THE INTEGRATION OF CDIO STANDARDS IN THE APPLICATION OF PROJECT BASED LEARNING AS A HANDS-ON METHODOLOGY: AN INTERDISCIPLINARY CASE STUDY IN PRODUCTION ENGINEERING.

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ABSTRACT

The use of active learning methodologies is being discussed more and more by higher education institutions in Brazil and in the world. Technological advances and the differentiated profile of new students are some of the reasons why many institutions are rethinking their teaching and learning processes. In this context, the use of active methodologies in engineering courses has been the subject of constant discussions and questioning by teachers and institutions.

The objective of this work is to report the experience in the application of Project Based Learning in the production engineering course of a University Center in Brazil, which allowed the integration of some CDIO Standards. The main motivation for choosing Project Based Learning was the application of interdisciplinarity and also the need to use a hands-on methodology that would put into practice the theories discussed throughout the project.

The case study presents an overview of the application of Project Based Learing through an integrative project of the 6th semester of the production engineering course that had as its theme the manufacture of orthoses that made possible integration of the disciplines in the semester, integration with the physiotherapy course of the institution. Throughout the case study the integration of some CDIO Standards is also presented.

The method used to collect the data to demonstrate the students' perspective was a two-part survey: at the beginning and at the end of the development of the integrating project. The information obtained shows a greater engagement of students and improvement in the teaching and learning process. The application of new teaching and learning methodologies should be widely discussed with the teachers and coordinators of the courses, in order to first identify which competences they intend to develop and identify the methodology that best applies. The alignment and qualification of all teaching staff for the use of new methodologies in the classroom is of paramount importance and the educational institution must provide actions that contribute to the implementation of new methodologies and resources in the teaching and learning process.

KEYWORDS

Project-based learning, integrative projects, interdisciplinarity, engineering teaching, Standards: 2, 3, 5, 6, 7, 8, 11

INTRODUCTION

The constant changes that occur as a result of the technological advances demand more and more professionals prepared and with a differentiated profile for work in the labor market. The training of an engineer needs to be as complete as possible encompassing both technical competencies and behavioral skills, thus requiring constant changes to adapt to this new reality.

In this context, the use of active learning methodologies play an important role in the formation of the professional future. Among these methodologies is Project Based Learning that places the student at the center of the learning process, identifying a potential problem that can be solved through a project (Lima et al., 2014). Masson et al. (2012) proposes that project-based learning is a systemic approach, involving students in acquiring knowledge and skills through a process of investigation of complex issues, authentic tasks and products, carefully planned for efficient and effective learning. effective.

The application of interdisciplinary projects in undergraduate courses allows a greater commitment on the part of the students, as well as a greater motivation for the studies (Koch et al., 2016). The learning practices provided by project-based learning are being studied and demonstrate the benefits of applying to students. (DeFillippi, 2001).

The CDIO ™ initiative addresses this reality and aims to contribute to the training of the next generation of engineers through 12 standards to describe CDIO programs. These guiding principles were developed in response to program leaders, alumni, and industry partners who wanted to know how they would recognize CDIO programs and their graduates.

The objective of this work is to report the experience in the application of Project Based Learning in the production engineering course of a University Center in Brazil, which allowed the integration of some CDIO Standards.

INTEGRATOR PROJECT

The Production Engineering course at the Toledo Araçatuba University Center - UNITOLEDO, located in the city of Araçatuba, state of São Paulo - Brazil, was launched in 2013, after a survey was made in the region on the demand for qualified professionals to work in the industry regional.

The application of Project-Based Learning reported in this study occurred in the second half of 2017, at the time, with the 6-semester class through an Integrator Project, developed during the semester, whose main objectives were: integration between the subjects of the the use of a hands-on methodology in which Project-Based Learning and the development of skills were used, in addition to the integration with another course of the institution, Physiotherapy, which assisted in the elaboration of the new product.

Table 1 below presents the competencies proposed for development throughout the integrative project.

Table 1. Skills to be developed in the integrative project.

COMPETENCES AND PERSONAL AND PROFESSIONAL ATTRIBUTES (to be developed)	**Reasoning of Engineering and Problem Solving** (Identification and formulation of the problem by models, estimates, analysis and recommendation of solutions)
	Experimentation and Discovery of Knowledge (Hypothesis Formulation and Testing, Survey of Electronic Literature, Experiments)
	Systemic Thinking (Holistic, vision of the whole, urgency, prioritization, focus, trade-offs and balance in resolution)
	Personal Skills and Attitudes (Initiative and willingness to take risks, perseverance and flexibility, creative, critical, time and resource management)
	Skills and attitudes Professional (Ethical behavior, integrity, responsibility, continuous updating, proactive career planning)
INTERPERSONAL SKILLS (to be developed)	**Teamwork** (Effective Leadership Team Formation, evolutionary technical operation)
	Communication (Strategy and structure through writing, oral, graphic and interpersonal)

The professor responsible for conducting the Integrator Project was the professor of the discipline called Manufacturing and Construction Processes II, whose main objective is to present the theory and practice of the development of new products of several industrial segments. The other disciplines participating in the Integrator Project, which are part of the semester of the sixth semester of Production Engineering, and their contributions can be observed in table 2 below.

