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Industrial Internship Mentoring Model for Industrial Engineering Education in Public Universities*

MARIA DA GLÓRIA DINIZ DE ALMEIDA, FERNANDO AUGUSTO SILVA MARINS and ANDREIA MARIA PEDRO SALGADO
Department of Mechanical Engineering, School of Engineering of Guaratinguetá, São Paulo State University, Av. Dr. Ariberto Pereira da Cunha – Parque Alberto Bayington – CEP 12518-010 – Guaratinguetá – SP, Brazil. E-mail: gloria_uerj@yahoo.com.br

RITA DE CÁSSIA DA SILVEIRA MARCONCINI BITTAR, JOSÉ GLÊNIO MEDEIROS DE BARROS, ANTONIO HENRIQUES DE ARAÚJO JUNIOR, NILO ANTONIO DE SOUZA SAMPAIO, BERNARDO BASTOS DA FONSECA and GESSICA NAIRA DINIZ BARONTO
Department of Industrial Engineering, College of Technology, Rio de Janeiro State University, Rodovia Presidente Dutra, km 298 - CEP 27537-000 – Resende – RJ, Brazil

ANDRESA DEOCLIDIA SOARES CÔRTES
Department of Mechanical Engineering, Campinas State University, Rua Mendeleyev, 200 – Cidade Universitária, CEP 13083-860 – Campinas – SP, Brazil

This article aims to present an industrial internship mentoring model for undergraduate industrial engineering education in public universities. The study proposed that the constructs of "mentoring" and "industrial engineering education" can be combined in order to develop a model for teaching. Its reliability has been confirmed by Cronbach's α coefficient test, whereas the statistical hypothesis test has confirmed the validity of the model according to the opinion of 52 pairs of mentors and mentees participating in this applied research with a qualitative methodological approach using a combination of case study and survey. Regarding results, 85% of mentees stated that the model had made a significant positive difference during their internship period, while mentors confirmed that 98% of mentees developed industrial engineering skills and abilities. Thus, the model relies on a detailed procedure about the content that should be assessed in each phase. Its major contribution lies in its pioneering role in developing an industrial internship mentoring model for industrial engineering education and in bringing universities and industries closer together during internship periods.

Keywords: mentoring program; industrial engineering teaching; internship; professional education.

1. Introduction

The word "mentor" means an experienced person who counsels and assists a less experienced individual for a given period of time [1]. In the study in question, mentoring is defined as an attempt of an experienced professional (mentor) to impart specialized knowledge to a less experienced one (mentee) within an organization. It functions as a path through which the mentor oversees the activities and performance of a youth who must learn quickly [2].

Contemporary business researchers have been assessing the benefits of mentoring in studies since the 1970s [3]. Mentoring has long been addressed as an important resource for professors in promoting students' intellectual development [4], as described below:

- Professors should mentor students during the early years of their university studies, still towards student development and increased retention rates [5].
- University professors ought to be mentored during the early years of their professional career [6].
- Mentoring in universities towards career guidance of young professionals graduated in different areas of expertise [7].

These examples show that mentoring on early stages of undergraduate courses can be found, supported by professors. They are mainly applied in areas such as nursing, medicine, social services and teacher education [8]. However, by the literature review, it was possible to identify a lack of mentoring studies focused on the professional cycle, including industrial engineering. So this gap was identified as an opportunity to review the existent mentoring knowledge and methodology from different authors and applications to create an internship industrial mentoring model to support students to enter their professional life cycle as industrial engineers. By the way, the literature review was the main strength to comprehend how the already existing mentoring models focuses and applications could support the idea of necessity of the undergraduate model proposed.

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Thus, this paper has been structured based on the assumption that it is possible to combine the constructs of industrial engineering education and mentoring in order to develop an industrial internship mentoring model in public universities, linking curricular guidelines, i.e. professional skills and abilities required in this area of expertise and the concept of mentoring.

Its main contributions are:

- Academic: to suggest improvements in industrial engineering undergraduate courses by incorporating the proposed industrial internship mentoring model.
- Scientific: to provide industrial engineering researchers with reference material, as there are few studies that combine the constructs of mentoring and industrial engineering education.
- Professional: to provide an instrument to improve learning and professional development of interns based on the application of the proposed mentoring model.

