# THE BRAZILIAN ENGINEERING MODERNIZATION WITH THE INTEGRATED MASTER'S DEGREE MODEL 3 + 2

**VICENTE MACHADO N.**[(1)] – vmachado@utfpr.edu.br
**CARLOS MAGNO C. D.**[(2)] – magno@utfpr.edu.br
Federal University of Technology – Paraná (UTFPR), Electronic Department [(1)], Math Department[(2)]
Address Av Sete de Setembro, 3165
Postal Code 80230-901 – Curitiba – Paraná - Brazil

***Abstract:*** *Many studies have been done aiming at curriculums models of Engineering Courses in Brazil. In the search for a model it is necessary to dare, to became them compatible with international reality. The purpose of this article is to present a model suitable to the international education community that complies with Brazilian legislation. The model also helps the creation of innovative Engineering Courses, between areas of knowledge and it promotes greater Courses integration with the labor market and graduate programs. The methodology used in this article to arrive at an Engineering Course model that may be appropriate to the Brazilian reality was initially based on an extensive research of the Engineering Courses offered worldwide. Due to the research, the authors' experience and the Brazilian reality, some important conditions were detected to verify the adequacy of the proposed model. After the model introduction there were general discussions on several topics to reach the quality in education. Concluding, the University is no more the only source of society knowledge. It's necessary models that can include in harmony new sources of knowledge, outside the University environment, inside the Engineering Courses. The current models and the departmentalized University structure do not answer to innovative Engineering Courses. Finally, it's must recognize that Brazilians Engineering Courses are in disagreement with what is practiced internationally.*

***Keywords:*** *Engineering education. Integrated master's degree. Model 3+2. Teaching of engineering. Brazilian engineering.*

## 1 INTRODUCTION

The educators are always looking for ways to improve content transmission and selecting the best skills to be developed in students (LIMA). In the academic environment it is common when a new Course coordinator comes, that a great curricular revision takes place, that almost always end with a new curriculum. Everyone thinks to have the perfect solutions for many challenges that modern education presents. There is nothing wrong with this, it's must continue to try and refine the model, as long as the past is recognized, when necessary maintained, or improved, to meet the future.

The National Confederation of Industry (CNI), in its recently launched document "Recommendations for the Strengthening and Modernization of Engineering Education in Brazil," presents its contributions to the discussion. In this document, the CNI recognizes the

existence of an education model, derived from the Bologna process, that is already adopted by almost all European Courses (EUROPEAN UNION), however, CNI is in an undecided position to recommend the same model for the Engineering teaching in Brazil. The CNI argues that changes need to be make in the basic Brazilian educational system, in order to have students more prepared for this model, before it to be adopted in Brazil.

The challenges posed by modernity are demanding a so-called "disruption" in the Brazilian Engineering teaching. The institutions are unprepared to host innovative Courses that can meet the demands of the current multi-area problems of knowledge. It's need to find ways to align Engineering Courses with the demands and evolution of society. Models from the 1960s (BAMBIRRA) that result in high evasion rates, continue to be repeated. A new model is necessary, different from the already established model of 5 years duration.

Engineering Courses such as the Federal University of ABC (UFABC) and the so-called Complex Engineering Course - USP (POLI - USP) are some new solutions that appear on the horizon.

This article intends to put in discussion a model of Course that is not new, a long time it's already practiced in the world. The goal is to modernize, optimize and synchronize the resources spend in engineering College education in general. The model proposed by this article has as main merit its compatibility with the current conditions of Brazilian undergraduate Courses as well as its legislation. It's also presents a series of conditions in order to have an efficient implementation of the model.

## 2 METHODOLOGY

The methodology used in this article to arrive at an Undergraduate Engineering Course model that may be appropriate to the Brazilian reality was initially based on an extensive research of the Engineering Courses offered worldwide. As well due to the research, the authors' experience and the Brazilian reality, some important conditions were detected to verify the adequacy of the proposed model.

