PROJECT-BASED LEARNING METHODOLOGY IMPLEMENTED IN A SHORT COURSE OF FINITE ELEMENT METHOD

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Abstract. *The aim of this paper is to discuss and analyze the application of Project-Based Learning in a short course of Finite Element Method for undergraduate students. This methodology has been tested around the world and in Brazil it is applied only in elementary school and it is a new discussion in undergraduate courses. This paper presents a brief characterization of students, their proposals and projects, the solutions found during the course. In one of the projects, analysis was performed using a commercial Finite Element software, which performs static and dynamic analysis of structures.*

Keywords*: Project-Based Learning, Prosthesis, Self learning, Finite Element Method*.

1. INTRODUCTION

This work discusses the application of Project-Based Learning methodology in a short course about Finite Element Method. This methodology has been tested around the world and in Brazil it has been applied in elementary school.

> In Project-Based Learning, real-life scenarios are used as the point of departure for the learning process. The rationale for this is to stimulate students prior knowledge and to provide a meaningful context that also relates to the students future professional work. Learning in a context resembling that of professional work is also considered important for the retention of knowledge when encountering similar situations later on in practice. Working with real-life scenarios brings about some important consequences for the organization of the syllabus and the educational process. In contrast to the traditional way of organizing the syllabus, Project-Based Learning curricula are usually organized thematically. This means that different fields of knowledge appear in the curriculum as real-life problems, events or phenomena, instead of in the form of traditional disciplines. (Dahlgren (2003a)).

The methodology was applied in a class of twenty students and they were separated into groups of three to five. The groups proposed projects to their teacher, who analyzed the difficulty of each project.

One of the projects, about the design of a new prosthetic leg, will be detailed in this article. Static and dynamic analyses were performed in order to make a comparison between two materials, carbon fiber and titanium alloy in order to analyze the performance and applicability of the titanium alloy prosthesis.

The project aimed to awaken in the student a more active attitude, a desire for practical approach.

> Metacognitive skills and self-directed learning are considered important for students development into independent, life-long learners, responsible for their own learning. Schraw apud Dahlgren describes two aspects of metacognition that he claims are necessary for self-directed learning: the knowledge of cognition and the regulation of cognition. These skills are teachable, he argues, and he emphasizes that instructional strategies should promote the construction and acquisition of metacognitive awareness. Self-directed learning comprises the ability to formulate learning goals, identify resources for learning, choose relevant and appropriate strategies for learning, and evaluate the learning outcomes. (Dahlgren, (2003b)).

The research process should be taken as a model by the educational process, i.e., instead of teaching solutions, the school should teach to investigate problems and propitiate students involvement in questioning, encouraging them to think critically, creatively and carefully).

As Kilpatrick (1977) postulated, “students, actively, litigants who feel like their designs, and which assume responsibility”. The teacher is also a learner, he does not know deeply the subject chosen by the student, but is able to help him to find the resources to better understand the theme selected. "It is thought that if that who teaches not assume that he should change his professional view on what is globalizing, the way they relate to the information to transform it into shared knowledge, can hardly live on what is definitely an experience of knowledge" (Hernandez, 2007).

> Project-Based learning can be characterized as:
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> - A creative and branching process triggered by an authentic need or problem, leading towards a working solution.
> - A progression of stages of varied nature required for the devise of the solution, e.g., accurate definition of the problem, and its solution requirements and constraints; generation of alternative solutions and their evaluation by defined criteria; model building.
> - The demand for a wide array of skills related to different functions, e.g., information search and retrieval; representing ideas using formal notations; building physical models.
> - The demand for collaborative work skills, e.g., distribution of functions according to expertise; parallel and cooperative work.
> - Continuous evaluation of each stage's products and of the solution at all.
>
> (Mioduser and Betzer, 2007).

According to Mucchielli (1981) apud Giancaterino (2011), Educating is to mark as relevant the presence of strong identity and/or conceptual intercession, about the importance given to experience, and emphasis on thinking and problem solving, operative characteristics common to andragogy active discovery or by project and that denote the same privilege to the idea of learning as pleasurable process of active investigation, proactive, creative and contextualized, that enhance the autonomy, self-direction and intrinsic motivation of the subject, as actor / author of the learning process.

To provide an environment for self-learning the curriculum should change, to become more flexible, i.e., the school must adapt to the student who comes to her. In this sense, according to Ludojoski (1986) apud Giancaterino (2011), Curriculum flexibility should mean a moment to take advantage of these diverse experiences that students bring with them, such as the ways they work their times and their routine. Flexibility can meet this characterization of time through modules, through combinations between face classes and distance classes, tuning with themes of the student's everyday life, so that could become generators of a curriculum relevant.