A combination of the constructs mentioned in the present study with the applicability of the model in universities and industries make it groundbreaking, unique and quite useful for professionals in the field and the academia. Up until recently, no similar example of publication has been found, thus characterizing the groundbreaking theoretical contribution of this work to the academia. Therefore, it proposes to fill this gap in literature.

The benefits of mentoring have been widely published in journals. Some authors offered some contributions.

Booth [9] states that mentors' undivided attention to mentees and the satisfaction provided from the program are among some of its advantages. According to mentees, having someone who devotes part of their time and imparts much of their knowledge is of fundamental importance in order for them to be able to see their professional future, deal with people and tackle a large variety of problems more easily. On the other hand, the mentor's main advantage is personal satisfaction from beholding the progress made by mentees.

According to Stewart and Knowles [2], some advantages offered to mentees are the support towards professional development as engineers in technical and behavioral terms, the opportunity to demonstrate their skills and potential for more advanced or complex activities in the future and self-confidence boost. On the other hand, mentors can develop their leadership skills to train personnel and promote feedback.

Mentoring as an activity offers benefits to both workgroups and organization. It builds up self-esteem and improves the knowledge, skills and abilities of those involved [10].

According to Gannon and Maher [11], mentoring is also acknowledged as a pro bono practice in which individuals develop relationships that will benefit the person, group or organization. This altruistic behavior is seen as beneficial to mentors, either professionally or personally. An important fact about bonding is that some mentees may still keep in touch with their mentor, even after the process is over.

As regards the main risks of failure and disadvantages of implementing a mentoring program, some authors present their view on the matter through their respective studies. Gibb [12] cites the natural divergences (in other words, jealousy, diffidence, envy) that may occur, especially in higher-ranking positions. Lack of training by mentors and mentees is another risk of mentoring failure [13]. Still concerning personnel training, Scandura [14] proposes it as a way to avoid relationship problems. Some of them do not achieve their primary goal, which leads to personal injury, fueling discontent, anger, resentment, mistrust, and frustration.

Still with respect to risks, Rolfe [15] identifies seven fatal flaws in a mentoring program: unclear strategic values, insufficient lead-time and planning, lack of resources, inadequate support, insufficient training, lack of structure, guidance and monitoring, feedback and inefficient evaluation.

The aforementioned authors found that the initial training of mentors and mentees, as well as planning, guidance and actions, are essential to ensure the success of a mentoring program. In addition, as previously stated by Stewart and Knowles [2], their commitment, confidentiality and transparency are essential to minimize risks in implementing the program. As a guide to mitigate them, the authors recommend either preparatory training or training mentors and mentees by carefully planning the program in advance.

The remainder of the paper is divided into six further sections. Section 2 presents its theoretical framework. Section 3 describes the steps for developing the mentoring model and the research classification. In Section 4, there are details about how the proposed model was developed. Section 5 details a real-world case scenario of its application and results, which are discussed in Section 6. Finally, Section 7 draws its conclusions and offers suggestions for further research, followed by its references, biographies and lists of figures and tables.

2. Theoretical Framework for the Internship Mentoring Model

The constructs illustrated in the concept map of Fig. 1 were used to develop the theoretical internship

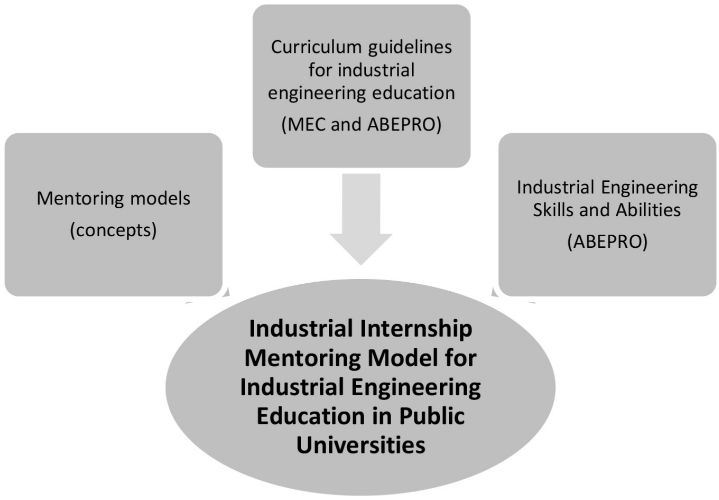

Fig. 1. Concept map for designing the theoretical industrial internship mentoring model.

mentoring model. These constitute the theoretical framework upon which the model is based.