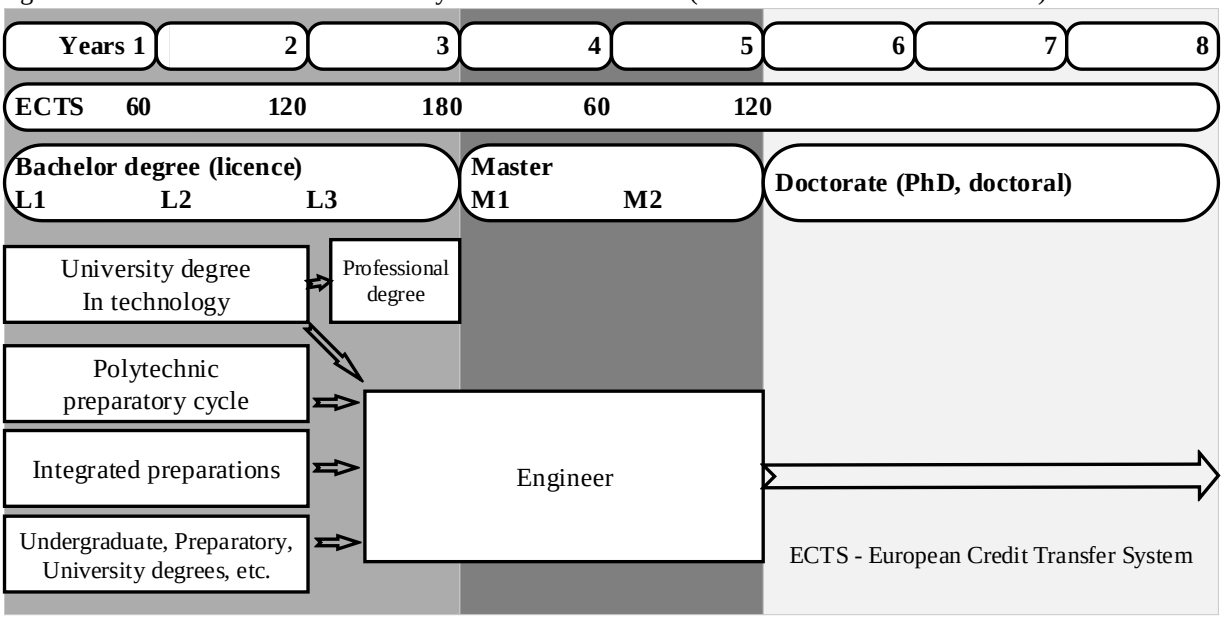
### 2.1 Extensive world-wide research for models

The extensive research shows some outstanding world patterns. Beginning in Europe where the Bologna Treaty promoted a broad modernization and curriculum compatibility. In this way, it can be summarized, with the appropriate exceptions, the European Course pattern through figure 1 of the University of Lorraine in France (UNIVERSITÉ DE LORRAINE). Figure 1 shows, among other things, that Engineering Courses have a structure based on 2 basic preparatory years and a third year already focused on the engineering specialty. By the end of the third year the student can already have a Bachelor's degree. The fourth and fifth year can lead the student to deepen his / her specialty and even to the degree of master.

The University of Hong Kong (THE UNIVERSITY OF HONG KONG) have a 4-year Course pattern for Engineering. One possibility available is the double diploma offered by some Courses, mainly relating Engineering and Business Administration Courses. For this, the student will have to do one more year beyond the 4 years of Engineering. It is observed in the Courses of the University of Hong Kong a strong integration with the Graduate Programs and the lines of research established.

The North American Courses reality is 4 years of duration with many variations, where the first two years are basic, following two years more applied to the Course's focus (UNIVERSITY, EAST BAY). Accreditation Board for Engineering and Technology (ABET) is a strong influencer in terms of standards for the North American market (ABET).

Figure 1 - Course Model of the University of Lorraine in France (UNIVERSITÉ DE LORRAINE).




Source: Université de Lorraine.

In Brazil there is some Courses that can be considered cutting edge, or at least, they are presented to the market, in this way. Among these is the ABC University Courses. The pedagogical project of the University of ABC seems to be very good, being able to join different Courses in the same proposal. The philosophy unification of the Courses is important, so that it promote a greater integration among them, as it is required for modern society problems solution. The Complexity Engineering Course proposed by São Paulo University (USP) presents the innovative aspect of bringing together knowledge areas that have not yet been accessed by other Engineering Courses such as urbanism, petroleum, and others not yet defined. However, in terms of model it does not have advances, it continues with the traditional Courses of 5 years duration.