At this point, there is an important question: teachers will have more work with this methodology? Maybe. According to Boss & Krauss (2007, p. 20), it is important to keep in mind that "you are investing. Project design is front-loaded work. This means the teacher invests in preparation and planning to set the stage for a project. After that, you shift control to students. Then, it's their turn to invest effort in the learning experience, and you become more a facilitator and guide, as well a sounding board for their questions. Your initial investment in project design begins to pay off right away, as soon as you set the stage for student-driven learning."

The next item presents the methodological procedures used in conducting research. Aspects related to Finite element Theory as well as Dynamic theory will be omitted, because the focus of this paper is the analysis of the Project-Based Learning.

2. Methodological procedures

The needs of modern life brings new challenges, industries need more qualified professionals, new courses are created all the time to meet market demand, but schools have not yet adjusted to the new characteristics of their students, few advances have been made in methods of teaching and learning. Universities still break knowledge into disciplines, and are too traditional to understand the changes in society, too centered in teacher's power. According to Kilpatrick (1978a), "we need, therefore, liberal attitudes to see and hear suggestions about what is new, we need critical thinking relevant to assess and judge with certainty. The measure we face the frequent industrialization of the world, there are so many requirements it is necessary to proceed to its selection, so as not erring in the midst of its complexity."

Professionals formed in schools and universities where the project-based methodology has been applied are better prepared to deal with the problems of real life. According to Kilpatrick (1978b), "we face an unknown future, not perfectly defined as to their goals. Whether we like or not, the philosophy of change is the only one who can address our time well, to serve as our guide."

In early July 2010 it was published a notice about a short course (90 hours) of Finite Element Method on Campus Araraquara of the Instituto Federal de Educação, Ciência e Tecnologia de São Paulo. It was offered fifteen seats, but twenty students were enrolled and accepted for the course. In the first lesson it was said that the course would be taught through Project-Based Learning Methodology by three professionals. During this class, each student spoke briefly about his professional life and expectations for the course. Data were noted so that we could verify that sixteen worked in industries of the region, as engineers (10) and technologists (4) and they use the Finite Element Method in their day-to-day routine. The others were engineering students in institutions of Araraquara and region, three students of Mechatronics Engineering and the other three students of Mechanical Engineering.

The meeting could take place daily or weekly. The students decided that the meetings would be held weekly, with six hours per meeting on Saturdays. After discussion, it was decided by students that the teacher would minister two theoretical and traditional classes, with approximately ten hours. During these classes the basic Finite Element Method theory and concepts related to static and dynamic analyses were treated in the classroom.

The class was divided into groups. Each group received a questionnaire with questions about what were their intentions about the course, if they wanted to deepen their knowledge in theory or practice. The class, declined to work the Finite Element Method in a theoretical way, preferring to go directly to the software. Still, there were three classes with the fundamental theoretical principles that guide the theory of Finite Element Method. In this three classes, corresponding to about ten hours, basic equations were presented and the focus was on defining methods and procedures –modal analysis, frequency response and so on.

The course had a total workload of 90 hours, the classes took place on Saturdays and presence was monitored using a list that was issued to the students every week. The course was taught by three people – a teacher of the institution and two undergraduate students, a specialist in Finite Element Method and a specialist in Project-Based Learning.

According to Thiollent (2002), In conventional research, representativeness of groups by quality criteria often refer to ‘intentional samples’, i.e., a small number of people chosen deliberately because of their relevance for a particular subject. The principle of intentionality is appropriate in the context of social research with emphasis on qualitative aspects, where all units are not regarded as equivalent or with the same relevance. The principle of intentional samples was applied in this research, so every student was considered an object of study. Both the labor of the groups as the work itself are subjects of discussion in this paper.

3. Case study

A group of three students chose to study the design of a new prosthesis for marathons runners, testing two different materials. The model was implemented using a commercial Finite Element computer program. Both static and dynamic analysis were performed, with carbon fiber and titanium alloy Ti-35Nb-7Zr-5Ta, where they were compared and the performance and applicability of the titanium alloy prosthesis were analyzed. Specially Ti-35Nb-7Zr-5Ta alloy (TNZT), which has a low modulus of elasticity (55 GPa), can be considered as the best material to be used as a orthopedic implant. In addition, this alloy is composed of non-toxic and non-allergic elements with excellent mechanical properties and workability. (Taddei, 2007)

The students followed, in their project, the basic steps involved in any finite element analysis:

1. Create and discretize the solution domain into finite elements;
2. Assume a shape function to represent the physical behavior of an element;
3. Develop equations for an element;
4. Assemble the elements to present the entire problem.
5. Apply boundary conditions, initial conditions and loading;
6. Solve a set of linear or nonlinear algebraic equations simultaneously to obtain nodal results.

