

Embraer High School: Engineering in the Preparation for College Program

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ABSTRACT

Embraer was created in 1969, through a government investment in the 1950s, to develop the capacity to design and manufacture airplanes in Brazil. In 2002, as a social responsibility initiative, Embraer launched a high school to help less privileged students coming from public schools. The main objective of Juarez Wanderley Embraer High School (JWEHS) is to improve student access to higher education institutions. JWEHS's Preparation for College (PFC) program was launched in 2004 to help students a) be better prepared to choose careers, b) get and keep internships and jobs while in college, and c) prepare to become better university students and professionals. In 2006, for the students who aimed to apply for engineering courses, a program titled Pre-Engineering (PE) was implemented. PE is organized in three phases. The first phase is oriented to personal development for career success and teaches competencies such as problem solving, critical thinking, teamwork, communication, and leadership. The second phase is oriented to engineering. Disciplines included in this phase are i) principles of technology, ii) material sciences, and iii) electrical, electronic, and digital systems. The third phase consists of a capstone project in which student teams participate in design-build experiences. Since 2010, more than 80% of participating students have been admitted to the best Brazilian universities. In 2010, JWEHS was ranked 30th nationwide. The objective of this paper is to present assessment results coming from a longitudinal study designed to evaluate the impact of the PE program. Surveys were administered to JWEHS alumni. Findings show that students recognize the value of the following competencies addressed through the PE program: handling lab equipment, teamwork, communication, problem solving, autonomy, working under pressure, and leadership. Examples of capstone projects are also presented.

KEYWORDS

Personal and professional skills, teamwork, hands-on activities, career pathway, social responsibility, enriched knowledge, design-build experiences, Standards: 1, 3, 5, 8

INTRODUCTION

Juarez Wanderley Embraer High School (JWEHS) was founded in 2002 in São José dos Campos, São Paulo, Brazil, through an Embraer Institute for Education and Research (IEEP in Portuguese) initiative designed to prepare students who have concluded their fundamental education in public schools to gain access to the best universities in the country, without the need for additional preparatory courses. Furthermore, the Embraer Institute believes that it is

possible to turn students into leaders in societal evolution through the comprehensive, global view of the world that JWEHS provides.

To be admitted to JWEHS, students take part in a rigorous and competitive entrance exam. The current “candidates to vacancy rate” is approximately 20:1. Those admitted attend three high-school grades (full-time, 10 hours/day) specially crafted to develop academic skills focused on social, cultural, environmental, and career-oriented activities. This “model” encompasses three broad programmatic areas: High School Content, the Preparation for College Program (PFC), and the Sustainable Alternatives and Socio-Cultural Activities Program. The three areas are interconnected and complementary, linking high school to university education, the workplace, and life (see Figure 1).

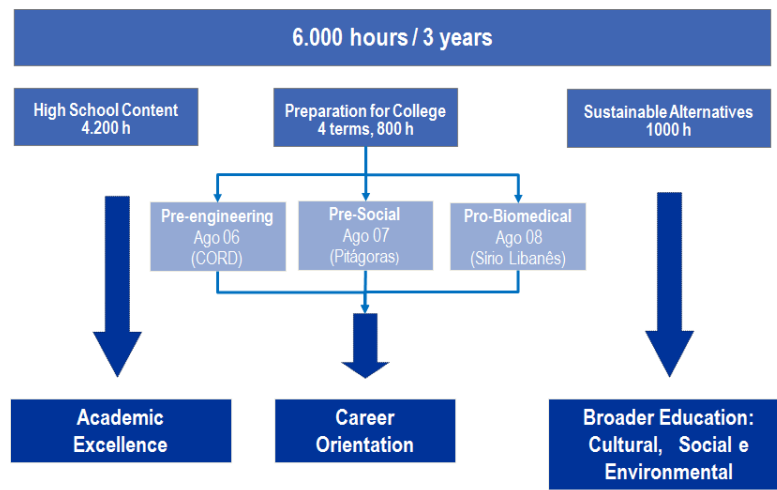


Figure 1: JWEHS Pedagogical Approach (Juarez Wanderley Embraer High School, 2014)

The PFC Program goals are two-fold. First, the program helps students make better academic choices. Second, it provides students with the skills necessary to earn extra income while in college to support themselves in cities away from their hometowns. The PFC Program is organized in three areas: **Pre-Engineering**, designed for students who intend to pursue careers in engineering; **Pre-Social Sciences and Administration**, designed for those who plan to pursue careers in fields such as business, economics, and advertising; and **Pro-Biomedical Sciences**, which targets future professionals in healthcare. The PFC Program is an educational experience, developed and implemented within the school, with the help and participation of experts in Brazil and from other countries, and with the collaboration of professionals in management and training in large companies such as Embraer.