### 2.2 Human resources optimization

Generally speaking, Brazil does not have a clear policy for education, which ends up promoting a dispersion of the few available resources (CARDOSO). With this, a model that promotes a greater integration among labor market, undergraduate, masters and doctorate Courses, is aligned with a better use of the available resources. If the student could be inegrated directly to the graduate, the Courses will have a qualified critical mass for deepening its researches and a greater synergy between the different levels of education. The labor market could be integrated in this equation with real business problems solving by the students, as research subject.

### 2.3 Model that can host innovative Courses

A new reality is presented every day. Thus, the integration between knowledge areas is one of the challenges imposed, so that modern problems solutions can be find. The 4.0 industry for example, requires connectivity, distributed intelligence, rapid integration, flexible configuration, open standards, and other demands for which it doesn't have simplistic solutions located in only one area.

The professional sought to meet the demands of modern society must have new skills. So, the Courses have to somehow seek the development of these skills. The old model of teacher

and chalk in the classroom is no longer enough, learning takes place today, much more by the interaction between students and the problems of society, than by learning content within the classroom. Emphasizing that content learned in classrooms is also important, but these should be internalized by the practice in real problems solving.

Within this context of change, it can be map some skills to be encourage. Skills such as: pro-activity, building fast solutions from the context presented, to know how the solutions present in the market, to know the available technology, empathy, communication skills, to work at a higher level of systems to find solutions faster, ability to work in teams, knowledge of the global context to be able to interact with several segments, among others.

### 2.4 Number of class hours and credits

In Brazil, hours outside the classroom don't be count as hours of learning. The legislation and catalogs of the Courses refer only to hours of learning in the classroom or laboratories. This is not the world practice, where hours of classroom or laboratory learning are added, with the hours spent in individual or collective studies, needed to attend the Course requirements, the so-called workload.

The European Credit Transfer System (ECTS) represents the workload and define the learning outcomes ("what the individual knows, understands and is able to do") of a given Course or program. Sixty (60) credits are the equivalent of a full year of study or work.

The volume of work in ECTS consists of the time required to carry out all the planned learning activities, such as hours in classroom, seminars, independent study, project preparation, exams, etc. Credits are awarded to all educational components of a syllabus (curricular units, modules, internships, projects, dissertations, etc.) and reflect the amount of work required.

For teaching in Portugal one (1) ECTS credit is equivalent to 28 hours of student work. Figure 2 shows the workload of a typical Europe Engineering Course, divided between theory, practice and autonomous work. It is observed that the relation between computed hours of autonomous work is 2.16 times higher than the hours in the classroom (theory and practice together).

Figure 2 - Number of hours of a standard Europe Engineering Course.

**Integrated Master of Engineering – European Standard**
300 ECTS = 8400 h (relation 1 ECTS = 28 hours)
Theory 1290 h + Practice 1365 h (2655 h in classroom) + Autonomous Work 5745 h
Mean relation (autonomous work / in classroom) = 2,16

Source: Own authorship, based on Uniminho - Portugal.

### 2.5 Brazilian legislation compatibility

Brazilian education legislation is somewhat restrictive in accepting different models of those, that have been used for over 40 years. The main innovations that had been included a long time ago, were the curriculum internship, integrative disciplines and Monograph. Actually, the same model has been maintained, changed only on the flexibility, based on a list of required subjects and a list of subjects by choice.

The resolution of the National Council of Education - Higher Education Chamber (CNE / CES) of March 11, 2002 established the national curricular guidelines of the Undergraduate Engineering Course. The general resolution has a core of basic contents, presents by a list of subjects, the Course has to include all basic subjects, composing "about 30% of the minimum hours required." The resolution also includes a core of vocational contents to be choose by the

Courses from a list of topics, composing about 15% of the minimum hours. Finally includes a core of specific content, with topics to be choose by the Course about the subject of Course specialization. The resolution also establishes as compulsory the curricular internship of at least 160 hours and a Monograph as an activity of synthesis and integration of knowledge.

Resolution 2 of June 18, 2007 of the Ministry of Education CNE / CES provides for the minimum hours of undergraduate in-person Courses modality. This resolution is based on legal opinion CNE / CES 8 / 2007. The resolution establishes that the internship and complementary activities of undergraduate in person Courses modality, should not exceed 20% (twenty percent) of the total Course hours. It also establishes for engineering in a generic way, minimum hours of between 3.600 and 4.000 hours, with a minimum limit of five (5) years. In the end, the resolution establishes that different types of completions than those drawn in the scenarios presented by the Resolution, may be practiced as long as the Pedagogical Project justifies its adequacy.

