PROJECT BASED LEARNING: AN APPROACH TO ONE ROBOTIC CELL DESIGN

Cleginaldo Pereira de Carvalho

Centro Universitário Salesiano de São Paulo, UNISAL, Departamento de Engenharia Mecânica, Lorena, São Paulo, Brazil.

ABSTRACT

We are observing changes in all human activities and one sector impacted by these changes is engineering. Since the technological revolution, the engineering world has demanded more flexibility, extra qualifications and more knowledge of specific areas. Therefore, a key change to the engineering universities is to increase the efficiency in learning, which demands a methodological change in their curriculum. The Project Based Learning (PBL) is a systemic approach, which promotes students to 'know how' and knowledge acquisition, through the investigation of complex questions and tasks, accurate planning, focusing on efficient learning. In the PBL approach, the student is in charge of obtaining knowledge on their own and developing the obtained knowledge.
Robotics is the study of robot applications replacing human activities, which can be attributed not only to robots but also for other devices used with the robots. These robots can be classified in six classes based on characteristics, such as: payload, stroke, accuracy and repeatability. The industries are the biggest beneficiaries after obtaining the robot service applications.

The purpose of this work is to analyze the performance application of PBL used as the foundation of a robotic cell for handling design, to be developed by Mechanical Engineering students. It commenced by explaining to the students the new learning methodology, followed by the explanation of the robotic cell for handling considering the input data. Afterwards, the class was divided into groups, each in charge of one cell designed to handle anything. In order to promote the project management issues, each group created a timetable for all activities for basic tasks such as: cell design conception, layout projects, material purchase, assembly, try run and presentation for final approval. Concluding this study, the results of the PBL efficiency measurement are presented as well as recommendations for future projects.

KEYWORDS

Project-Based Learning, Robotics, Learning Innovation, CDIO-Standards: 1, 7, 8 and 11

INTRODUCTION

The development of the learning methodology based on project begun in 1900, when the American philosopher John Dewey (1859-1952) proved that “learning under doing” was a revolutionary way of studying. He conducted a survey about the capacity of the students in thinking how in a gradually way, the learning acquisition related to the ability to solve real projects, adding study area contents with the goal of developing the physical, emotional and intellectual sides by experimental means.

Constructivism explains that humans learn through environmental interactions and this experience is perceived differently by each person. Therefore, the ‘student’ learns based on his current knowledge of the subject (Markham, Larmer & Ravitz 2008**)**. Constructionism does an examination on individual learning, every step of the way, confirming that humans learn more when they build and share something with others (Grant, 2002).

Ergo, the learning based in projects is related to the constructivism, where the know-how is not absolute, but rather built by the student through his knowledge and global perception, sizing the necessity of deeply understanding, amplifying and integrating the knowledge (Bolander*,* Fisher & Hansen, 2011; Crawley *et al*., 2007). The main characteristics of the Project-Based-Learning (PBL) methodology are (Niewoehner *et al.,* 2011; Wilkerson & Gijselaers, 1996; Mazur, 1996): student as being in the center of the process; personal and professional skills; communication; team work integration; active process, cooperative, integrated and interdisciplinary and learning oriented.

We can argue that the CDIO program focus on the product lifecycle, where the four steps are: Conceiving, Designing, Implementing and Operating. With that in mind, we incorporated some of these standards in our as guide lines, in order to conduct the PBL. Under these standards, we oriented our students to consider the product’s analysis, design and social responsibility. Following the standards, it was possible to identify the metacognition process as key for students increase in motivation, and understanding and connection of key concepts. Finally, following the standards, we evaluated the students based on how they implemented the concepts and how far they got (Roslöf, 2015).

According to the CDIO, we can define PBL as an instructional method in which students learn a range of skills while, also, creating their own projects, which could be a solution to a real-world problem. However, the most important part of the PBL is the knowledge gained by the students during this process. They work in groups and bring their own experiences, abilities, learning styles and perspectives to the project.

Niewoehner *et al*., (2011) conducted a study that supports the Susan Ambrose in “How Learning Works: 7 Research Based Principles for Smart Teaching” as the substantiation of PBL in engineering. In their work, they also conducted the trajectory of CDIO’s desired Engineering Education Reform emphasizing that contextual learning is frequently embodied on hands-on projects, and the PBL commonly overlapped or coincided in CDIO programs.

