents of the specific disciplines from the previous semester or those that runs in parallel to the design task in hand.

Also the technological topics such is the case of the simple machines concepts that are worked in the discipline helps the design tasks and exercises being performed along the semester but also acts as introductory topics for disciplines such is Manufacturing Processes and Design Management in the next semesters. The simple machines concepts especially help a lot in the understanding of the functioning principles of diverse artifacts. The understanding of those principles in equipments like turns and mills that happens in the discipline Manufacturing Processes in the seventh semester is also greatly enhanced by this approach.

**RAPID DESIGN AND PRODUCT INVESTIGATION**

Along the semester there are also assigned to the students some in class exercises that aimed to broad their view of technological issues and broke the idea that many products have a complexity beyond their capability to understand its basic concepts and functioning principles. Those tasks help in building a more strong confidence in their capability of analyze and understand products structures that can help in the design of new ones. Also they help in the main task that is the product investigation of a “complex” computer device: the mouse. The other is a rapid design exercise.

In the case of the mouse exercise there is assigned to the students the task of in one class period identify the computer mouse basic functioning principle and presenting it to the rest of the group using any kind of language. Each team is supplied with a mouse device and some simple tools such as screwdrivers and pliers. They don’t have to go deeply in the electronics aspects of the device. The mouse basic principle is the association of a mechanical principle with the basic binary computer language. That is the mechanical movement of the mouse must be translated to the two states of the binary language: on or off. This is accomplished by a mechanism associated with two electronic devices that emits and receive light.

This exercise is assigned in the beginning of the semester and is intended to build a better confidence on the students. That is, the intention is to show them that they are able to understand how a device that appears to be complex at a first sight can be dissected and understood with the knowledge and tools that they have in hand. The exercise shows that the students are really able to identify the principle and represent it in a short period of time.

In the rapid design exercise the student’s teams must generate a design concept of a device to support a digital projector in a classroom and represent it by technical graphic means. Some user’s needs and basic specifications are stated and the groups have the time of one class to generate the concept, represent it and make a presentation to the other groups. In this case there is explored many aspects of the product design process but the most significant are the possibility of many ideas generation in a short period of time with very simple resources like pencil and paper, the importance of management of the team work and the notion that the decisions made in this stage have a strong influence in diverse aspects of the product design life cycle such as manufacturing costs.

In fact those exercises help to show to the students at least two important things. One is related to the fact that if they understand the basic principles of machines and mechanisms among other technical areas, they are able to understand the functioning of more complex artifacts that result from an association of diverse of those basic concepts. Another is the feeling that although they don’t have yet all the necessary knowledge, they are able to design devices that are possible to be built and used in an environment familiar to them.

At last, those exercises among similar others that are assigned in the semester acts as very efficient tools in the
design process knowledge construction. They acts also as a means to put the students in a more close position to the applied technological concepts and linked to the contents of specific disciplines.

**SMALL VEHICLE PROJECT**

The small vehicle project is assigned to the students in the beginning of the semester. They must be organized in four or five member teams and the project will last all semester long. It is announced to the students in the beginning that they will compete in a race in the end of the semester. In this way, the competition acts like a very strong mean of stimulation leading the students to a more active and participative behavior in the class.

The theoretical concepts of design methodologies mentioned earlier are associated to the design tasks that are being performed by the team’s through some in class exercises. An example is the establishment of the initial product specifications that are numerical quantities translated from the user’s necessities. Those exercises intend to link the theoretical topics with the hands on approach of the small vehicle project.

This project came from a technical article in a Brazilian magazine of electronics [1]. The basic specifications of the project are showed bellow.

The small car must be powered by a DC electric motor that turns a propeller. The car must go in a straight line and the motor is controlled by a simple electronic circuit based on a LDR (Light Dependant Resistor). The circuit is showed in Figure 1.

![Electric Circuit for the Small Vehicle](image1)

**FIGURE 1**

**ELECTRIC CIRCUIT FOR THE SMALL VEHICLE**

When the LDR receives light the current flows through it and polarizes the transistor base. Then the transistor allows the current pass and feed the motor. So the small car can be “controlled” by a simple lantern.

The mechanical part of the vehicle must fit some previous specifications such as chassis dimensions propeller diameter, among other design constraints. Initially those dimensions where based on the ones from the magazine. These basic parameters are listed below:

- Chassis dimensions: 20 to 25 centimeters length, 6 centimeters maximum wide and 0.5 to 2.5 centimeters height.
- Propeller maximum diameter 13 centimeters
- 6 Volts battery pack

The experience along many semesters showed that a more flexible specification needed to be adopted to allow a better performance of the vehicles. Then those parameters where changed by allowing 10% increase in each one and permitting the use of a 9 Volts battery pack. Also it was defined that the chassis dimensions where related only to the structure of it and it will be permitted a more flexible form of the body of the car. Those modifications increased the performance of the designs and allowed the exploration of other kind of structures.

