CDIO PROGRESS: MECHANICAL ENGINEERING OF THE BRAZILIAN MILITARY INSTITUTE

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ABSTRACT

The purpose of this article is presenting the CDIO approach development in the mechanical engineering of the Military Institute of Engineering (IME). In 2017, through the triennial academic evaluation carried out by the Brazilian Ministry of Education, the Brazilian Government considered the IME's Mechanical Engineering the best undergraduate course of the 291 Brazilian undergraduate courses evaluated in this area. The IME is a higher education institution of the Brazilian Army, located in Rio de Janeiro - Brazil. The CDIO approach implementation in the IME's mechanical engineering represents a change in the teaching and learning process, maintaining the recognized academic content and integrating the practices described in the CDIO Standards. In this way, there is a plan to improve the academical formation of mechanical engineer of the Institute, taking advantage to the excellent theoretical knowledge and adding the skills and competencies described in the Syllabus CDIO. The article describes the reasons for the change, the use of CDIO standards for implementation, and the experiences of the academic staff involved during their development and implementation. This article also presents the development of this academic structure model in the mechanical engineering since 2017, to become a parameter to be used in other undergraduate engineering departments of the Institute, so that they adapt to the CDIO principles and carry out the necessary reforms to improve their curricula. The implementation activities were carried out without a significant increase in the faculty workload, with the creation of new learning experiences. The successful implementation of some CDIO standards has been demonstrated as being effective at increasing student motivation, innovation and problem-solving in both practical, active learning sessions and conventional theoretical knowledge learning sessions.

KEYWORDS

Implementation, CDIO Syllabus, Standards : 1, 2, 4, 5, 10

INTRODUCTION

The Brazilian Army has a higher education college denominated Military Institute of Engineering (IME), located in Rio de Janeiro. The Institute has ten programs leading to the bachelor´s degree in engineering (Figure 1) with the main objective that graduated engineers will work in the Science and Technology System of Brazilian Army.

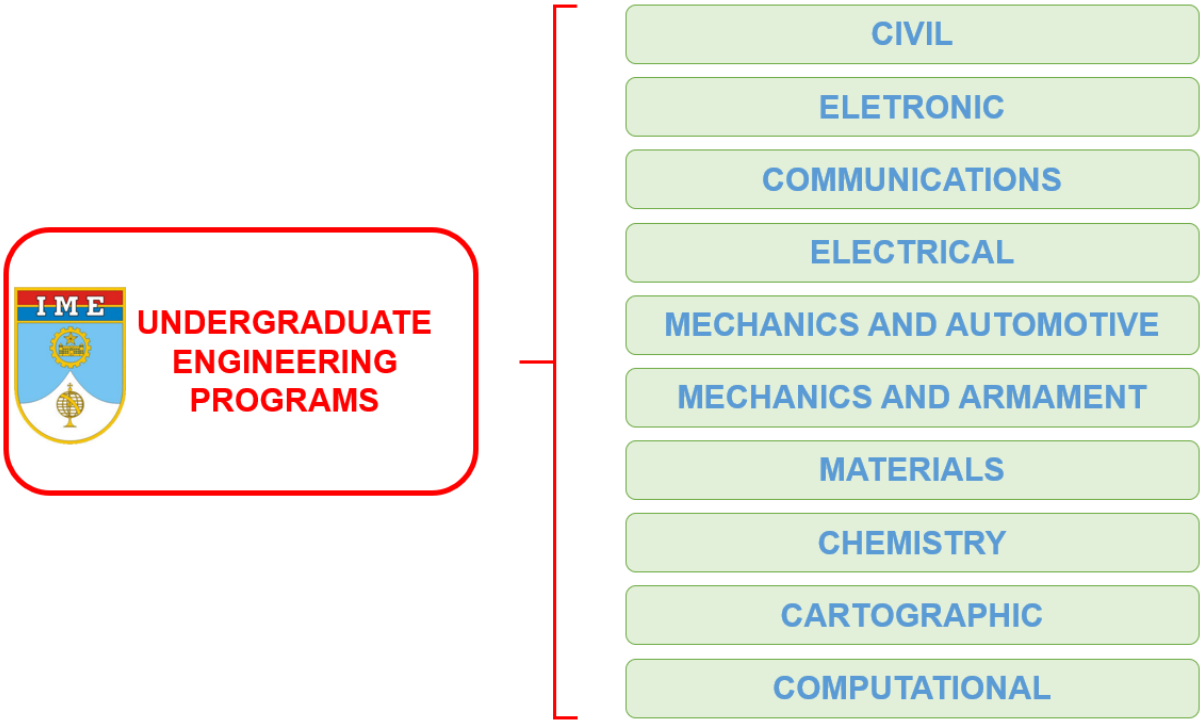

Figure 1. Undergraduate Engineering Courses of IME.