As for the mentoring models that were the basis for the study, Vela [16] contributes with a model composed of eleven steps along its preparation, start-up towards its implementation and assessment. Alred et al. [17] proposed a model that comprises three stages, which are exploration, new understanding and action plan. Poulsen [18], in turn, offered a model called ''alliance for learning''. Furthermore, a set of different experiences from mentoring models in universities worldwide has been used. These were the theoretical basis of this study due to the quality of their content which contributes to develop the present industrial internship mentoring model.

In addition to the concept of ''alliance for learning'', Bozionelos et al. [19] emphasize that one of the main characteristics of a mentor is the ability to listen to the professional being trained, their views, judgments and values. The individual must be inquired so as to seek their justifications and encourage the young apprentice to develop critical thinking abilities. This is the main focus of a relationship where there is mutual growth. Moreover, it is also stated that the mentor's duty is based on one of the essential concepts of the learning process: reflection. It allows analyzing and assessing one or more personal experiences, thereby generalizing a given thought. Thus, the young learner collects further data, acquires more skills and becomes more efficacious than before [20–22].

In addition to the importance of reflection in the learning process, the Socratic Method greatly collaborates on mentee's development.

This method, described by Lawrence [20], is a form of inquiring and discussing based on questions and answers in order to stimulate critical thinking and creativity, thus being one of the forms for developing critical thinking skills. Effective mentors use the Socratic Method in order to help people grow personally and professionally.

Furthermore, Lawrence [20] argues that educating people about what to do or simply giving answers is the easiest way to do something. However, helping them to solve problems on their own using the Socratic Method is a more efficient approach because, by not solving the problem for that person (i.e. just helping), the same problems are not going to arise once more to be eventually solved. Thus, mentees will be able to reflect and identify areas of improvement themselves.

The importance of reflection is also found in Sweeny, where it is described as one of the main elements in the search of improving the performance and learning of professionals who must always analyze their own behavior, their relationship with coworkers and responsibilities [21].

Sweeny also lists strategies to facilitate professional growth based on the Socratic Method, i.e. through questions that lead the mentee to reflections [22].

Kram's model, which is another way of mentoring, consists of two dimensions: career functions and psychosocial functions [23].

Career functions are those that provide a breakthrough in the organization's hierarchy. They emphasize the learning of organizational roles, career development, and prepare the individual to perform well in higher positions. These roles include sponsorship, exposure-and-visibility, coaching, protection and challenging tasks [23].

Psychosocial functions are those that affect the individual on a more personal level, thus building up their self-esteem within and without the organization. These functions are exercised through mutual trust and growing intimacy in interpersonal relationships. Emotional support, in such a case, often affects the mentor's professional identity, which can be fundamental to career advancement. These functions include role modeling, acceptance and confirmation, advisory and friendship [23].

On the other hand, individuals change over time and doubt is also cast upon the importance given to functions. The relevance of exercised functions can be affected by interpersonal skills and individual abilities. However, it is by these functions that individuals will be able to manage goals towards each stage of their career [23].

Regarding industrial engineering education, the internship mentoring model was based on Brazilian's curricular guidelines. The National Council on Education [24] of the Ministry of Education holds the prerogative to define the National Curriculum Parameters for Undergraduate Engineering Education. The National Meeting of Industrial Engineering Course Coordinators [25] recommends the curriculum guidelines for industrial engineering within the scope of the Brazilian Association of Industrial Engineering (ABEPRO), as well as the topic of internship. In addition, one must consider the pedagogical project of the industrial engineering course.

Ministry of Education is the body that establishes the education guidelines in Brazil, including the curriculum parameters for engineering courses [24].