The Pre-Engineering program (hereafter “PE”), the primary topic of this paper, was developed and implemented with the support of CORD (Center of Occupational Research and Development), an educational nonprofit organization in Waco, Texas, with more than 30 years of experience in the United States and internationally. The PE program is designed to help students choose career pathways and build a broader and deeper base of enriched knowledge to ensure better performance in university courses.

The PE courses are structured in three phases. Each phase aims to help students acquire critical skills related to important aspects of engineering careers. The first phase focuses on

basic subjects and addresses personal development for career success (problem solving, critical thinking, teamwork, communication, leadership, and the like) and IT tools for engineering (Internet, Microsoft Office, CAD). The second phase is more technology oriented and aims to get students into the world of engineering. Disciplines included in this phase are i) principles of technology (mechanical, electrical, thermal, and fluid systems), ii) the nature of things (metals, ceramics, polymers, and composites), and iii) electrical, electronic, and digital systems. The third phase consists of a capstone project in which student teams participate in design-build experiences (see Figure 2).

	Semester			
	1	2	3	4
Preparation for Work	Personal Development for Career Success (40 h)			
	Computer and Internet Tools for Engineers (40 h)			
Some Principles of Engineering	Principles of Technology I (80 h)	Principles of Technology II (80 h)	Principles of Technology III (60 h)	
		Electricity CC/CA (40 h)	Basic Electronics (40 h)	Digital Electronics (40h)
		Nature of things I (40 h)	Nature of things II (40 h)	
Learning by Doing			Capstone Project (120h)	Capstone Project (120h)

Figure 2: Pre-Engineering Courses Organization (Bond and Navarra, 2012)

The first phase comprises two courses. **A) Personal Development for Career Success** encourages the student to explore career options, discuss ethical and legal engineering issues, plan career fairs, and develop a portfolio of skills obtained during the course, such as problem solving, critical thinking, organization, goal setting, teamwork, leadership, time and resource management, research, and communication. **B) Computer and Internet Tools for Engineering** equips students with IT tools and skills that are transferable within a wide range of engineering environments. Students learn to use spreadsheet, database, word processing, presentation, and project-planning software and to apply career-specific concepts such as project planning and control, human factors, product life cycle, management of innovation, system thinking, and integrated product development.

The second phase focuses more on technical issues and comprises four courses. **C) Principles of Technology** involves application and integration of the four principal energy systems (mechanical, electrical, thermal, and fluid) and focuses on fundamental physics principles such as force, work, rate, resistance, energy, power, momentum, and transformers. Knowledge and skills are acquired through hands-on activities in lab settings that involve devices such as transducers, insulation pumps, pressure regulators, pulleys, multimeters, oscilloscopes, power supplies, motors, wattmeters, thermistors, photometers, and stroboscopes. **D) The Nature of Things/Materials Science** integrates physics, chemistry, and biology in the exploration of materials and how they are used in today's high-tech industry environment. In lab classes students identify the properties and uses of metals, polymers, ceramics, and composite materials, in preparation for workplace settings in which they would classify, form, shape, and alter the physical properties of materials using the appropriate equipment and procedures. **E) DC/AC Electricity** helps students understand the general characteristics of DC/AC electrical circuits; how DC and AC power differ; and how to set up, operate, and troubleshoot circuits. In lab settings, students learn how to use components and instruments such as DC/AC power sources; signal generators; dual-trace oscilloscopes; multimeters; resistors; capacitors;

inductors; switches; potentiometers; PN, NPN, and PNP junction transistors; and solenoids. Finally, in **F) Digital Electronics** students learn the differences between analog and digital circuits; compare binary and decimal numbering systems; and build integrated circuits on semiconductor materials using resistors, capacitors, and transistors. They also learn the use of logic families and basic gates in digital circuitry, along with the use of frequency counters, low-voltage power supplies, AND-OR logic gates, NOT-NAND-NOR logic gates, and buffers and inverters.

The third phase of PE consists of a **Senior Final Comprehensive Project** in which student teams participate in design-build experiences. The challenge is to solve real-world engineering problems using and consolidating the knowledge and skills acquired through the previous semesters of the PE program.