The IME is, at the same time, an engineering college and a military academy. As an engineering college, it must comply with, like all engineering bachelor´s degree programs in Brazil, the rules established by the Brazilian government. In a few words, all engineering undergraduate programs must have at least 3600 hours of academic activities and five years to be graduated (Brazilian Government, 2002) and (Brazilian Government, 2007).

IME's Mechanical Engineering has two specialties: Mechanics and Armament Engineering and Mechanics and Automotive Engineering. In both undergraduate courses are present the basic contents for mechanical engineering, such as Thermodynamics, Fluid Mechanics, Dynamics, Solid Mechanics and Machine Projects. For Armament Engineering there are disciplines involving ballistic phenomena and for Automotive Engineering there are disciplines involving the vehicular dynamics.

Around fifteen students are admitted to the IME's Mechanical Engineering every year. Most students are military (70%) and the others are civilian students. Military students will work in the engineering organizations of the Brazilian Army in the development of military weapons and vehicles. Civilians will join engineering companies.

The academic period for the student to become a mechanical engineer by the IME is five years, divided into ten semesters (or ten periods). The first four semesters, called the basic years, are the same for all ten IME's programs. Only after the fourth semester mechanical engineering students will have contact with the specific content. Each mechanical engineering program has 4,000 hours of activities in engineering education. Despite this number, most of the activities are theoretical activities, mainly a large number of lectures.

The quality of the mechanical engineering education in the IME, related to Brazil, is proven through ENADE. The ENADE is the Brazilian Performance National Examination Students (Brazilian Government, 2017b), and it has the objective to measure and monitor the learning process and the academic performance of students in relation to the knowledge, skills and competencies acquired during their studies. The examination is applied to students of the last period of undergraduate courses.

The application of ENADE for Mechanical Engineering began in 2005, being applied with a periodicity of three years. IME's mechanical engineering students always have exceptional results in ENADE. The results at ENADE have always made mechanical engineering of the IME recognized by the academic community in this area in Brazil.

Beyond the education in engineering, as a military academy, the military student has more than about 1700 hours of activities related to military education. These activities are scattered by the five years, even though more concentrated in the two first years, and they must comply with the Brazilian Army orientations. Figure 2 shows the curriculum´s structure of mechanical engineering.