3.1 Prosthesis

After studies with different prosthesis models a group of three students developed a new template design as shown in Figures 1 and 2:

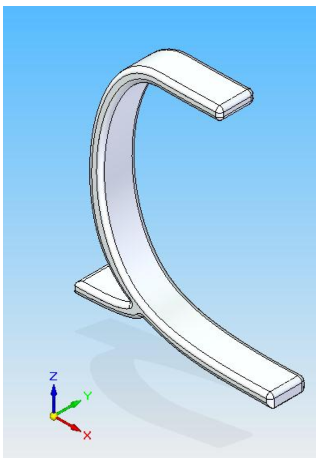


Figure 1 - Design of the prosthesis developed by students.

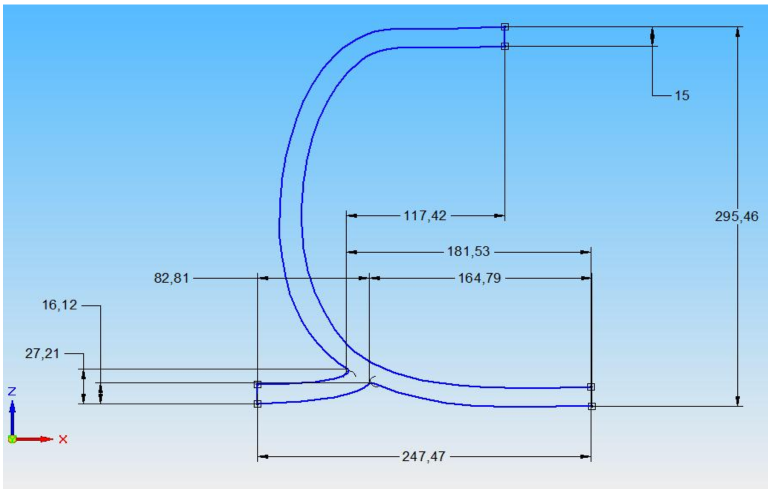


Figure 2 - Design of the prosthesis developed by students.

4. Results and Discussion

This section will be divided into two parts: the first one brings results of the finite element analysis and the second one presents a discussion of the Project-based methodology, based on the results achieved by the group.

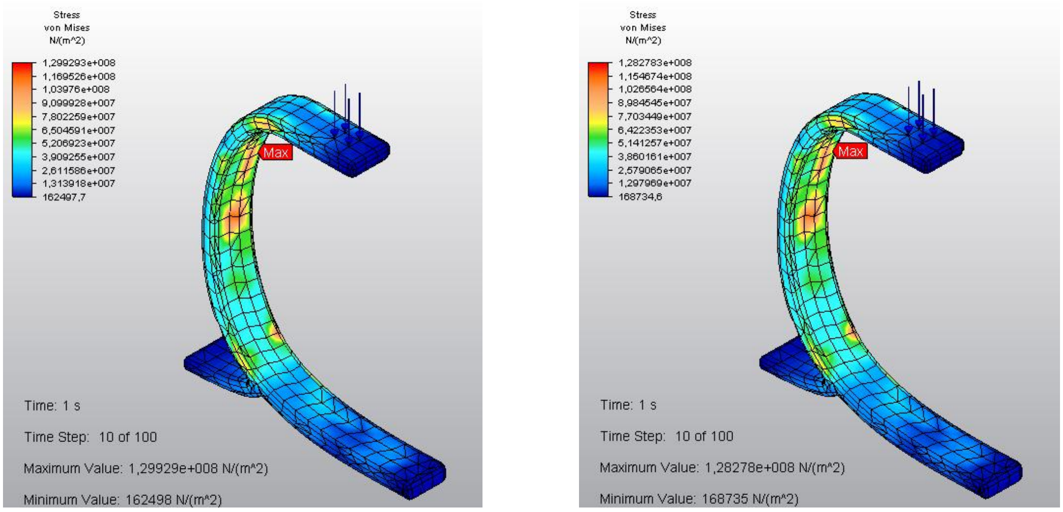
4.1 Results obtained with the Finite Element Method

Initially, the software was supplied with material data according to the Table 1.