According to Niku (2014), robotics is the study of robot applications replacing human activities. The robots can be classified in four categories, six different classes and their main characteristics are: payload, stroke, accuracy and repeatability. The industries are the largest beneficiaries after obtaining the robots service application. For university applications, we can have an assembled industrial robot, a kit that the students can assemble or build their own robots.

The conception of Arduino was emerged in Italy, 2005, with the subject creating a device which could be used in projects and prototypes as a cheaper alternative to the others in the market, focusing on the students and universities. The hardware and the software are cheap and available in several places. The Arduino is a processor able to measure variables in the external environment and transfer electrical signals, using sensors in its input and then processing all the information supplying output signals (McRoberts, 2011).

This paper describes the application of the Project-Based Learning as an innovative methodology using a robotic cell for handling design as a mean to motivate and teach the students. Starts by explaining the input data for the design and adopting the Arduino as the microprocessor, the students choose the robot design, programming and implementation. The CDIO standards were followed every step of the project development (CDIO, 2010). As a result, we present the final concept for the robotic cell and its features as well as the PBL efficiency measurement. Finally, some recommendations for further projects are presented.

MATERIAL AND METHODOLOGY

Microprocessor – The Family of the Arduino microprocessor used in the Project was the AT mega 2560, UNO version. This version has flash memory of 128KB and is indicated for robotics application, because of the number of inputs and outputs. This Arduino Maga has 54 digital pins for I/O and 14 of the total for analogical output signals PWM and 16 pins for analogical input.

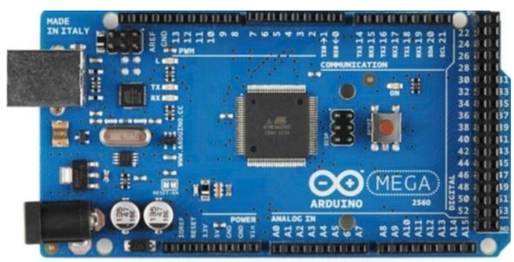

Figure 1. Overview of the Arduino microprocessor AT mega 2560 UNO

Robot – The robot concept used in the project was Class 3, which specifies the variable frequency, where one device executes steps according to one procedure allowing changes. The Category of the robot is number 2 in which the controller has one memory to record the moving sequence as well as the positions and speeds. The programming used was one method to control the commands through the control board with each component in charge by the moving sending signals and loaded in the programming code. The robot conception used 3 joints, 1 gripper and 5 servo motors. The robot structure was built by the students using hard plastic, as raw material, and laser cut shortly thereafter by the CNC milling machine.

Figure 2. Robot conception designed in 3D by the students

Project Time Table – The students were divided in teams and before they started their activities, each team elaborated a time table following the 5W2H concept. This methodology allows the project managing through the approach of the tasks answering the questions:
-What: The task which shall be done;
-Who: The person or group of people in charge of conducting the actions;
-When: The deadline to conclude the action;
-Where: The physical place to do the task;
-Why: The main reason to do the task;
-How: The way to conduct the task or the mean used to do the action;
-How much: The costs and investments involved to do each task.
The schedule was submitted as an assessment to evaluate the teams' capabilities in terms of project management skills. Afterwards, there were 'check-point' meetings with the teams and the students presented a new plan to correct the delays and the failure method analyze effect approach was introduced by each team in order to avoid that new problems appeared without any action to solve them.

5W2H Planning

Objective

Group	Student 1, Student 2, Student 3
	Student 4, Student 5, Student 6, Student 7

What	Who	When		Where	How	Why	How Much	% Completed	Today	Situation
		Beginning	End							
Choosing the Project	Everyone	20-Aug	27-Aug	UNIVERSITY	Agreement	Starting Point	-	100%	100%	ok
Internet Research	Everyone	20-Aug	24-Nov	UNIVERSITY	Google, Mags	Concept (design)	-	100%	100%	ok
Theoric Research	Student 1, Student 4, Student 5	20-Aug	3-Sep	UNIVERSITY	Library, Google	Theoric Basis	-	100%	100%	ok
Project (Sketch)	Student 3, Student 6	27-Aug	10-Sep	UNIVERSITY	AutoCad	Sketch for assembly	-	100%	100%	ok
List of Material	Student 2	22-Aug	15-Oct	UNIVERSITY	Manual	To provide materials	-	100%	100%	ok
Prototype Assembly	Student 7	29-Aug	20-Oct	Student 7 House	Office	To prepare assembly	-	100%	100%	ok
Material Purchase	Everyone	2-Sep	2-Nov	UNIVERSITY	Manual or Tools	Prototype	-	0%	80%	not ok
Programming	Everyone	1-Sep	2-Nov	UNIVERSITY	Arduino	To move the arm	-	0%	60%	not ok
Prototype Testing	Everyone	2-Sep	24-Nov	University Lab	Function Test	To assure correct function	-	0%	50%	not ok
Final Assessment	Everyone	2-Sep	24-Nov	UNIVERSITY	MS Word	To show the professor	-	0%	30%	not ok
Presentation	Everyone	16-Sep	24-Nov	University Lab	MS Powerpoint	For final avaliation	-	0%	0%	not ok
Final Data	Everyone	14-Sep	26-Nov	UNIVERSITY	Written work and presentation	Avaliation	-	0%	0%	not ok

