

Engineering project driver: fostering innovation and core values in technology education

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Abstract

This paper relates important concepts for technological professional education: interdisciplinarity, social and environmental responsibility, skills, innovation and knowledge management. In dealing with human capital, we present the organizational culture and the organizations that learn. In seeking elements on the composition of an academic environment, in the elaboration of its guidelines and the formation of human capital for scientific and technological development, the model of the Scientist Needs Hierarchy was used. The objective of this work was to identify through a multiple case study how students of CEFET/RJ technological education use these concepts in their pedagogical practices. By encouraging these projects, HEIs can contribute to the formation of a new model of institutional culture, which is based not only on training excellent professionals, but on changing the behavior of individuals to more conscientious citizens.

Keywords

Technological Professional Education, Interdisciplinarity, Social and Environmental Responsibility, Innovation and Knowledge Management.

1. Introduction

Innovation has become a key factor for survival in the business world: whether for the small entrepreneur or for large corporations. His perspective was based on a strong projection in economics and interpreted by areas such as sociology, engineering and technology management.

Some critics have argued that technical schools have distanced themselves from their primary purpose: the preparation of labor for industry. This view is mistaken and based on a perception of an outdated professional profile. In order to train new professionals, a paradigm shift based on a technology education that combines, at all levels, core values in technological education as well as fostering innovation is required.

This paper presents Technological Education students who embedded innovation within interdisciplinary approach based on competencies and core values such as ethical, social and environmental responsibility at Cefet/RJ, a higher education public institution established in Rio de Janeiro.

2. Fostering innovation and core values in technological education

Although preliminary studies on organizational learning date back more than half a century (Argyris, 1964), only at the end of the last decade of the twentieth century, a significant advance was seen in the generation of scientific knowledge: the landmark of this change was the publication of Peter Senge's *The Fifth Discipline*.

From the beginning of the 21st century, a stream of authors can be observed (Easterby-Smith and Araújo, 2001; Loiola and Bastos, 2003; Porto, 2008) indicate two predominant lines about learning approaches at the organizational level: those of organizational learning and learning organizations. And how does organizational learning and innovation processes initiate their interaction? In this section, some of these perspectives will be presented through the main concepts considered in this research: interdisciplinarity, social and environmental responsibility, skills, innovation and knowledge management. Finally, Scientist Needs Hierarchy Theory will be presented to contextualize this multiple case study.

2.1 Interdisciplinarity and Social-Environmental Responsibility

According to Fazenda (1991), in an interdisciplinary field, doing research means the search for the collective construction of new knowledge. For Huutoniemi et al. (2010), interdisciplinary research challenges the establishment of a traditional and unified concept. Interdisciplinarity can also be considered as a complement and alternative to current thinking (Alvarenga et al. 2005; Sommerman, 2006). However, in its context, interdisciplinarity is more than just an 'integration between knowledge areas'. Interdisciplinarity is a completely new way of producing knowledge in science because:

“There are many problems in society which cannot be fully addressed by one scientific discipline. Examples are global warming, natural resource management and poverty alleviation [...] No single discipline has a monopoly in defining what such problems are. Therefore, drawing on several disciplines may be helpful to planners and decision-makers” (Buanes and Jentoft, 2009, pp.446-447).

Sustainability aims to achieve and maintain the quality of life, both in times of availability and lack of resources, through actions based on cooperation and solidarity between peoples and future generations. Sachs (2009) puts social dimension ahead of the environmental one in terms of importance in the attempt to highlight sustainability faces, often perceived "only" as environmental (Maruyama et al, 2017).

For Barbieri (2011), environmental education should stimulate people to be solutions and not just denunciations, although these should be the first attitudes in the face of social and environmental disorders. It should also produce changes in your own behavior, for example by changing your eating habits. According to Tauchen and Brandli (2006), although they represent only 0.5% of the total number of Higher Education Institutions in Brazil, HEIs have great potential for generating significant environmental aspects.

2.2 Competencies and knowledge management

Maruyama and Maciel (2015), before considering innovation as a factor not only in favor of the transformation of education, but also as an important agent of scientific production and national technology raised the question: Can innovation be learned? Knowledge Management, individual and organizational learning, interdisciplinary and organizational culture were taken into consideration when analyzing corporate environment in this study.