### 2.6 International model

The societies integration demands an international level of education. For this to happen, the Brazilian Courses need to be compatible with the others in the world. In general, by the imposition of class organs and regulations of the Ministry of Education – Brazil (MEC), Brazilians Courses are what European Engineering Courses were in the past. That is, with excessive number of hours in the classroom and excessive content. Brazilian engineering Courses staffs are very scared of the shorter Courses, they cannot break the paradigm of the duration of 5 years, especially by the legislation constraints.

### 2.7 The educator attitudes

The goal of seeking new competencies and skills in undergraduate cannot be met solely with a change in the curriculum model. The form of content presentation by teachers, assessments and extra class work play a key role.

A conscious attitude of educators is necessary about belonging to a team, that aims to deliver to the market a professional with different abilities, that are impossible to be reached by the individual effort. Thus, an integration of knowledge must be encouraged among all disciplines, not only in knowledge integration activities.

Increasingly transverse knowledge is a requirement of modern society, so skills such as: second language (English); entrepreneurship; team work; social consciousness; creativity; stimulating the search for solutions; writing skills; communication skills; critical thinking, among others described in item 2.3, should be encouraged in all disciplines.

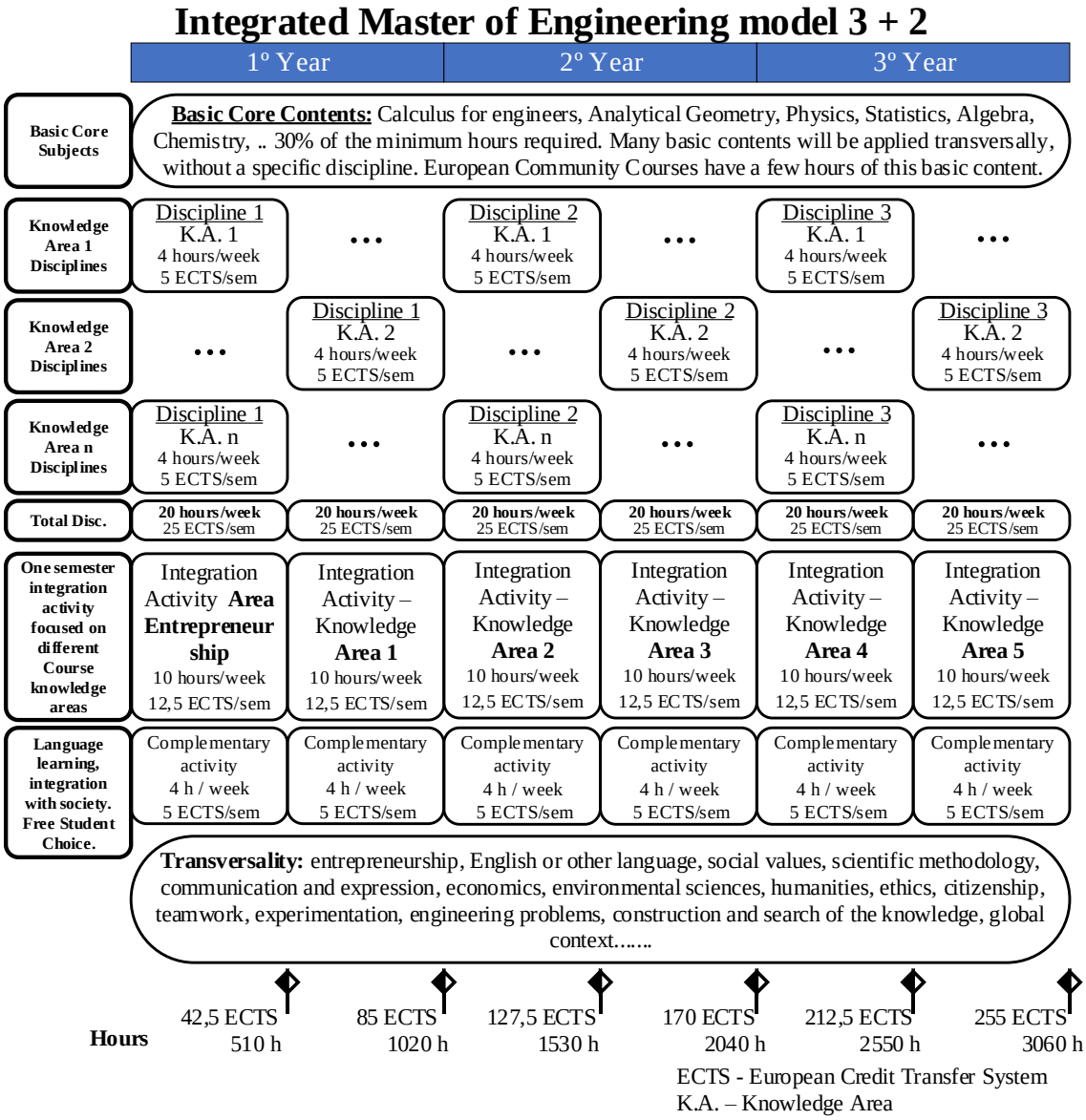
## 3 PROPOSED MODEL – INTEGRATED MASTER OF ENGINEERING 3 + 2

Figure 3 presents the proposed Course model in its first three years. The structure of the model is formed by basic content subjects, chosen from the list of basic contents of the legislation 11/2002. Also included in the structure of the model are the knowledge areas disciplines, the knowledge integration activities and the complementary activities. The structure of the model is detailed in the following paragraphs.