Figure 3. Time table of the main activities using 5W2H conception

Methodology for the PBL Efficiency Measurement – The data was collected via an electronic survey, which was answered by the students without the teacher's interference. The electronic survey generated statistical data and the results were exported to an Excel spreadsheet. The survey compounded for six questions presented in the following order:
- About the quality of the team job;
- Level of the team commitment with the results;
- The prototype conception;
- Team capacity in project management;
- Knowledge acquisition.

During the check point meetings, every group had their tasks checked and if a problem occurred, an action plan was adopted by the respective team, in order to correct the deviations.

RESULTS

Robotic Cell for Handling – The robotic cell was conceived, designed, assembled and implemented on time and its features were:
- Total length of the rod: 55 cm
- Stroke max. in x axle: 50 cm
- Stroke max. in y axle: 55 cm

- Stroke max. in z axle: 50 cm
- Maximum Moment: 11 Nm

The robotic cells for handling also reached the specifications for precision and repeatability.

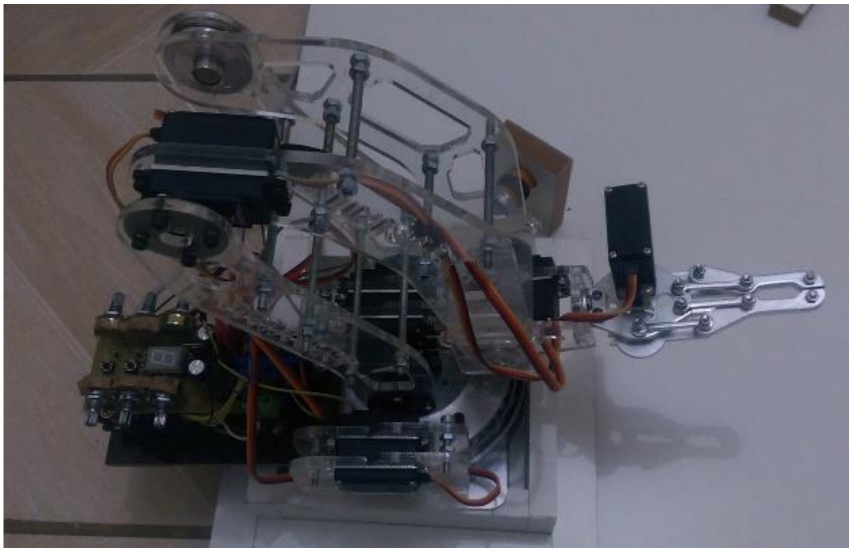

Figure 4. The robot final assembly located in the cell layout

The Project-Based Learning Efficiency Measurement Results – The survey was conducted to all students with six questions. The students had the choice between five levels of specialization conformity and in accordance to the personal perception of the PBL methodology. The outputs are as followed with comments being pointed out.

Figure 5. Evaluation of their work quality

The majority of the students have the perception that their work was conducted in accordance with the input data given to them in the beginning of the project as well as the quality of their work reached the established standards. In fact, the students amplified their range of knowledge in terms of automation and robotics, using a multidisciplinary approach.