According to Schuler (1992), strategic human resource management (SHRM) focuses on the relationship between individual motivations and performance and business development strategy. Lacombe (2005) defines that company culture is a precious resource management and can be used to achieve strategic objectives by aligning technology, production inputs, equipment, financial and human resources through its symbols, codes and value.

Knowledge management (KM) ability emerges as mediator between strategic human resource practices and innovation performance (Maruyama and Braga, 2014). Davenport and Vopel (2001) assert organizations must learn to employ knowledge workers from their attitudes and motivation in relation to knowledge. Furthermore, Takeuchi and Nonaka (2008), the renowned Japanese authors, consider knowledge an internal process within the individual person and then, externalized. In this sense, KM is suggested to be the core strategy for competitiveness in organizations (Bem et al., 2013).

2.3 Innovation and university-enterprise interaction

The review of the various perspectives on innovation shows the importance of scholars and scientists know the distinctions between the types of approaches to the theme. Although innovation had its importance recognized in the 1990s in Brazil, it had not yet been assimilated at the end of this decade. Brazil's industry results were still quite modest in terms of innovation (Cassiolato, Lastres, 1998).

The role of academia has undergone number of changes through academic revolutions: in the first, universities were taught and researched; in the second revolution, they are now seen as agents promoting the country's economic development. The Triple Helix model (Etzkowitz, 2008) presents the university-industry-government interaction and is the key to innovation in knowledge societies that aims to address the following questions: How to enhance the role of universities in regional and social economic development? How can governments encourage citizens to play an active role in promoting innovation? How can these citizens seek this government support to innovate? How can companies collaborate with each other, government and universities to become more innovative? What are the critical elements to achieve these goals?

Gassmann, Enkel and Chesbrough (2009) summarize the three main processes that can be differentiated in terms of how to make open innovation: (i) outside-in; (ii) inside-out; (iii) coupled. The precepts of open innovation, in particular the three sets of processes presented, seem to be useful tools for Technological Innovation Centers to use in their

interaction with companies. Cassiolato and Lastres (2005), renowned researchers in the field of innovation in Brazil credit the first definitions of National Innovation System - SNI, to the works of Freeman (1987), Lundvall (1992) and Nelson (1993).

Although the approaches to open innovation, Triple Helix, and National Innovation System are not exactly in harmony with each other, they seem to converge with the functions that university Technology Innovation Centers (NITs) seem to play in: relating teaching activities, research and extension with the demands, especially those coming from the companies (Rapchan et al, 2017).

2.4 Scientist Needs Hierarchy

The Scientist Needs Hierarchy proposed by Maruyama and Braga (2013), was used as a proposed approach to CEFET/RJ and presented to interpret the possible roles that teachers and students may play within the institution depending on its objectives, motivations and achievements (Figure 1).



Figure 1. Scientist's hierarchy of needs

What many proposals focused on the innovation process and especially on education do not consider is that there is a crucial component in the development of any technique - human behavior. This behavior is not linear and varies according to the needs and expectations of individuals. To substantiate a proposal for an approach to stimulate the technological innovation requires consideration of this fact, especially if the positive results from this change remain continuous. The analogy of Maslow's hierarchy of needs with that of scientists themselves assumes that each phase in the development of a professional or scientist requires meeting a specific need.

Currently, considering all the aforementioned concepts, the main challenge of CEFET/RJ is to show how the incorporation of attitudes, converging in sustainable practices and rationalization of expenses, in operational day-to-day university campuses in teaching, research, extension, considering environmental and ethical issues (Maruyama et al, 2018; Zeitone et al, 2019).

3. Cefet/RJ multiple case study

Cefet/RJ had its origin in 1917 as Wenceslau Brás Normal School of Arts and Crafts. On June 30, 1978, through Law 6,545, it was transformed into Centro Federal de Educação Tecnológica Celso Suckow da Fonseca. It offers technical courses integrated to secondary, post-secondary, technological, undergraduate, masters and doctorate degree, including both local and distance modalities. Nowadays, this HEI counts on more than 1,500 employees and 16,000 students.

Since 2016, supported by a guiding teacher, students took advantage of all break intervals between classes to study, practice and research. Practice in assembly and product development provided an extra-curricular experience favorable to their formal education, supported by project-based learning approaches. Due to the integrative character of this project, elements of technological education, management tools, constructivist approach, added to technical content on solar energy and recycling, were contemplated.