The National Curriculum Parameters for Undergraduate Engineering Education set the principles, fundamentals, conditions and procedures to train Undergraduate Engineering Students of Higher Education Institutions in Brazil. Graduate/professional engineers are trained to be generalist, humanistic, critical and reflective, and capable of understanding and developing new technologies in order to stimulate their critical and creative role in identifying and solving problems by considering their political, economic, social, environmental and cultural aspects, with an ethical and humanistic view so as to meet the demands of society [24].

With regard to skills development, Locurcio and Mitvalsky [26] state that graduates need to acquire skills that are not part of the engineering curriculum, since academic courses should mainly focus on technical content. Thence, the constructs of a general mentoring model, the requirements to make it applicable to engineering education, and finally the ABEPRO skills and abilities are combined so as to characterize the model for industrial engineering. Thus, the proposed theoretical model should be focused on including the development of skills and abilities recommended by ABEPRO [25]. The mentor's role is, in turn, fundamental to develop and advise the mentee on acquiring these skills and abilities while performing industrial engineering functions as interns.

Some examples of mentoring programs can be cited, including universities and companies.

A mentoring program practice is found in Hamilton-Jones [27] whose main idea is to emphasize the role of tutor-mentor, highlighting the importance of the mentor's role in teaching mentees participating in the program. It points out great results and benefits of applying this methodology through action research by taking into account the great pressure faced by young people who quickly suffer a change in their amount of responsibilities, which is now greater due to academic duties that already existed, in addition to those at work.

Richter et al. [6] presents another example of mentoring program for professors in the first two years of their careers. It is carried out by professors who are more experienced in the classroom, which includes pedagogical guidance, classroom observation, formative assessment and support during difficulties. There are mixed results, but all reveal that there is an improvement in the professor's way of teaching.

Santora et al. [28] advocate a progressive mentoring model to improve the teaching process and present data from an international and interinstitutional research study where mentoring was observed in the field of science and engineering based on Vygotsky's zone of proximal development. It is considered the point where students have enough mastery and knowledge to proceed, regardless of whether they are without the figure of a mentor for a long period. Therefore, according to Santora et al. [28], students cease to be passive and become active in the process through progressive mentoring, which leads to improved information flow, wider global view and freedom to make decisions and forge relationships, where they can be mentors and apprentices and their original mentors serve more as a guide and example, while the university is more like a supporter to ensure quality and effectiveness.

George and Mampilly [29] address mentoring in managerial development schools. They cite that when it comes to skills required for good management, knowledge must be transferred experimentally, making management education an essentially interactive process between professor and student. Therefore, mentoring is considered a stable intervention in management development and an important resource for learning and making organizational changes appropriately.

Examples of mentoring programs for engineering can also be observed in Russell [7] who describes mentoring as a support provided by a professional engineer to engineering students who have recently started working at the industry. The article analyzes the gains for the mentee, mentor and company.

Beaty et al. [30] cites an example of a company-university interaction in an engineering course. Industry professionals interact with students in a variety of ways, providing them with project advice, establishing teaching partnerships and participation in a mentoring program for students, an advisory committee, an interdisciplinary design project and an undergraduate program based on industries.

Raber, Amato-Henderson, and Troesch [31] show the implementation of a mentoring program at Michigan Tech University for engineering students in which the mentors were its professors. One of the most surprising results was that most students (about 91%) achieved better grades after the program. This improvement might have been influenced by the program, as the commitment to focus on solving real-world problems and teamwork structure impacted college studies.

Young engineers need models and guidance in order to be successful. This is important so that the newcomer can face the challenges of an interconnected world and encourage young professionals to keep studying engineering instead of abandoning their career and pursuing others instead [32].

According to Russell and Nelson [32], the actual leaders in the profession are experienced engineers who are mentoring young graduates. They understand the value of educating the next generation and its importance in the constant success of professionals and companies.

3. Classification and Phases of Research

3.1 Research Method

This is an applied research on account of addressing the application of an internship mentoring model in an undergraduate industrial engineering course by combining the constructs of mentoring and industrial engineering education.

Qualitative research is shown to be the most adequate for this study for assuming an interpretive approach for data collection [33]. The research is based on a qualitative argument [34] and gives emphasis on the profile of the individual under study [35].