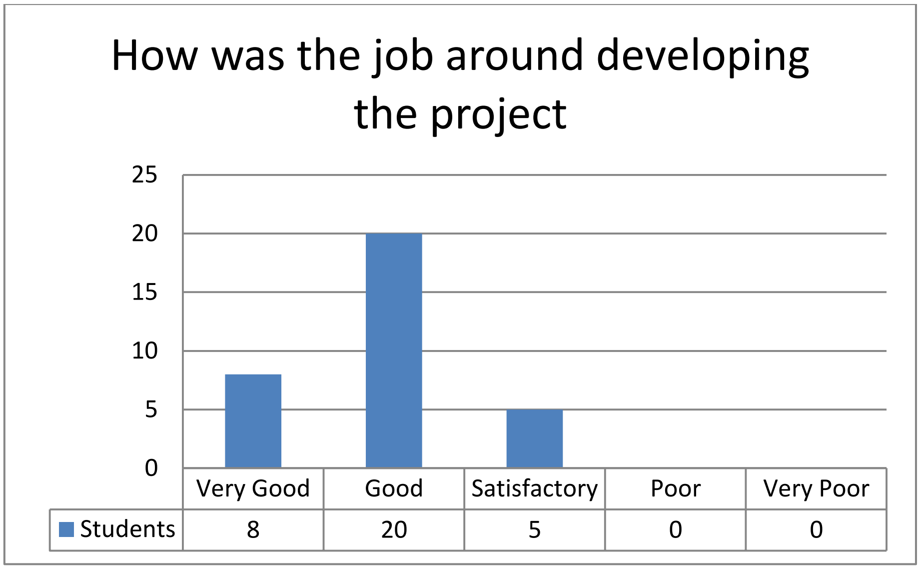

Figure 6. The job around the project and commitment with the results

Almost all the students had the feeling that they were responsible for the final results of the project. It shows that the PBL methodology gave them the sense of responsibility to conduct all the activities for the project success.

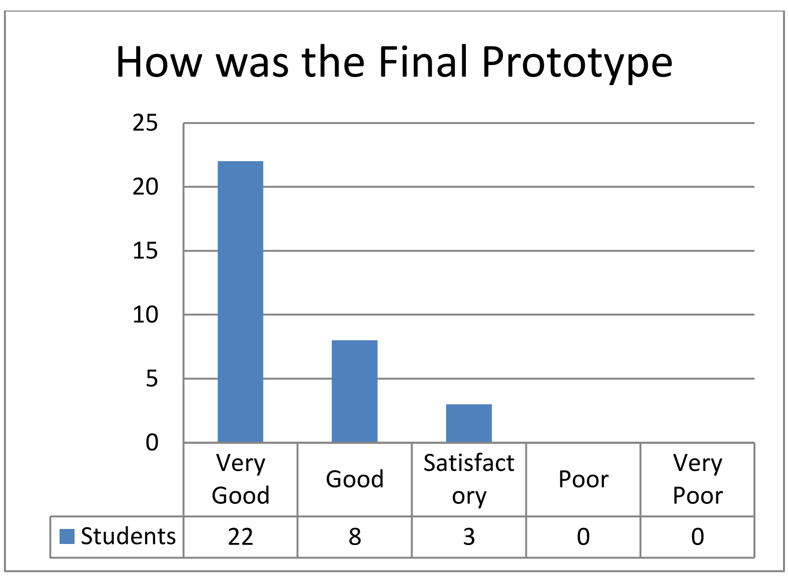

Figure 7. Evaluation of the performance for the final assembled robot

The methodology developed in the group had the capacity to go over their limits and encourage them to reach the goal established for the project. They worked in the conception, design, manufacturing, assembly and try run. All the robotic cells ran well within the specifications and on time.

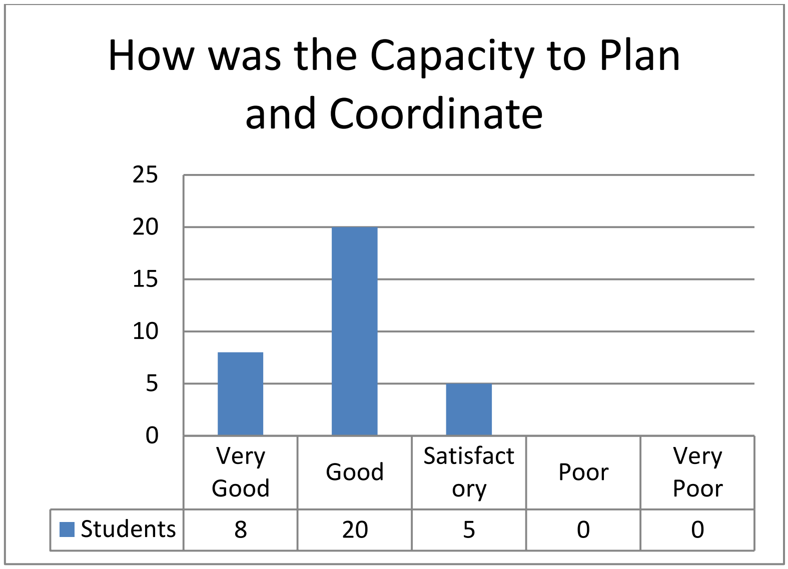

Figure 8. Project Management Abilities

The Project-Based Learning as the innovation learning methodology gave the students the sense of planning and project management abilities. Although the original discipline was related to Computer Aided Manufacturing the students learned deeply about management.