The basic content subjects provided for the legislation may be fulfilled, not necessarily with the allocation of a specific discipline, but also and preferably, to be taught together with other professional disciplines, as a way of integrating knowledge. Therefore, a composition that meets the 30% of the minimum hours, according to the requirement of the legislation (3.600h), has to be sought. It should be emphasized here that, in general, Engineering Courses in other countries do not have such a high requirement of basic content subjects. There is a trend towards

the use of computational and simulation tools, thus providing basic training contents at a higher and more dynamic level.

Figure 3 - First 3 years of the model and main guidelines.




Source: Own authorship

Twenty (20) hours in classroom weekly, that is, 5 disciplines per semester, each with 4 hours of weekly classes. There is only one recommended sequence of disciplines, with no pre-requisites. This equates to 5 ECTS per discipline, 25 ECTS or 300 hours per semester.

Knowledge Integrating Activity will correspond to 10 hours. This activity is equivalent to 12.5 ECTS or 150 hours per semester. The activity will be performed about one different Course knowledge area per semester, on the guidance of a teacher. It is recommended that the first integrative activity be about Entrepreneurship, with the purpose of encouraging the students to be entrepreneurs throughout the Course. The Knowledge Integrating Activity will not be developed in classroom during the Course, being able to have at least two semester meetings, one to present the objective of the activity and another to deliver the result and consequent presentation and defense of the solutions chosen. It should be emphasized that the other

disciplines of the semester should all contribute with ideas and integrations to the success of this activity.

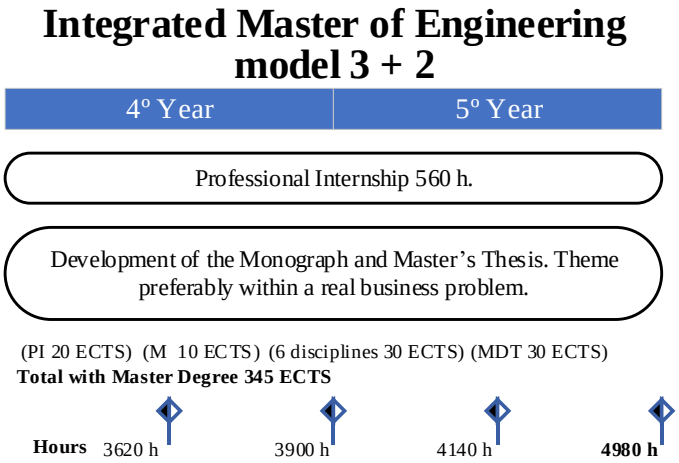
Complementary activity with 4 hours per week is equivalent to 5 ECTS or 60 hours per semester. This activity will also have the accompaniment of a tutor and may have a free choice of among a list of activities allowed. For example, study of languages, disciplines taken in other Engineering Courses, development of other skills, etc. It should be emphasized here that learning another language, preferably English, should be an orientation, and its charging and encouragement, should be made by all the Engineering disciplines in a transversal way.