The adopted research methodology combines a survey with a case study. The survey was carried out due to the need to translate theory into practice, as a conceptual model has been proposed. It was explained why it was sought to develop relations between the three concepts shown in Fig. 1 [36]. Moreover, after developing the conceptual model, the survey allowed identifying and defining constructs, i.e. the relevant conceptual elements from which the variables to be assessed have been found [36], named mentoring and industrial engineering education. Finally, it was assumed that mentoring contributes to train production engineers by managing the relation between constructs, which has been assessed as regards their validity through questionnaires aimed at mentors and mentees.

As regards the case study, an empirical study has been carried out in which the object of study was a Public Education Institution in Brazil, and the hypothesis test validity determined as the research objective has been investigated [37]. With respect to the type of case study, it can be classified as descriptive, since it depicts research on the mentoring program and aims to validate the hypothesis of mentoring efficiency along production engineering students' graduation process [38].

As for the data collection method, surveys and interviews were used. Thus, this is an applied research with a qualitative methodological approach using a survey and descriptive case study, since it aims to create a norm by means of a model on the basis of surveys and interviews for data collection.

3.2 Survey Sample

The research has been carried out in three application cycles (or three semesters) in a Brazilian public university. Between first and third cycles, 52 mentor-mentee pairs participated in the internship mentoring model program.

As regards the definition of survey topics, the mentoring model development involved two distinct groups, which are:

- Industrial engineering undergraduates (group 1), who were the mentees.
- Experienced industrial engineers (group 2), who were the mentors.

Their characteristics were:

1. Group 1: MENTEES or STUDENTS – students of the undergraduate industrial engineering course (higher education) of a Brazilian public university, undergoing supervised internships and working as interns in industries, comprising a total of 52 students.
2. Group 2: MENTORS or EXPERIENCED ENGINEERS – at least four years of experience as engineers in industries. They are responsible for implementing the internship mentoring model to students. The survey comprises 52 engineers, who formed mentor-mentee pairs with students. It is important to note that the minimum experience that an engineer must have in order to be considered as "experienced" in the program in question is four years.

3.3 Data Collection

The three cycles of the internship mentoring model were carried out with the purpose of collecting data to develop it in an improvement way basis and also consolidate the evaluation of results of its implementation. Regarding development, mentors' and mentees' opinions were collected through open-ended questions that were the basis for designing the mentoring model. The mentee's development from the mentor's opinion, however, was obtained from closed-ended questions.

Questionnaires and interviews were used to collect data. Firstly, two questionnaires were carried out: the first one was to observe the mentee's development from the mentor's point of view as regards the two areas of improvement concerning industrial engineering skills and abilities through a practical project carried out at an industry, as well as their view on the model; the second one was performed with the aim of seeking the mentee's opinion on the mentoring model.

Access to the knowledge of mentors and mentees was obtained by questionnaires. As interns, they were responsible for filling out their questionnaires, taking and bringing them from their mentors at the end of the semester, as well as returning them to their respective professors.

Another used tool was structured interviews. The first one was called an interview with mentees which has been carried out with the aim of verifying whether the mentoring model enhanced industrial engineering education during their internship period through closed-ended question according to their opinion. In addition, the main strengths highlighted by mentees have been qualitatively discussed during the interviews. These interviews were carried out at the end of the semester during a project presentation developed by mentees in the discipline of supervised internship at the end of the project presentation in the classroom.

The second interview, called interviews with experts, aimed to validate the constructs of the theoretical model with six industrial engineering and human resources experts using open-ended questions. Questions were provided by mail, while interviews were carried out by phone.

3.4 Statistical Validation

Statistical researches should be based on reliability and validity, which are criterias for assessing its quality [39], and usually, it is adopted for that the Classical Test Theory. During the development of the case study in this research a key concern was how to guarantee the reliability of questionnaires carried out with mentors and mentees in order to define how often the test tool or survey is producing the same result in repetitive situations [40]. Thus, Internal Consistency Test – ICT [41] was chosen because is an appropriate methodology to find the interrelationship between the individuals or the structure reliability in a case study. The main indicator of such test is Cronbach's α value, that was introduced by Lee J. Cronbach in 1951 as a way to estimate the reliability of a survey questionnaire [42, 43], and because it calculates the correlation among responses of a questionnaire.