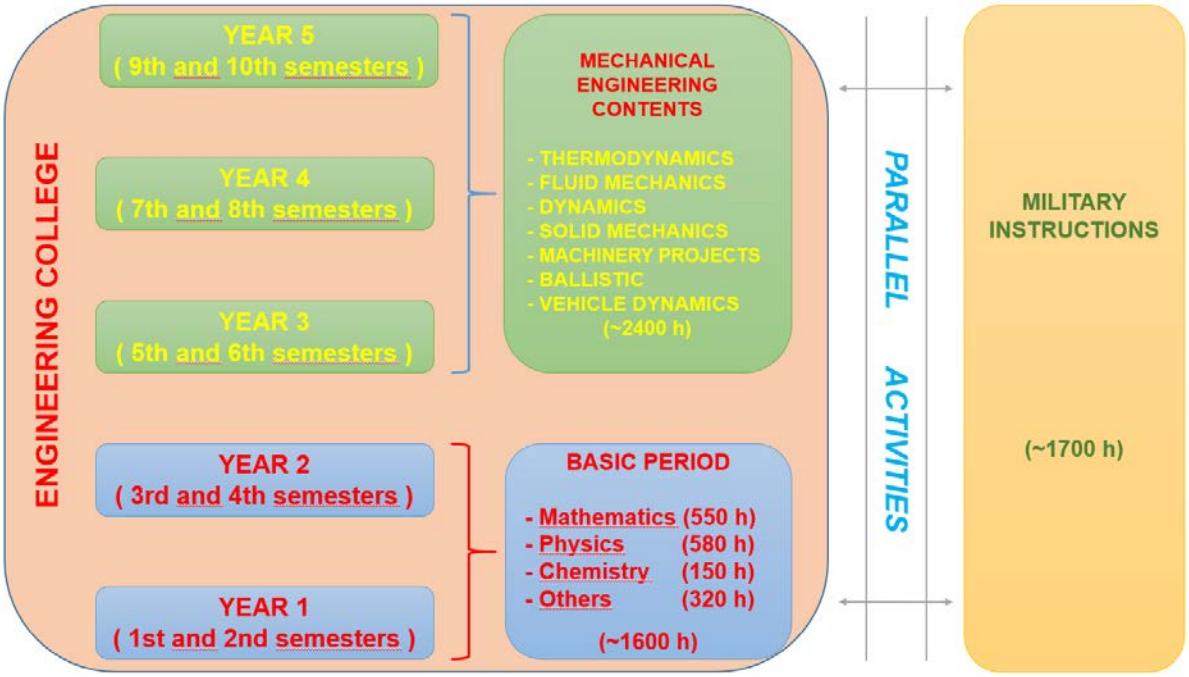

Figure 2. Curriculum structure mechanical engineering in IME.

Since 2012, a project to transform the Brazilian Army's Science and Technology System has been running, involving and introducing new aspects, such as the innovation and triple helix concept (Ranga & Etzkowitz, 2013). It created an opportunity for the mechanical engineering program to initiate a reflection about how to improve and adapt to the formation of the engineer to the new scientific and technological system.

At the same time, in recent years, there has been an increase in student dissatisfaction. This dissatisfaction is mainly related to the large number of theoretical activities in mechanical engineering classrooms. In fact, in the past, IME students had more practical activities. However, recently, education has been based mostly on scientific foundation with or without

practical activities, leading to superficial learning (Elmgren & Henriksson, 2014). This type of feedback was received, to a certain extent, by some engineering institutions of the Brazilian Army.

In 2010, a new activity was included in the mechanical engineering programs, which increased this demand. The students of the fourth year started to participate in international exchanges, created directly by IME or by Brazilian government educational programs, such as Science Without Border (Brazilian Government, 2017a). These exchanges allowed students from IME to attend six months of courses at some renowned engineering international institutions, such as West Point United State Academic, Texas Tech, Massachusetts Institute of Technology, Michigan Technological University, University of Cambridge and ParisTech. The feedback about the student performance, of all these universities, have been excellent. The students that return from the international exchange are very motivated but start to compare this with the IME's mechanical engineering structure. This comparison in relation to learning and teaching methodology, curriculum structure and teaching activities contribute to increasing the dissatisfaction among the students.

The students now have the perception that how the learning and teaching at the mechanical engineering program could change and could be.

In this way, the students forced mechanical engineering in IME to start a process of improvement in their learning process in engineering, despite its excellent results. Based on the demands of the students and the Brazilian Army, and after visiting some universities and analyzing some possibilities, the introduction of the CDIO approach in the IME's mechanical engineering was chosen, at the end of 2014, as the core of this improvement process. The CDIO structure is best suited to mechanical engineering requirements.

INTRODUCTION OF CDIO IN MECHANICAL ENGINEERING – CDIO STANDARD 1

Through presentations and meetings with mechanical engineering program faculty, the problems that generated the lack of motivation for the engineering learning and the current needs of the Brazilian Army and the companies were shown. The following subjects were discussed:

- Very theoretical courses. Lack of practice in disciplines;
- Demotivation for learning;
- Overload of non-academic activities for students;
- Need for integration between disciplines;
- There is no provision of improvement courses in teaching of higher education in engineering; and
- The current needs of the engineering professional – CDIO Syllabus (Crawley et al., 2014).

In this context, the CDIO approach (CDIO Standard 1) was introduced as a solution, providing to the future mechanical engineers the ability to perform their engineering skills with a more mature assessment of how a product meets the real needs of the Brazilian Army and society in general.

It was explained to the mechanical engineering program faculty that this choice was based on the alignment between the desired changes and the CDIO concepts, as shown in Table 1.