At the end of these 3 years the student will have a equivalent to 255 ECTS or 3060 hours.

Figure 4 shows the fourth and fifth year of the model. In the next paragraphs it has the detail of the activities of these years.

Mandatory internship equivalent to 20 ECTS or 560 hours (using 28 as coefficient). How this activity will be developed within a Company, an integration with the activities of Monograph and Master's Thesis will be encouraged in order to solve real problems of the market. The number of hours dedicated to the internship activity also takes into account that student learning nowadays gives much more in the reality of the market and in the contact with other cultures, than in the content taught in the classroom. Depending on regulation, the internship activity can be fulfilled in universities technological business incubators but considering that would not be the ideal setting because this can lead to a too academic training.

Figure 4 - Last two years of the model.




PI – Professional Internship
M – Monograph
MDT – Master Degree Thesis
ECTS - European Credit Transfer System

Source: Own authorship

The Monograph is equivalent to 10 ECTS or 280 hours (using 28 as coefficient). Like the Master's Thesis, this activity should preferably be developed based on real problems of the Companies.

Master's Thesis is equivalent to 30 ECTS or 840 hours (using 28 as coefficient). Like the Monograph, this activity should preferably be developed based on real problems of the Companies.

Six (6) Master's degrees disciplines, equivalent to 5 ECTS each, total of 30 ECTS or 240 hours. Master's degrees will be offered within the knowledge areas of the Course. These disciplines, depending on the interdisciplinary nature of the Course, can be fulfilled in one or

more departments of the same Teaching Institution or in diverse institutions of Brazil or abroad, increasing student and institutional exchange.

This model also provides greater flexibility so that the student can fulfill the final two years in a different University, either in Brazil or abroad, mainly due to the compatibility of the proposed model. Double diplomas become easier on this model, especially with European Courses.

For the student who does not want the Master's Degree, he / she can complete the Course in 4 years, doing beyond the 3rd full year, 560-hour of internship and the Monograph. In this case the student will finish the Course with 285 ECTS i.e. around 3900 hours, considering internship and Monograph. It is estimated a workload of 7980 h, that is 285 ECTS x 28 (taking the coefficient used in Portugal).

At the end of the five years, with Master's degree, the student will reach 345 ECTS with 4980 hours. The Model total is a workload of 9.660 h, multiplying 345 ECTS for 28, this total is higher than the European Engineering Courses. Figure 5 shows a summary of the hours number and ECTS of each activity.

Figure 5 - Summary of the amount of ECTS and hours of the proposed model.

| **Course ECTS numbers** | |
|---|---|
| 5 courses / semester = 5 x 5 ECTS = | 25 ECTS |
| Complementary Activ. / semester = | 5 ECTS |
| Integrative Activity / semester = | 12,5 ECTS |
| Total: | 42,5 ECTS/sem |
| Within 6 semesters: | 255 ECTS |
| Professional Internship : | 20 ECTS |
| Monograph : | 10 ECTS |
| **Bachelor Degree Total :** | **285 ECTS** |
| | |
| 6 master disciplines 5 ECTS : | 30 ECTS |
| Master Thesis : | 30 ECTS |
| **Integrated Master Total :** | **345 ECTS** |

| **Estimated Hours Number** | |
|---|---|
| 5 courses / semester = 5 x 60 h : | 300 h |
| Complementary Activ. / semester : | 60 h (*) |
| Integrative Activity / semester : | 150 h (*) |
| Total | 510 h / sem |
| Within 6 semester : | 3060 h |
| Professional Internship : | 560 h (*) |
| Monograph : | 280 h (*) |
| **Bachelor Degree Total :** | **3900 h** |
| Workload estimated: | 7980h |
| 6 master disciplines 6x40h : | 240 h |
| Master Thesis : | 840 h (*) |
| **Integrated Master Total :** | **4980 h** |
| Workload estimated: | 9660h |
| * Autonomous Work | |
| The workload is defined as the hours need to complete the activity | |

Source: Own authorship

## 4 DISCUSSIONS

Some topics should be discussed in order to aid learning, keeping in mind that changes are not made solely by modifying the curriculum model.