Many researchers consider that Cronbach's α value must be greater than 0.7, which is considered a good indicator of the ICT [44]. In order to achieve a minimum desired effect size of 0.7 or more, a sample size of 30 is recommended [45]. On the other hand, in order to confirm the validity of mentors and mentees questionnaires and interviews with mentees, the statistical hypothesis testing between two data sets was used [46]. This test was selected on account of allowing a comparison of the ratio of positive to negative responses in questionnaires and interviews in a statistically valid way.

According to Montgomery and Runger [46], it is often desired to test hypotheses concerning the difference between two data sets, H_0 and H_1, where H_0: $p_1 - p_2 = \Delta_p$, instead of the convenient H_1 alternative.

Data typing and tabulation relied on the use of an Excel spreadsheet for converting data into information.

4. Industrial Internship Mentoring Model Design

This section aims to present the method used to develop the industrial internship mentoring model so as to allow its implementation in other universities/industries. A compiled scheme of the model can be seen in Table 1 and its details from Phases 1 to 4.

Table 1. Compiled scheme of industrial internship mentoring model

Phases of the industrial internship mentoring model
Preparation of industrial internship mentoring model at university: • Structuring the mentoring model at the university
Mentoring planning at university: • Definition of mentor/mentee relationship • Detailed delineation of the model forms and profiles of participants
Implementation of industrial internship mentoring model at universities/industries: • Establishing the mentor/mentee relationship • Skills development
University evaluation of industrial internship mentoring model implementation: • Model assessment

Table 2. Preparation of industrial internship mentoring model at university

Steps of Phase 1 – Preparation of industrial internship mentoring model at university
Step 1. Explain the purpose of mentoring to develop industrial engineering skills and abilities: Focus: understanding why the development of mentoring is carried out and what is expected to be achieved as regards mentoring development of industrial engineering skills and abilities.
Step 2. Adjust to conditions of the university in which it is going to be implemented: Focus: align its implementation with the pedagogical project of the industrial engineering course. It should be checked whether the course's pedagogical project provides the model leader with freedom for mentoring as an alternative activity within the context of the internship syllabus.
Step 3. Define the role of the mentor program coordinator at the university: Focus: coordinate the customization of implementing the pedagogical project in the industrial engineering course, as well as its planning, development and evaluation at the university.

Table 3. Mentoring planning at university

Steps of Phase 2 – Mentoring planning at university
Step 1. Define the roles of mentee and mentor: Focus: describe the reason for everyboy's assignment and the next steps to be followed with the aim of developing the mentee's industrial engineering skills and abilities.
Step 2. Define the profile of mentors: Focus: guide the mentee on the profile of the mentor so that it is aligned with the purpose of mentoring.
Step 3. Define the training content to be assigned to mentors and mentees: Focus: specify what knowledge and skills the mentor should put into practice and how mentors and mentees should act according to their roles.
Step 4. Define how the mentor-mentee pairs will be formed: Focus: define who will choose the mentor and how it will be done (mentor coordinator or mentee).
Step 5. Define how the mentor will be invited to participate in its implementation: Focus: guide the mentee on how to approach the mentor, in addition to formalizing their commitment.
Step 6. Define how the internship mentoring model will be presented to the mentor and industrial HR sector: Focus: to inform the mentor (experienced engineer) and the industrial HR sector about the development of mentoring.
Step 7. Work towards an agreement between mentor and mentee and set expectations as regards areas of improvement by the mentee: Focus: to formally ensure confidentiality of information exchanged between both parties and define what is expected from mentee's improvement as regards the development of industrial engineering skills and abilities through a practical project to be developed, and how it will be observed.
Step 8. Define the content of mentor-mentee meetings: Focus: guide on what should be addressed by mentor and mentee at each meeting in order to contribute to the mentor's development of industrial engineering skills and abilities and how it should be done.
Step 9. Define monitoring forms for conducting mentor-mentee meetings: Focus: standardizing for good quality of mentor-mentee meetings.
Step 10. Define how the mentor and their practical project will be monitored by the university: Focus: monitoring mentees, their practical project development and the completion of its implementation, as well as identification of difficulties and suggestion of alternatives.
Step 11. Define how the development of the mentee's skills and abilities will be analyzed: Focus: defining how to observe the development of the mentee's skills and abilities set to be developed through the practical project to be carried out at the end of the application from the mentor's point of view.
Step 12. Define how it will be observed whether its implementation adds value to industrial engineering education from the mentor's point of view: Focus: defining how to observe, from the mentor's point of view, whether its implementation added value to their internship period as for the development of industrial engineering skills and abilities.
Step 13. Adapt the implementation schedule to the university's: Focus: adapting the time of mentoring implementation to the academic period of the university aiming to enable a connection of mentoring with internship recommended by MEC and ABEPRO curricular guidelines.
Step 14. Prepare training material for mentors, mentees and industrial HR: Focus: explaining how the mentoring model will start to be developed and the purpose of the mentee's development as regards industrial engineering skills and abilities, supporting the project monitoring, resolving possible doubts and defining the results to be obtained. All content covered in this mentoring planning phase will be drawn upon this training.