From Administration concepts, with the objective of collaborative work in Engineering, it was possible to make the first interdisciplinary contact among students and teachers to discuss these projects and their action plan. However, one issue bothered the project's guiding teachers: Would it be possible to keep these projects active with other students in the future? Some already published papers (Quintanilha et al, 2016; Brito et al, 2017; Guimarães et al, 2018; Gouveia et al, 2019) stated the initial stages of this successful story. The following projects (Figure 2) belong to mixed portfolio in different maturity levels in education research.



Figure 2. Cefet/RJ Technology Student's scientific portfolio

3.1 Soyuz

The Soyuz team, an OBR participating team was selected to participate in the survey. Because OBR itself requires students to meet various deadlines and goals in pursuit of a functional 'final product', it is characterized as a project. The Brazilian Robotics Olympiad (OBR) is a Brazilian scientific Olympiad that has been held since 2007 and is currently considered the largest robotics event in Latin America, supported by the National Council for Scientific and Technological Development (CNPq), Ministry of Education (MEC) and Ministry of Science, Technology, Innovations and Communications (MCTIC).

3.2 Alçar

The Alçar project works as a consultancy, only with an exclusively educational and pedagogical focus. Made for and by students, Raise aims to spread learning based in projects for more and more students, reinforcing the importance of combining theory with practice to maximize learning. How does this project work? Through the application of business administration tools and techniques, using themes from the areas of marketing, communication, project and people management and also interdisciplinary. It aims to unite the students of the various technical courses to shorten the distances between the learning produced in CEFET.

3.3 Bernouilli

The Bernoulli Aerodesign is a project run by Alçar and has the specific objective of: focusing on the teaching of aerodynamics and sustainability, applying the vision of building an efficient solar-powered airplane prototype in the future. Its general objective is to apply aerodynamic studies and materials to develop prototype aircraft.

3.4 Placa Solar (Solar Plate)

The Solar Plate Research project is the second project managed by Alçar organizers and aims to study and elaborate ways to apply photovoltaic energy in aeromodelling. That is, both projects communicate with each other in their activities focused on energy efficiency.

3.5 Braço Biônico

This project will offer the opportunity for people with low financial income to access efficient, cheap and quality technology. It aims to assist elderly people, adults and children who had their upper limbs amputated, enabling them to do the same activities as a person with both organic arms. The construction of this artifact will combine inclusion, technology, creativity, management and accessibility. The idealizing students, motivated by the high cost of the bionic prostheses in the market, intend to build this artifact at a modest and affordable value. The Bionic Arm intends to reestablish the connection lost by people without upper limbs to the simple things in life such as eating their own hands, grabbing a glass or even hugging someone.

3.6 Solariom

The Solariom Project aims to develop solar powered chargers. The first prototype is located behind the kiosk, in the woods of CEFET / RJ, Maracanã campus. It was developed during the year 2018 and presented at EXPOTEC 2018, winning 3rd place in the Electronics category. This year, the Omega team plans to devise and develop a portable solar charger to be produced in 2020, as well as renovating the already installed prototype. Solariom's goal is to bring technology to people in a sustainable and conscientious way.

3.7 Grila

The Grila project, started in 2013, allowed students to understand the concepts, elements and application of Metrologia - "science of measurements and their applications". The project improved, with the support of the students themselves, and in 2018 Arduino technology was introduced in the construction of artifacts (measuring instruments). The goal of this year's project is to stimulate students' interest in learning, especially robotics, in a fun and intelligent way. It aims to build a model of electric car, unmanned, and remotely controlled or to develop a measuring instrument to measure the quantities involved: torque, speed, mass, time etc In order to achieve this goal, former students will be able to exchange their previous experiences with newbies which will bring more cohesion and alignment of ideas throughout the whole process of creation. The project also aims at an exhibition of the cars produced, where through a contest will be chosen the best project to be manufactured, in 2020, in Mechanics' maker space.

3.8 Zuplast

Aligned with the vision of making the school a "maker" space and motivated by the need for greater sustainability for the environment and the very subsistence of life on planet Earth, comes the project of producing a 3D printer that goes through the deepening of polymers. plastics, their collection, separation and treatment in the end to be processed and used as a uniform filament.