The goal of this paper is to present the assessment results from a longitudinal survey designed to evaluate the impact of the PE program. The survey targeted PFC students and teachers, former PFC students, and university professors. The survey was administered to JWEHS alumni, who are finalizing their engineering courses this year.

PE VERSUS CDIO

Although the PE program was originally designed with different objectives, its structure is closely related to CDIO building blocks as presented in Figure 3. The first point of similarity is recognition of the need to develop personal, professional, and interpersonal skills as a basis for the competencies necessary to design and build engineering solutions. Another positive side effect of developing those soft skills (as envisioned by the PE pioneers and observed by JWEHS teachers) is that the students are better motivated and show more focus on learning hard skills such as math, physics, and chemistry. A second point of similarity is the use of capstone projects to create conditions in which students see the connections between technical disciplines and business, society, and the environment.

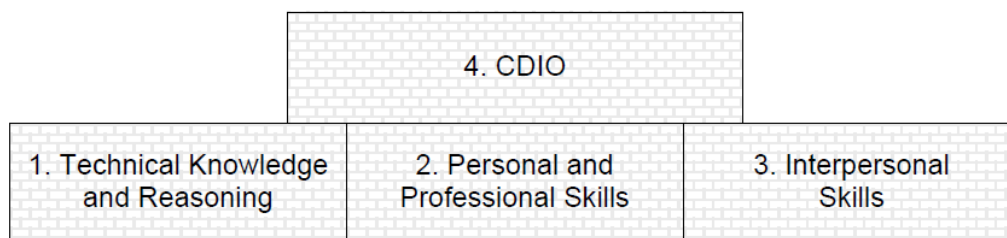


Figure 3. CDIO Building Blocks
(Crawley et al., 2011)

Table 1 presents more information about each building block. The following remarks identify links between the structure of the PE program and the CDIO syllabus.

Table 1. CDIO Syllabus V 2.0
(Crawley et al., 2011)

<p>1 DISCIPLINARY KNOWLEDGE AND REASONING</p> <p>1.1 KNOWLEDGE OF UNDERLYING <u>MATHEMATICS AND SCIENCE</u></p> <p>1.2 CORE FUNDAMENTAL KNOWLEDGE OF ENGINEERING</p> <p>1.3 ADVANCED ENGINEERING FUNDAMENTAL KNOWLEDGE, <u>METHODS AND TOOLS</u></p> <p>2 PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES</p> <p>2.1 <u>ANALYTICAL REASONING AND PROBLEM SOLVING</u></p> <p>2.2 <u>EXPERIMENTATION, INVESTIGATION AND KNOWLEDGE DISCOVERY</u></p> <p>2.3 SYSTEM THINKING</p> <p>2.4 <u>ATTITUDES, THOUGHT AND LEARNING</u></p> <p>2.5 <u>ETHICS, EQUITY AND OTHER RESPONSIBILITIES</u></p>	<p>3 INTERPERSONAL SKILLS: TEAMWORK AND COMMUNICATION</p> <p>3.1 TEAMWORK</p> <p>3.2 COMMUNICATIONS</p> <p>3.3 COMMUNICATIONS IN FOREIGN LANGUAGES</p> <p>4 CONCEIVING, DESIGNING, IMPLEMENTING, AND OPERATING SYSTEMS IN THE ENTERPRISE, SOCIETAL AND ENVIRONMENTAL CONTEXT</p> <p>4.1 EXTERNAL, SOCIETAL AND <u>ENVIRONMENTAL CONTEXT</u></p> <p>4.2 ENTERPRISE AND BUSINESS CONTEXT</p> <p>4.3 <u>CONCEIVING, SYSTEMS ENGINEERING AND MANAGEMENT</u></p> <p>4.4 DESIGNING</p> <p>4.5 IMPLEMENTING</p> <p>4.6 OPERATING</p>
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The **first phase** of the PE program focuses on three areas: a) interaction with others (communication and teamwork, which are represented by the third block in Figure 3); b) personal values (attitudes, ethics, and other responsibilities, which are part of the second block in Figure 3); and c) the right use of engineering methods and tools (the third section of the first block in Figure 3).