The high rate of evasion of Engineering Courses is a reality that must be faced. The causes of the high evasion are diverse, perhaps the involvement of veteran undergraduate students in freshmen reception, can help new students feel as part of a team, for which both have obligations and can at the same time find support in adapting to academic life. A student tutor is also an alternative to being experienced.

In general, University is lacking a more direct form of communication with students. Some alternatives should be encouraged, among them web pages friendlier to the students, which speak their language. At the same time, the web pages can serve as an element of dissemination of the Courses and their values to society.

The incentive to creativity and entrepreneurship should be seen as a cross-curricular content. Thus, the development of these skills must be explored throughout the Course in the most different disciplines, it is necessary an internalization of the teaching staff for the

importance of this content. The same occurs with content such as foreign language, social values, ethics, communication and expression, citizenship and many others, it takes a philosophical change among teachers.

Today, due to the complexity of modern problems, it is faced with the demand for Undergraduate Courses that go beyond University departmental barriers. To meet this need, the departmental University structure needs to be broken to give vent to transversal Courses. The University has to face this challenge, put the departments to dialogue and build solutions that meet the modern demands.

## 5 CONCLUSIONS

The prolongation of the internship periods comes in the direction of more students' exposure to the market, even when they belong to the Courses, this can greatly help everyone. The student being inside a company can be a factor of approaching the subjects of the Monographs and Theses with the real problems of the Companies.

Brazilian legislation is, actually, quite restrictive. Brazil has a legalistic tradition of following the regulations in a way that is often more restrictive than they already are. Although restrictive legislation, it gives room for creativity by putting terms like "in about". The legislation also allows to teach the subjects, not only with a specific discipline in the curriculum, but also in an integrated way with other subjects.

The University body effort as a synchronized team can have a very significant impact on the students learning. Only models can't promote this, some may facilitate, but also the change of consciousness is necessary.

A general statement without exceptions, even when one speaks of the Federal University of ABC, which is constantly cited as a model, is that the Brazilian Engineering Courses are in disagreement with what is being practiced in the world. In this way, the Brazilian Engineering Courses are isolated because of the difficulty of integration. It can no longer be used as an excuse the poor learning of students in high school, the Engineering Courses have to dare and match to international standards in terms of time to complete the Course and the workload.

Finally, the academic culture of English must be intensified in Brazilian Engineering Courses, the fall of national barriers is imperative to form multicultural students, who can work in different markets, adapted to the constant changes. The adaptability today is an important value to be brought to the education.

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## A MODERNIZAÇÃO DA ENGENHARIA BRASILEIRA COM O MESTRADO INTEGRADO MODELO 3 + 2

***Resumo:*** *Muitos estudos têm sido feitos na busca de modelos para os Cursos de Engenharia no Brasil. Na procura por um modelo é preciso ir além, e tornar os cursos compatíveis com a realidade internacional. O propósito deste artigo é apresentar um modelo compatível com a realidade internacional e ao mesmo tempo com a legislação educacional Brasileira. O modelo também deve ajudar a criação de Cursos inovadores de Engenharia, entre áreas de conhecimento, promover a integração com o mercado de trabalho e com os programas de Pós-Graduação. A metodologia usada neste artigo para chegar-se a um modelo para os Cursos de Engenharia apropriado à realidade Brasileira baseou-se inicialmente em uma extensa pesquisa de Cursos de Engenharia oferecidos mundialmente. Devido à pesquisa, a experiência dos autores e a realidade Brasileira algumas condições foram detectadas para verificar a adequação do modelo proposto. Após a apresentação do modelo segue-se uma discussão de tópicos para melhorar a qualidade da educação. Concluindo, a Universidade a muito não é mais a única fonte de conhecimento da sociedade. São necessários modelos que possam incluir em harmonia as diversas fontes de conhecimento dentro dos Cursos de Engenharia. Os modelos atuais e a estrutura de divisão em departamentos das Universidades não atendem às necessidades de Cursos inovadores de Engenharia. Finalmente, é preciso reconhecer que os Cursos de Engenharia Brasileiros estão em desacordo com a prática internacional.*

***Palavras-chaves:*** *Educação em engenharia, Mestrado integrado. Modelo 3 + 2. Ensino de engenharia. Engenharia brasileira.*