Table 1 - Mechanical properties of materials used in analysis ((Liu et al., 2004) (Taddei et al., 2004b) (Oldani and Dominguez. apud Niiomi, 2007))

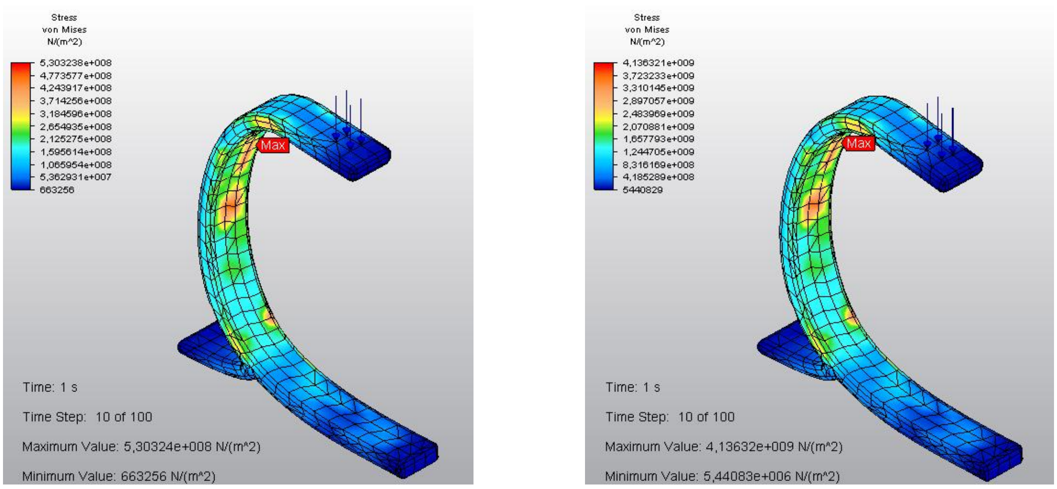
Material	modulus of elasticity [GPa]	Density [kg/m³]	Modulus of shear [GPa]	Yield stress [MPa]	stress Maximum Traction [MPa]	Poisson coefficient
Ti-35Nb-7Zr-5Ta	55	5720	21	530	590	0,33
Carbon fiber	242	1810	89,6	4137**	4137	0,35

Static analyses were performed to determine the maximum stress that the prosthesis supports, according to the Von Mises criterion. Initially, it was considered the load of 980 N, which represents one of the most critical situations in which prosthesis should work. The group found that the prosthesis does not suffer any damage if subjected to such load. In this stage of work, the students realized that they were conducting a research, which consisted of searching for papers and books about the alloys, about the Finite Element Method and about the different types of static analyses. After several simulations, it was obtained the results presented in Figures 3 and 4.



(a) (b)

Figure 3: Static analysis of the prosthesis, considering a total load of 980N. In Figure (a), it was used the material Ti-35Nb-7Zr-5Ta, and in (b) it was used a Carbon Fiber.



(a) (b)

Figure 4 – Simulations in which the prosthesis reaches a value near the Yield Stress of the material. In (a), it was used the Ti-35Nb-7Zr-5Ta alloy, considering a total load of 4000 N. In (b), it was used a Carbon Fiber, considering a total load of 31600 N.

Table 2 summarizes the data obtained through simulations.

Table 2 - Data obtained through simulations.

	Phase 1			Phase 2		
Material	Total force applied [N]	Maximum stress [MPa]	Mass applied [kg]	Total force applied [N]	Maximum stress [MPa]	Mass applied [kg]
Ti-35Nb-7Zr-5Ta	980	129,92	100	4000	530,32	408,16
Carbon fiber	980	128,27	100	31600	4137	3224,49

After the analyses, the group concludes that the titanium alloy Ti-35Nb-7Zr-5Ta can be used in fabrication of prosthetic legs using the proposed design. However, the leg will present some mechanical limitations, if compared with a prosthesis built with Carbon Fiber.

4.2 PBL results and discussion

The main discussion of this paper is about the Based-Learning Methodology and the solutions found to overcome the problems inherent in the methodology. The engineering solutions, although valid, are not subject of deep analysis. Here, we are not interested in commercial application of the design of the prosthesis, at least at this stage of the project.

The Project-Based Learning Methodology is more expensive than traditional methods because it requires a higher ratio teacher/student and, without careful and appropriate planning, does not guarantee greater effectiveness in reduction of the student evasion. In this project three professionals worked in a classroom with twenty students and sometimes the number of tutors needed to be even greater, since the learners had many questions and needed more guidance to continue their projects. Thus, in terms of practical application, in this particular case, this may have contributed to the evasion – sixteen of the twenty students who started the course finished it.