Table 1. Desired changes by mechanical engineering program and CDIO

DESIRED CHANGES	CDIO APPROACH
The concept that the engineer education should be based on fundamentals but with a context of Conceive-Designing-Implementing-Operating systems and products.	CDIO Vision and CDIO Standard 1
Creation of new opportunities for students to perform more engineering practice in the academic activities, as elaboration of engineering systems, well-designed work and design-build-test courses.	CDIO Standards 4, 5 and 8
Implementation of teacher training and improvement in new teaching methodologies, encouraging the use of more active learning activities.	CDIO Standards 8, 9 and 10
Inclusion of integrated learning, which means learning experience where the theoretical knowledge and professional skills are obtained simultaneously.	CDIO Standard 3
Implementation of the constructive alignment concept (Biggs, 1996) as a model for courses design, as also executing a revision of the intended learning outcomes and the curriculum of the programs	CDIO Syllabus, CDIO Standard 2, 3 and 12
Introduction the concepts of innovation and triple helix (Ranga & Etzkowitz, 2013) as part of the knowledge, skills and attitudes of the student	CDIO Syllabus

NEW CURRICULUM – SELECTION OF COMPETENCES AND ABILITIES

Starting in 2017, according to the CDIO implementation process diagram (CDIO Initiative, 2017), the selection of the knowledge, skills, and attitudes that engineering students must have when leaving university is the next step in the development of the integrated curriculum (CDIO Standard 2).

The mechanical engineering program began the curriculum design process through a careful study of the CDIO Syllabus 2.0, in order to compare it with the learning outcomes established by the Brazilian education laws, the Brazilian Army and the engineering companies.

For mechanical engineering higher education, the Brazilian law that determines the learning outcomes is called the National Curricular Guidelines for Engineering Undergraduate Programs (Brazilian Government, 2002). In order to exercise the mechanical engineer profession in engineering companies, the Federal Council of Engineering and Agronomy (CONFEA, 1973) establishes the activities, abilities and responsibilities of the engineer.

The knowledge, skills and attitudes, determined by the National Curricular Guidelines of Engineering Undergraduate Programs (Brazilian Government, 2002) and by the Federal Council of Engineering and Agronomy (CONFEA, 1973), present a strong similarity. In this way, Table 2 correlates the demands of National Guidelines and CONFEA with the skills and knowledge proposed by the Sections of the CDIO Syllabus 2.0.

Table 2. Correlation of competences between the Brazilian aspects and the CDIO Syllabus for mechanical engineering program.

Competencies established by the National Curricular Guidelines and by CONFEA		*CDIO Syllabus*
Apply mathematical, scientific, technological and instrumental knowledge to the engineering	➡	Disciplinary knowledge and reasoning
Design and conduct experiments and interpret results	➡	*Personal and professional skills and attributes*
Planning, supervise, elaborate and coordinate engineering projects and services		
Identify, formulate and solve engineering problems		
Develop and/or use new tools and techniques		
Understand and apply professional ethics and responsibility		
Assume the posture of permanent search for professional updating		
Communicating effectively in written, oral and graphic forms	➡	*Interpersonal skills: teamwork and communication*
Work in multidisciplinary teams		
Conceive, design and analyze systems, products and processes	➡	*Conceiving, designing, implementing and operating systems in the enterprise, societal and environmental context – the innovation process*
Supervise the operation and maintenance of systems		
Evaluate the impact of engineering activities in the social and environmental context		
Evaluate the economic feasibility of engineering projects		

There is another important aspect to be considered in the IME, which are the skills and attitudes that the future military engineer should have for the Brazilian Army. Since seventy

percent of the students are military, Table 3 shows the correlation between the skills and attitudes needed for the future Brazilian Army Officer and the CDIO Syllabus.

Table 3. Correlation of competences between the Brazilian Army and the CDIO Syllabus.