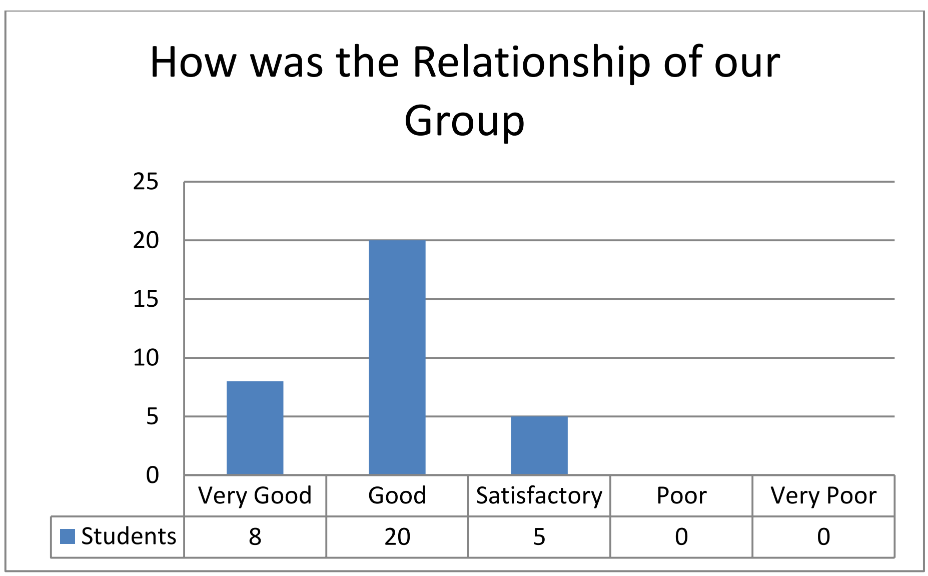

Figure 9. Capacity in team work

More than an interdisciplinary methodology, PBL motivated the students to work as a team. This ability is essential for an engineer in the job market and sometimes is neglected in the engineering curriculum.

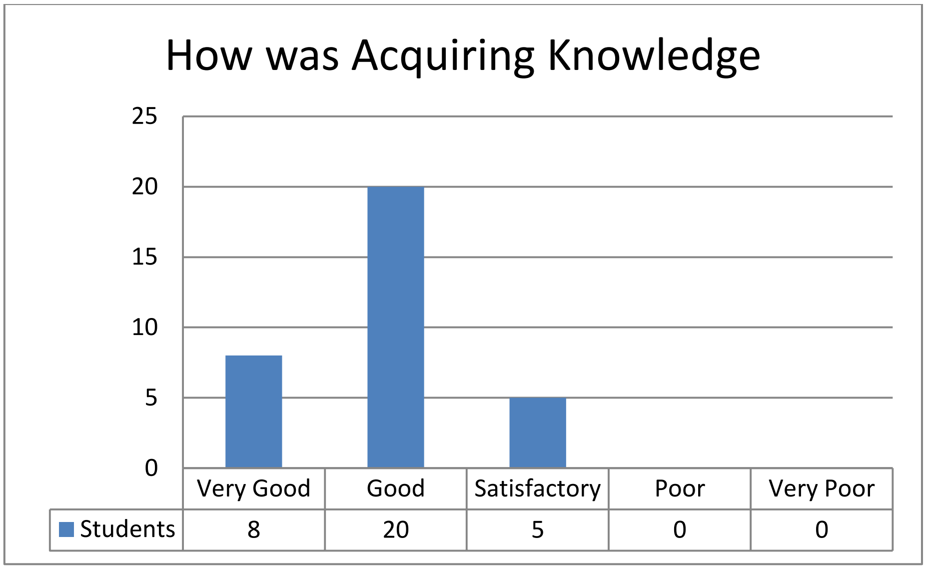

Figure 10. Knowledge Acquiring using PBL as the learning methodology

Finally, PBL showed that it was a strong tool when knowledge acquisition is demanded. The students faced many difficulties during the project development, but solved all of them with the knowledge acquired from several fields.