The **first phase** focuses on the following: i) **personal development for career success** and ii) **computer and Internet tools for engineering**. The first step in this phase involves helping students learn about different types of engineering careers. Students use online tools to do their research and use presentation tools to show each other what they have learned about engineering careers. The second step involves helping students define their professional goals and anticipate time and finance management issues associated with their career choices. During the next steps, students learn to use spreadsheets, define document layout, create presentations, and manage projects with the right tools. Students learn how to communicate orally, graphically, and in writing, and to understand the content of communication based on its purpose and intended audience. They also learn to demonstrate the results of an investigation, the operation of equipment, and steps involved in various procedures so that others can replicate them correctly and safely. The next step is to show the students how to act in negotiations and conflict resolution situations, how to respond to different leadership styles, and how to deal with diversity issues. And, finally, in this first phase students learn to present themselves professionally and to advance in their careers, always taking into account workplace values, ethical considerations, and good work habits.

The **second phase** of the PE program focuses on technical issues and includes three content areas: principles of technology (mechanical, electrical, thermal, and fluid systems), ii) the nature of things (metals, ceramics, polymers, and composites), and iii) electrical, electronic, and digital systems. Those disciplines are presented to the students via practical experiences that allow them to discover concepts and acquire knowledge with investigation and experiments. Students are able to create and study different systems and to identify problems during experiments. Those aspects are reflected in topics 1 and 2 of Table 1.

Still in the **second phase** of PE, the experiments are explained and confirmed by theoretical classes in which the students record their results, make calculations, and research the experiments. Those actions help them to understand the practical aspects of different engineering fields. Through those experiments, students acquire enough mathematics and science knowledge to organize their own engineering projects; this completes the sections of the first block themes in Table 1, Disciplinary Knowledge and Reasoning.

The **third phase** of the PE program consists of capstone projects in which student teams participate in design-build experiences. The first step of this phase is to propose projects. Students show how their proposed projects impact society, the environment, and/or business and industry (sections 4.1, 4.2, and 4.3 from the fourth block – Table 1); identify the equipment needed; create lists of materials; estimate the time required for completion; and assign the appropriate number of students with the interests and aptitudes needed to carry out the projects (project design – 4.3 - concluded). Students organize their teams and identify what each team member must do to accomplish the required tasks within the estimated time (as agreed upon with the teacher). Only projects that can be implemented within the estimated timeframe are approved; all students participate in the implementation (4.4). The projects that are implemented stay at the school and are supported by the next class of students in the course (4.5). This is the final step in the development of a good engineer.

RESULTS

The first cohort of students who graduated from the PE program left JWEHS in 2008. Since then, a longitudinal evaluation process has been applied to determine the impact of the program on former JWEHS students through their academic (university) and professional lives. Figure 4 describes the control points used for assessment and evaluation.

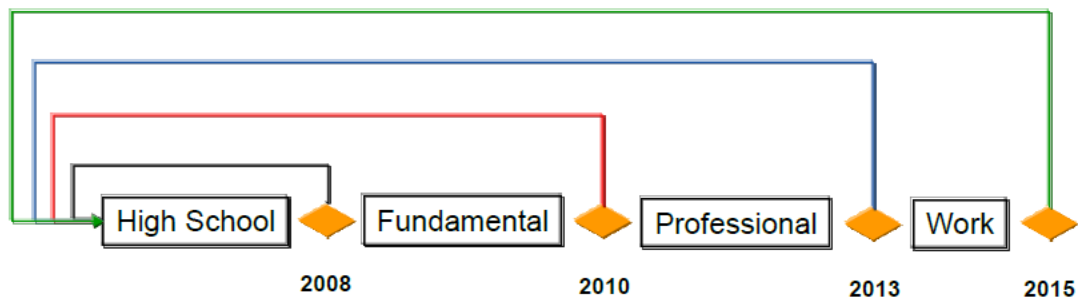


Figure 4. Control points for evaluation process (Lourenção & Ferraz, 2012)

The goal of the evaluation is to assess the effectiveness of the PE program in helping students to a) be better engineering students, b) get internships or jobs, and c) become better engineers (Lourenção & Ferraz, 2012).

Surveys were administered to a) current students in the final semester of high school, b) JWEHS teachers, and c) former students and professors from the universities where those students are enrolled in undergraduate courses. Information and data were collected through focus groups, interviews, and surveys using both open-ended and multiple-choice questions (using a LIKERT type scale).

With respect to the first objective—to help students choose better university courses—Figure 5 presents the results taken by the first group of students who left JWEHS in 2008 and are finalizing their undergraduate courses in 2014–2015.