Competencies established by the Brazilian Army		*CDIO Syllabus*
Technical-professional	➡	*Disciplinary knowledge and reasoning*
Self-improvement, moral courage, discipline, initiative, objectivity, integrity, dedication, responsibility	➡	*Personal and professional skills and attributes*
Tact, camaraderie, emotional stability, communication, flexibility, leadership	➡	*Interpersonal skills: teamwork and communication*
Creativity and project management	➡	*Conceiving, designing, implementing and operating systems in the enterprise, societal and environmental context – the innovation process*

Both Tables 1 and 2 show that the CDIO Syllabus addresses all the needs of Brazilian education laws, the Brazilian Army and the exercise of engineering activity in companies (CONFEA requirements). Given that the CDIO Syllabus is a current document, covering the needs of the modern engineer, the mechanical engineering program decided to adopt the CDIO Syllabus completely and without any customization. In this way, the CDIO Syllabus 2.0 has been translated into Portuguese and is being submitted to the faculty for further development of the integrated curriculum. To this end, it is intended to use the tools called matrix ITUE Matrices and Black Box exercise (Crawley et. al., 2014).

CDIO IMPLEMENTATION – INITIAL ACTIVITIES

Introductory Engineering Course Implementation – CDIO Standard 4

In 2017, the engineering introduction course was designed to be carried out in two periods, that is, in the third and fourth periods of the second year, as explained in Figure 2.

In the first part of the course, held in the third period, the students learned the methodology of PMBOK project management (PMBOK, 2017), wrote technical reports and made professional presentations. In the second part of the course, held in the fourth period, the students were separated into teams and they received academic projects that had requirements and deadlines to be met.

In this way, the course took place in the year 2018, being considered a success of learning and motivation by students and teachers, according to preliminary qualitative survey.

Introduction of Disciplines for Design-Build Project Development - CDIO Standard 5

The mechanical engineering program decided to include two Design-Build disciplines. One in the sixth and seventh periods, called Initiation to Research, and another in the ninth and tenth periods, denominated Final Project of Course.

In both disciplines, students will use previously learned project methodologies and will perform activities to properly meet project requirements within the established deadlines. These disciplines already exist in the mechanical engineering curriculum of the IME, but they are not of the design-build type.

As an experimental design-build activity, in 2018, students were offered an academic competition for aero model design (Figure 3). The proposed design had simple requirements, such as maximum span length, maximum payload for in-flight transport, deadline for flight test, and written and oral presentation of the final report. With this different activity, it was possible to perceive the enthusiasm, the application of the theoretical concepts learned in the conception and construction of the prototype, the organization for teamwork and, most importantly, the consolidation of the mechanical engineering learning.

Figure 3. Experimental design-build activity

In progress, there are two academic spaces for the development of design-build projects by students. These spaces will be used in the courses of Introduction to Engineering, Initiation to Research and Final Project of Course (CDIO Standard 6).

These academic activities are expected to occur in this year 2019.

Improvement of the Pedagogical Update Stage and School Administration

In the IME there is a preparation for teachers called Pedagogical Update Stage and School Administration (ESTAPAE). This stage was only meant to present the administrative rules for the new teachers.

In order to implement the CDIO approach, ESTAPAE has been reformulated and now has as main objective to promote the updating and improvement of the pedagogical knowledge needed for teachers, instructors and monitors, in order to establish a debate on the feasibility of implementing improvements in the conditions of the process of teaching and learning, especially in the scope of graduation, including discussions on updating the curricular flow, active learning methodologies, evaluation, complementary activities, teaching of engineering in the 21st century, technological innovation, educational legislation and internal teaching standards.

In 2018, the new ESTAPAE was started with the faculty of the mechanical engineering program. Active teaching methodologies and new forms of assessment are priorities for improving the quality of teaching and learning (CDIO Standard 9 and 10).

CONCLUSION

This article showed the initial process of implementing the CDIO approach on Mechanical Engineering Program of the Military Institute of Engineering (IME). The main motivations for adopting CDIO were the transformation process of the Brazilian Army's Science and Technology System and the students' feedback on the need to make the courses more interesting and with academic activities of engineering practices.

From then on, the vision of the CDIO approach was spread among teachers and students. In addition, there was an in-depth study comparing the competencies desired by the Brazilian Government and the Brazilian Army, and the main conclusion was that the CDIO Syllabus can be perfectly used by the IME.

Some academic activities are already being used, aiming at the implementation of CDIO, with great success among students and teachers.

Finally, all this initial process of implementing the CDIO was considered adequate to the needs of the Mechanical Engineering Program. The CDIO approach is being accepted with great motivation. Implementation will continue to occur within the CDIO Standards guidelines.

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