Once built, new knowledge is given a new meaning and the notion of sustainability is solidified by removing plastic from its destination as waste, thus reducing its negative impact on the environment. With the partnership of the project "Less Plastic is More", the project aims to finalize the plastic cycle by building a crusher, an extruder and a 3D printer.

3.9 Solmar

SolMar is an integrative project, created in 2016, which aims to provide participants with a theoretical, practical and engaging learning environment. To achieve this goal, each team must design and build a small unmanned vessel with recyclable / recycled material powered by solar energy.

Among the current sponsors of the event are two shipping companies that are now SolMar's partners: Brana (small boat design and shipbuilding company) and Abravella (Brazilian Academy of Educational Sailing). From the information gathered regarding both the project integration and the management system adopted, Guimarães et al (2018) conclude that SolMar provides an environment where 'everyone involved has space', regardless of the hierarchy or function they occupy. The interdisciplinary profile makes it possible to include various aspects of knowledge to the project, dividing the obligations and giving autonomy to each participant.



Figure 3. SolMar Project 2020 competition call for teams

The project includes a competition, which will take place during Expotec 2019, in which each team will have the opportunity to demonstrate their level of technical and interpersonal development. This year, the students plan to expand to SOLMAR RIO, a competition involving several students from schools in Rio de Janeiro, which will take place in Flamengo Park.

4. Student's Technological Education Portfolio Analysis and Discussions

Five main concepts used in this research (interdisciplinarity, social and environmental responsibility, competences, innovation and knowledge management) were used to observe the practices performed in the different projects developed by the students.

Through participant observation, over two semesters in 2018 and 2019, students were analyzed on their behavior and team organization in nine projects. By informal conversations, the teachers tried to understand how these young people behaved in problem solving and in the search for innovative initiatives that were associated with the concepts analyzed. The results stratified by team, qualitatively, sought to establish whether that concept existed (yes) or not, within each student practice.

Table 1. Name of the table

Student Projects	INT	SER	HR	INN	KMG
<i>Soyuz</i>	Y	N	N	Y	Y
<i>Alçar</i>	Y	Y	Y	N	N
<i>Bernouilli</i>	Y	Y	N	Y	N
<i>Placa Solar</i>	Y	Y	Y	Y	N
<i>Braço Biônico</i>	Y	Y	N	Y	N
<i>Solariom</i>	Y	Y	N	Y	N
<i>SolMar</i>	Y	Y	Y	Y	Y
<i>Zuplast</i>	Y	Y	N	Y	N
<i>Grila</i>	Y	N	N	Y	Y

INT – interdisciplinarity; SER – Social and Environmental Responsibility; HR – Human Resources (Competencies); INN – innovation; KMG – Knowledge Management.

Some projects are at an early stage and so have not yet had some characteristics such as skills development and knowledge management. The interdisciplinary, social-environmental responsibility and innovation components are present in almost all projects.

Although university-business interaction is important for national, regional or sectoral development, the existence of explicit policies in this sense cannot overcome obstacles to innovation and development created by (i) the set of (implicit and explicit) public policies, (ii) the limitations of the absorptive capacity of business technology, and the fragility or even nonexistence of collaborative interaction networks among other agents (Rapchan et al, 2017). Cefet/RJ portfolio strives with no external financial support which creates a financial dependence on the institution's budgetary resources. Thus, student projects are restricted to the scholarships that young people use to subsidize their own research and develop their scientific projects.

5. Conclusions

The hierarchy of the scientist's needs presents an important interpretation of the journey the student will take within his academic and scientific journey. This perspective assists in valuing and fostering student-based projects focused on innovation and core values in technology education. In addition to technical knowledge, leadership skills and interpersonal relationships are required to interact with professionals and students from different backgrounds. It is expected that the student who starts his journey from a scientific initiation and proceeds to obtain his doctorate, will be improving at each stage, each of the concepts generally observed in this pilot study.

Thus, one contribution of this study is to conduct an initial research on innovation and core values embedded skills for young people developed in projects using Project Based Learning in technological education. Besides, this study contributes to consolidate the literature on leadership development in high school, making it available to students and teachers interested in the scientific journey. Therefore, it is expected that these projects have a further cross analysis in order to provide a broader perspective regarding these issues.

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