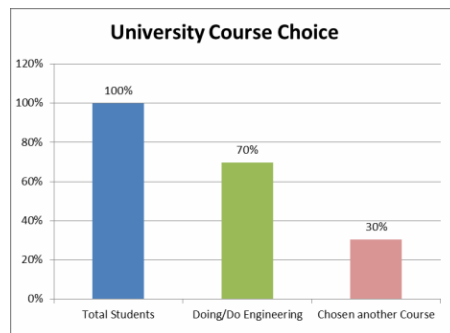


Figure 5. How the PE program helped to choose university course

Among the students enrolled in engineering courses, 96% have been admitted to the best Brazilian public universities, and 70% of the respondents stated that PE participation was decisive in their choices. The other 30%, although not enrolled in engineering courses, also stated that PE participation helped them to decide about courses.

With respect to the second objective—to help students get internships or jobs—the respondents agreed that this objective was reached, since the majority got paid positions that enabled them to defray their living expenses and gain professional experiences. The main paid activities performed by the students were scientific initiation, company and university internships, foreign exchange, junior companies, and lab monitoring.

With respect to the third objective—to help students become better engineers—the respondents indicated that the skills they acquired through the PE program set them apart from other engineering students. More than 90% of the respondents (out of a total of 72 from 2010, 2011, and 2012) highlighted the following skills they acquired: teamwork, responsibility and commitment, “get the job done attitude”, autonomy and independence, previous engineering contact, career selection, communication, skills for public speaking, report writing, scientific method, equipment handling, initiative and creativity, leadership, time management, and forecasting and avoiding problems.

DESIGN-BUILD PROJECTS

This section describes five of the senior projects performed by JWEHS students during the last PE semester. These design-build projects integrate the subjects covered in the previous semesters and provide an opportunity for students to use skills acquired through the PE program.

Electronic Scoreboard

This project was developed by the students to track the scores and times of the games performed on the high school’s multisport court. It used electric and electronics concepts acquired through PE. It was the first project developed after implementing the PE program.

Although the project did not place strong emphasis on mechanical engineering concepts, it involved a real-world situation and was closely connected to the needs of the school.

Automatic Irrigator

This project integrated two programs developed by JWEHS: PE and Sustainable Alternatives. The objective was to design and build an automatic irrigator to supply water to plants. The main concepts used were mechanical fluids and electronics.

Green Pump

This project developed a water pumping system powered by solar energy. The main concepts involved were mechanical, fluid, and thermal energy.

Sustainable House

This project consisted of designing a house with sustainable materials. The project included the logical distribution of materials so as to maximize the effects of prevailing climate conditions. It absorbed most of the solar energy available. The project used civil, mechanical, energy, and fluid concepts. Figure 6 shows parts of the project that were designed and built by the students.



Figure 6. PE students involved with the sustainable house project

Bike energy

The objective of this project was to design and build a system that can absorb clean energy from a stationary bike placed in the high school gym. The solution developed by the students used mechanical and electrical concepts.



Figure 7. PE students involved with the bike energy project

COMMENTS AND CONCLUSIONS

This paper presents results from an assessment coming from a longitudinal survey designed to evaluate the impact of the Pre-Engineering Program implemented at Juarez Wanderley Embraer High School. The PE program was launched with three main purposes: a) to help students choose engineering careers and become better learners, b) to provide students with the skills necessary to get part-time jobs as interns or lab assistants, and c) to provide the basis for these students to become better engineers in the future.

In the introduction, the PE program organization and disciplines are presented. In the next section, the PE program is compared with the CDIO structure and important similarities are identified.

Evaluation cycles were proposed to find positive points and opportunities for program improvement. Information was collected from several actors, including alumni and university professors involved with them. The main points identified from the survey are related to the impact that the PE program had on the development of personal and interpersonal skills that helped the students as undergraduates.

To summarize, interesting key findings are as follows: a) The “school within a school” structure works well in the PE context, with participating students developing their competencies in a contextual manner through labs with hands-on activities and design-build projects. b) Although technical skills are addressed in the program, the students recognize more value in personal and interpersonal skills, which are in high demand in today’s professional activities.

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BIOGRAPHICAL INFORMATION

Paulo T. M. Lourenção Dr. Sc. is Technical Coordinator for the Engineering Specialization Program at Embraer. He has experience in the areas of Experimental Aerodynamics, Dynamics and Control of Aerospace Vehicles, and Advanced Training of Engineers. In addition to

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