The race itself is programmed to take place in a gymnasium and there are adopted some basic rules. First of all the teams must follow the same basic specifications that are distributed for them in the beginning of the design process. There will be a grade for the design solution and a grade corresponding to the place in the competition. The only mean of control is a lantern and there is permitted another member of the team to help only in the start. The students must not touch the vehicle during the race. The circuit is a straight line marked on the floor of about 15 meters.

Figure 2 shows one sample of the designs produced by the student’s teams. This design in particular was very interesting although it was placed in second at the final race in their semester.

![Sample of One Small Vehicle Design](image2)

**FIGURE 2**

**SAMPLE OF ONE SMALL VEHICLE DESIGN**

This design in particular don’t won the race because doesn’t pay much attention in the wheel and axis structure. They had some problems in the directional control of the car.

One aspect that can be enhanced in this case is that the team followed a concept that used some design and manufacturing principles to lose weight and maintain a good structural strength.

Figure 3 shows the turning of a PVC tube aiming to reduce the weight in the body of the car. The team also opened some windows in the tube in order to lose weight and allow the access to the battery and the circuit. The use of such kind of equipment was supervised by the teacher because the practical classes with those machines happen only in the next semester.
One of the more challenging tasks that the teams have to accomplish is to design a car that goes in a straight line. In that sense some designs tried to solve this problem with interesting proposals. Figure 4 shows one of these tries that works well in the end. The wide distance between the wheels allows a straighter run of the car. This example also shows the structural concept associated with the use of thin aluminum profiles in order to have a lightweight and a body with good strength.

There were many other designs that not explored those kind of solutions presented here and performed very well in their races. However, from the educational point of view, these two showed here represents ones of the best design solutions that were identified. They tried to match a perfect balance between lightweight structure, good mechanical fittings and good aerodynamic performance of the propeller. Achieving that balance can be considered as not that easy as it probably appears at a first sight. Finally, the experience of design and built a product with those characteristics by the students help them to brake the ice related to their capacity to realize some physical artifact. That is, many students in those classes had not taken contact with experiences like this in the disciplines of the course until that moment.

There is not yet a systematic and quantitative methodology in use to evaluate the knowledge acquisition by the students in this discipline. However, from a qualitative point of view and with the use of some questionnaires in the end of the semester, one can derive some conclusions and directions of change in the experiences and in the structure of the discipline itself.

Although the small car project and the product itself could be considered a very simple design, the experience shows that it performs a very efficient role when viewed as an educational mean to integrate diverse technical areas such as electronics, materials, mechanics, manufacturing and aerodynamics, among others. It can be confirmed when one see that the students goes beyond of the discipline requirements and search for manufacturing process that could fit their design intents.

In that sense the link between the small car design solutions and the technical topics worked in the discipline resulted in some good designs that take advantage of it. However it shows also that the technical topics must be better worked in the following semesters. These changes are related to the necessity of a more deeply view of the technical topics associated with more real world samples and case studies. In this case it is a matter of preparing new material to the classes.

In the end of the semester the teams must generate a report explaining the design process of their car and articulating it with the theoretical concepts worked in the discipline. In most of these reports the students says that the vehicle project open a broad view about the design process, not only in the technical aspects but also another aspects such as the social relations inside and outside the team, the importance of management of the process as a whole and the concept of designing for manufacturing and assembly that will be worked in the Product Engineering II the next semester.

More specifically, the student’s reports some interesting topics related to the discipline structure and the small car project itself. The issues related to the discipline are linked to the fact that this is the first time in the course that they have a more technical and hands on activity. Some disciplines in the same semester or the former ones usually approach some basic technology and engineering contents but don’t put them in a very practical task like designing and building an artifact. The students that have been passed trough this discipline and are now in more advanced semesters also says that the small car design process have showed them some significant aspects of team work and knowledge acquisition. Almost all of them stressed that it was an opportunity to learn how to solve conflicts and take important design decisions and also to share with others the individual experiences and knowledge of each one.

They also have to fill a form with questions that try to take account of how is the effectiveness of the exercises and project developed along the semester. From those forms it is clear that those experiences have a fundamental role in their motivation with the theoretical aspects. In the other hand they asked for a more management approach related to the design process itself. Although this topic will be deeply viewed in the
following semester there is the possibility to explore those contents in the small car project.

Another aspect that must be stressed is the fact that the small vehicle project has a very low cost which is very important considering the challenges of the Brazilian public universities.

There are many issues to be worked and in order to improve the design teaching and learning process in the discipline. Many of those issues are related to the lack of a better infrastructure for the course like well equipped manufacturing and prototyping laboratories. In the other hand, one can see a positive aspect when the students felt stimulated and bring those difficulties to the design process. In this way it is explored in the class with discussions about the various unexpected aspects of the design process.

Among other directions of change and improvement, one that will be implemented soon is the use of computer aids to simulate some aspects of the small car design and to allow a better understanding of technological principles such as mechanisms and simple machines. In this direction there will be adopted in the next semester the use of CAE software like Working Model or others in a similar way that is being used in other universities [6].

Finally, despite the difficulties and challenges mentioned earlier, projects like these can bring very good results and also acts as an instrument of dissemination of new approaches to the engineering teaching and learning process.

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REFERENCES