CONCLUSIONS

In this paper, the Project-Based Learning application was evaluated. It was discussed the PBL conception as well as the concepts regarded to robotics and automation as a mean to apply the innovation learning methodology.

The steps of PBL and the CDIO standards were followed and all project activities were controlled by 5W2H methodology as the tool to guide the project management. Using the hands-on concept the students conceived, designed, assembled and implemented the robotic cell for handling. The robot features were measured and checked with the project input data specification. The students' skills in terms of project management were developed.

A survey was used to verify the efficiency of the PBL using the robotic cell project as the main students' motivation. The results of this innovative learning methodology were presented with great grades and vast comprehension with the majority of the students to which the survey was conducted. As a result, the perception of the teams regarding to their job quality, commitment, prototype building, planning capacity, team work spirit and knowledge acquire were conducted in an efficient way when the PBL was applied as the learning innovative methodology.

As to further research works, it is recommended that a personal assesment should be conducted and followed by a peer evaluation, in order to measure the level of assimilation of the multidisciplinary contents by the students as well as a way to also measure the efficiency of the Project-Based Learning that could be obtained by the results evaluation.

REFERENCES

Bolander, T., Fischer, P. Hansen, T. K. (2011). From Frustration to Success: A case-study in Advanced Design-Build Experiences. *Proceedings of the 7th International CDIO Conference*, Technical University of Denmark, Denmark, June 20-23.

CDIO (2010). *The CDIO Standards V.2.0*, www.cdio.org.

Crawley, E. F., Malmqvist, J., Oestlund, S. & Brodeur, D. R. (2007). *Rethinking engineering education: The CDIO approach*. New York: Springer.

Grant, M. M. (2002). Getting a grip on project-based learning Theory, cases. A Middle School Computer Technologies *Journal. State University*, Raleigh, Vol.5.

Markham, T. Larmer, J., Ravitz, J. (2008). *A Aprendizagem Baseada em Projetos.* Artmed Editora S/A, Porto Alegre.

McRoberts, M. (2011). *Arduino básico*. 1 º ed. Tradução e Rev. Rubens Prates, Camila Kuwabata, Rodrigo Stulzer, Marta Almeida de Sá Carolina Kuwabata, Rafael Zanolli, Edgard Damiani. São Paulo, SP copyright 2013 pela Novatec Editora Ltda.2011**.**

Mazur, E. (1996). *Peer Instruction: a Users Manual* .Benjamin Cummings.

Niewoehner, R. et al. (2011). A Learning Science Foundation for Project-Based Learning in Engineering. *Proceedings of the 7th International CDIO Conference*, Copenhagen, June 20-23.

Niku, S. B. (2014) *Introdução à Robótica: Análise, Controle, Aplicações.* 2º ed. Tradução e Rev. Técnica. Sérgio Gilberto Taboada. Rio de janeiro, RJ: LTC.

Roslöf, J. (2015).Sustaining CDIO Elements in an Institutional Restructuring Process. *Proceedings of the 11th International CDIO Conference*, Chegdu, Sichuan, P.R. China, June 8-11.

Wilkerson, L, & Gijselaers, W. H. (1996).*Bringing Problem-Based Learning to Higher Education: Theory and Practice. New Directions for Teaching and Learning,* N.68, San Francisco, CA. Jossey-Bass.

BIOGRAPHICAL INFORMATION

Cleginaldo Pereira de Carvalho, Ph.D. is a Mechanical and Industrial Engineering Professor in the Centro Universitário Salesiano de São Paulo, Brazil. He holds a D.Eng. in Material and Project, a M.Eng in Mechanical Engineering from Universidade Estadual Paulista (Brazil) and an MBA in Strategically Business from Fundação Dom Cabral (Brazil). Currently, he works as a researcher in the Universidade de São Paulo (Brazil), where he is also an Industrial Engineering Professor. With years of experience as an Industrial Director in the corporate world, he incorporates his background onto his current research, which focuses on Learning Innovation, Project Management and Lean Manufacturing.

Corresponding author

Dr. Cleginaldo Pereira de Carvalho
Centro Universitário Salesiano de São Paulo
Rua Dom Bosco 284,
Lorena, São Paulo, Brazil 12600-100.
55-12-31255882
cleginaldopcarvalho@hotmail.com