Table 2. Disciplines participating in the Integrator Project.

SUBJECTS	CONTRIBUTION
Production Planning, Scheduling and Control I	Determine product data sheet and manufacturing process.
Inventory Management	Determine the standardization and coding of materials, components and finished product, as well as stock control.
Supply Chain Management	Determinar a necessidade e gestão dos fornecedores de materiais.
Information systems	Determine the need and management of materials suppliers.
Manufacturing and Construction Process II	Basic discipline for the realization of the Integrator Project. Students will develop a new product through the real needs presented in the integrator project.
Strength of Materials II	Determine the strength of the materials used.
Prosthesis and Orthesis (course of Physical Therapy)	Assist in the development and validation of new products.

As a theme for the application of Project-Based Learning, the orthotics segment was chosen, where students, divided into teams of no more than 5 members, should develop an orthosis to meet a demand from the institution's physiotherapy clinic.

The use of active learning methodologies in the course of Production Engineering has been discussed by the course collegiate, which brings together the course coordinator, teachers and a student representative. The teacher responsible for the discipline that led the project during the semester, held some meetings with the other teachers of said semester in order to present the proposal and seek contributions from the other disciplines for the project that was developed.

The steps of the integrator project were based on the principles of the CDIO framework, as reported by Edström & Kolmos (2014), and can be visualized in table 3 below:

Table 3. Stages of project development.

STAGE CDIO	**MAIN ACTIONS AND DELIVERIES**
CONCEIVE	1- Generation of concept (term of project opening) 2- Project Planning (project scope, product scope)
DESIGN	3- Information Project (QFD) 4- Conceptual Design (EAP, BOM) 5- Detailed Design (Model, FMEA, Drawings)
IMPLEMENT	6- Preparation for Production (cost, process, full-size prototype)
OPERATE	7- Product Launch (marketing) 8- Follow Product / Process (product performance and customer satisfaction) 9- Plan Product Discontinuation

The manufacturing process and the developed product were manufactured in the Laboratory of Production Practices II of the Production Engineering course and are presented in Figure 1 below.

Figure 1. Products developed in the Integrator Project.

According to the data collection method to demonstrate student expectation and perception, and consequently the development of competencies, Table 4 below presents the data collected from the 18 students participating in the project, at the beginning of the project, with the objective of collecting expectations of students. The table shows the number of responses at each of the levels of development of this competence.

Table 4. Data collected with the expectation of the 18 students before the project.

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SKILLS	Be experienced or exposed to ..	Being able to participate and contribute to ..	Being able to understand and explain ..	Be skilled in the practice or application of..	Being able to lead or innovate in ..
SKILLS AND ATTITUDES: PERSONAL AND PROFESSIONAL					
Reasoning of Engineering and Problem Solving (Identification and formulation of the problem by models, estimates, analysis and recommendation of solutions)	10	3	2	2	1
Experimentation and Discovery of Knowledge (Hypothesis Formulation and Testing, Survey of Electronic Literature, Experiments)	7	3	3	5	
Systemic Thinking (Holistic, vision of the whole, urgency, prioritization, focus, trade-offs and balance in resolution)	6	6	3	3	
PERSONAL SKILLS AND ATTITUDES (Initiative and willingness to take risks, perseverance and flexibility, creative, critical, time and resource management)	8	3	5	2	
Skills and attitudes PROFESSIONAL (Ethical behavior, integrity, responsibility, continuous updating, proactive career planning)	3	9	2	4	
INTERPERSONAL SKILLS: COMMUNICATION AND MULTIDISCIPLINARY TEAM					
Teamwork (Effective Leadership Team Formation, evolutionary technical operation)	2	7	9		
Communication (Strategy and structure through writing, oral, graphic and interpersonal)	8	3	5	2	

At the end of the project, the data were collected again with the objective of collecting the students' perceptions, which shows an evolution by the total number of students who demonstrated a higher level of proficiency after the project was carried out. The data obtained can be visualized in Table 5 below.

Table 5. Data collected with the perception of the 18 students after the project.