The remaining students stayed in the same room for some time, divided into groups, working on their projects. Later it was observed that it was better to distribute them in three rooms and each one of the tutors taking turns to stay in the rooms. This happened because the students began to disperse with the high number of colleagues in the same class.

Some groups had a greater improvement in their projects so it served as incentive and they struggled even more and worked even harder. Two groups felt discouraged because they failed to achieve immediately their goals. They did not want to research alone, so they asked to the tutors to solve their problems. When they realized that they were not advancing in their projects they stopped going to the course gradually. It is important the attitude of the teacher to adapt the methodology to avoid this problem.

Thus, we performed along the course, some traditional classes on specific topics. These issues needed not necessarily be treated by the teacher. If it was a matter that would escape its jurisdiction, speakers could be invited.

The insecurity of the students was the main problem with the methodology. The question "Am I learning something?" was often heard in the classroom. This is due to the fact that students do not know whether the research they are doing is correct, or if they are applying properly what they read or if whether the results obtained correspond to a correct response of the system studied. Thus, the teacher's intervention was crucial, with his experience on the subject, suggesting changes in projects, improvements and directing the study. The evaluation has an important role in controlling the insecurity - when the student is evaluated, he can realize his progress and his shortcomings. The insecurity is generated in this methodology because the student has to make decisions and need to interpret and adapt the results in their projects.

The methodology of learning by projects may suggest some kind of improvisation, but it cannot take place during the course. Everything must be minimally planned, including the need for visits, internships, partnerships, lectures and so on. This does not mean that the teacher does not have to be creative – in this methodology, creativity is an important prerequisite for students and tutors.

While a project-based methodology may excite the students the theoretical mastering of the subject may suffer? Yes, this is true. The student has a natural desire to see the application of a certain theory, especially in the early years of engineering, primarily theoretical. He has an urgency of solving a real problem to realize that the theory has its own importance. Students interpret a theory as an escape from what is real, as a simplification and an idealization of the real phenomenon.

If the teacher does not direct the studies of students and do not take time to discuss the theory and implications related to the lack of theoretical interpretation and correct resolution of problems, this hands-on approach can lead to an inadequate training. Thus, according to our analysis, the students completed the course with a certain theoretical deficiency, although very good in handling the software and in interpretation of the results. On the other hand, with the Project-Based Learning the students go further in practical approach of real problems.

We need to implement a methodology or a fusion of methodologies that encourages the students to seek theoretical interpretations to solve their problems and at the same time gives subsidies to the resolution of real problems, which are usually multidisciplinary, in an exciting and challenging way.

5. Conclusion

The project-based methodology is not the final solution to the problem of evasion, since it also has some weaknesses. It is important that the teacher be aware that student evasion is the result of a complex combination of several factors and a change in methodology may not be able to extinguish it. The school should join forces and tackle the problem – each employee of the institution is responsible for the loss of a student and the student himself has responsibility in the process.

An institution that wishes to open an undergraduate course based on this methodology should choose to adopt a hybrid model, with 50% of the curriculum based on the system of disciplines and the remaining 50% dedicated to project-based methodology. The sixteen students in the program were favorable to this division. Students would begin the course with a grid filled with traditional disciplines, where the teacher defines the theme and the methodology, and the amount of these classes decrease as the student advances in the course.

Once students have experienced throughout life the traditional system of education where the teacher is the center of the process, this can generate a clash of cultures and the apprentice becomes resistant to the methodology. Since childhood people learn that the institutionalized education requires someone teaching, children quiet, alert and queued, waiting for knowledge. Standardization of knowledge and learning has always been their truth, so they learn to live with it and worse, learn to learn this way. If someone learn since elementary school being active in his search for knowledge, experiencing other methodologies, this person will feel more comfortable with the Project-Based Methodology.

The evaluation process plays a key role in the Based-learning Methodology. If students are not evalueted, they may feel insecure. Then, it is important to define clear strategies to evaluate the acquisition of new knowledge and the understanding of content already taught. If possible, the evaluation criteria must be jointly negotiated with the students.

The student divides learning into two moments, one, in which he is passive and receives knowledge and judges that it is everything right, because he learned that this methodology is institutionalized and in consequence it is the better for him, and other, at home, at work, at leisure, in which he is active and subject of his own learning, independent and master of his decisions. He transfers, therefore, the responsibility for his learning to the school, so his failure is a failure of the school.

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7. RESPONSIBILITY NOTICE

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