SKILLS	Be experienced or exposed to ..	Being able to participate and contribute to ..	Being able to understand and explain ..	Be skilled in the practice or application of..	Being able to lead or innovate in ..
SKILLS AND ATTITUDES: PERSONAL AND PROFESSIONAL					
Reasoning of Engineering and Problem Solving (Identification and formulation of the problem by models, estimates, analysis and recommendation of solutions)			2	7	9
Experimentation and Discovery of Knowledge (Hypothesis Formulation and Testing, Survey of Electronic Literature, Experiments)			3	12	3
Systemic Thinking (Holistic, vision of the whole, urgency, prioritization, focus, trade-offs and balance in resolution)		1	3	7	7
PERSONAL SKILLS AND ATTITUDES (Initiative and willingness to take risks, perseverance and flexibility, creative, critical, time and resource management)		1	1	4	12
Skills and attitudes PROFESSIONAL (Ethical behavior, integrity, responsibility, continuous updating, proactive career planning)	1		1	6	10
INTERPERSONAL SKILLS: COMMUNICATION AND MULTIDISCIPLINARY TEAM					
Teamwork (Effective Leadership Team Formation, evolutionary technical operation)		1		9	8
Communication (Strategy and structure through writing, oral, graphic and interpersonal)	1	1	3	8	5

The integrative project presented in this study demonstrates the integration and application of some CDIO Standards, as presented in Table 6 below:

Table 6. CDIO Standards developed in the integrator project.

CDIO Standards	Description	Note
2. Learning Outcomes	Specific, detailed learning outcomes for personal and interpersonal skills, and product, process, and system building skills, as well as disciplinary knowledge, consistent with program goals and validated by program stakeholders	We identified the personal and interpersonal skills to be developed throughout the project, as well as the skills of building products, processes and systems.
3.Integrated Curriculum	A curriculum designed with mutually supporting disciplinary courses, with an explicit plan to integrate personal and interpersonal skills, and product, process, and system building skills	The course subjects allow integration for the development of multidisciplinary projects.
5.Design-Implement Experiences	A curriculum that includes two or more design-implement experiences, including one at a basic level and one at an advanced level	The disciplines allow each semester to elaborate integrative projects with the theme of development of new products, processes or systems.
6.Engineering Workspaces	Engineering workspaces and laboratories that support and encourage hands-on learning of product, process, and system building, disciplinary knowledge, and social learning	The institution's laboratories used in the project allow the production of products from several industrial segments.
7. Integrated Learning Experiences	Integrated learning experiences that lead to the acquisition of disciplinary knowledge, as well as personal and interpersonal skills, and product, process, and system building skills	The integration with another course of the institution throughout the integrating project made possible the exchange of information and experiences that contributed to the development of established competencies.
8.Active Learning	Teaching and learning based on active experiential learning methods	The use of Project Based Learning enabled the use of active learning methodologies including students at the center of the teaching and learning process.
11.Learning Assessment	Assessment of student learning in personal and interpersonal skills, and product, process, and system building skills, as well as in disciplinary knowledge	Data collection before and after the project made it possible to evaluate the evolution of the students and also of the learning process.

DISCUSSIONS AND CONCLUSIONS

With the application of project based learning through the integrator project applied in a class of students of the course of Production Engineering, it is possible to identify an evolution of the students who have evaluated themselves in two moments of the application of the project, since in the second evaluation made at the end of the project the proficiency level of the competences had a greater weight than the first evaluation made before the beginning of the project.

As for the evaluation of the educational process that was discussed among the professors who ministered the disciplines integrating the project, the application of the project based learning made it possible to integrate the contents of most of the disciplines of that semester, taking the subject of multidisciplinarity in the discussions of the groups of students .

The case presented in this article demonstrates the contribution that the active learning methodologies can provide the improvement of the teaching and learning process, according to the information obtained in the data collections with the students. A very important factor that has been the subject of doubts in higher education, particularly in engineering courses, is precisely the way to apply the practice along with the theory exposed in the classroom. Another issue is the development of behavioral skills such as leadership, teamwork and conflict resolution, which are just as important as technical skills and the use of active learning methodologies provide support for this development, generating better results in the teaching and learning process .

The application of new teaching and learning methods should be widely discussed with teachers and course coordinators in order to identify first what skills they intend to develop and how to identify which methodology is best applied. Alignment and training of all faculty for the use of new methodologies in the classroom is extremely important and the educational institution should provide actions that contribute to the implementation of new methodologies and resources in the teaching and learning process. The experience acquired in the application of project-based learning brought satisfactory results, which allowed several discussions between teachers and course coordinator in the methodology for application in the next semesters and also for its application in other engineering courses of the institution. Additional research should be done to identify the profile of the student entering higher education in order to assess the paradigm shift and the problem of drop-out and how the use of active learning methodologies can contribute positively to these issues.

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Sergio Ricardo Mazini is a coordinator and professor of the course of production engineering, holds a master's degree in production engineering. He participates in the Nucleus of Innovation and Academic Formation of the institution that is responsible for the continued formation of the teachers.

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