4.1 Phase 1: Preparation of Industrial Internship Mentoring Model at University

The first step of the model consists in aligning the mentoring with the pedagogical project of the industrial engineering course, which is performed by the model leader who is the person that is interested in the project at the university. The main steps to be taken are shown in Table 2.

4.2 Phase 2: Mentoring Planning at University

The second step of the model is to lay out the details of mentoring planning aligned with the pedagogical project of the industrial engineering course by the model coordinator, who is the professor responsible for the discipline of supervised internship at the university. The main steps to be taken are presented in Table 3.

4.3 Phase 3: Implementation of Industrial Internship Mentoring Model at Universities and Industries

The third step of the model focuses on the mentoring implementation per se, as defined in phases 1 and 2 which set the preparation and planning for mentors, mentees, HR personnel and model coordinator at universities and industries. The main steps to be followed can be seen in Table 4.

The focus of each step shown in Table 4 consists in:

- Step 1 – focus: inform mentors about the details of its implementation defined during the planning phase in the form of oral and face-to-face presentation at the university.
- Step 2 – focus: assist university mentees in choosing a mentor who can contribute to develop their industrial engineering skills and abilities. This choice should be based on the profile of the mentor.
- Step 3 – focus: engage the mentor in its implementation at the industry.
- Step 4 – focus: inform mentors and HR sector on the details of its implementation defined during the planning phase by e-mail.
- Step 5 – focus: draw up a confidentiality agreement between them at the industry regarding the information exchanged during meetings and formalize the two areas of improvement, the description of a small practical project and the results to be achieved by the mentee, which will be addressed in the following topics.
- Step 6 – focus: define two industrial engineering skills and/or abilities that must be improved by the mentee during the mentoring project at the industry. The choice of the two skills and/or abilities was originated from the list of the 10 skills and 12 abilities recommended by ABEPRO [25].
- Step 7 – focus: define the practical project with the two areas to be improved by the mentor as regards the industrial engineering skills and/or abilities in the context of project development at the industry. In addition, it should be defined how the two areas of improvement will be assessed at the end of the implementation from the mentor's point of view. With regard to the practical project, it must be made clear that it is only a means to create a context. Its main objective is to create an opportunity to develop skills and abilities related to the two areas of improvement of mentoring in the practice of industrial engineering.
- Step 8 – focus: conduct face-to-face meetings at the industry. It is worth mentioning that the meetings should cover feelings and emotions, which should be shared between mentors and mentees.
- Step 9 – focus: effectively observe the mentee's development regarding the two areas of improve-

Table 4. Industrial internship mentoring model at universities and industries

Steps of Phase 3 – Industrial internship mentoring model implementation at universities and industries	
Model Coordinator Responsibilities	Responsibilities of mentors and mentees
Step 1. Inform mentees about the mentoring implementation	
Step 2. Guide mentees as for the mentor to be chosen and invited by them	Step 3. Invite the mentor to participate
Step 4. Inform Industrial Mentors and HR Sector	Step 5. Execute a mentoring agreement between mentor and mentee
	Step 6. Define the two mentoring areas of improvement concerning industrial engineering skills and abilities
	Step 7. Define a practical project to be developed
	Step 8. Conduct meetings between mentor and mentee
Step 9. Observe the implementation results from the mentor's point of view	Step 10. Monitor mentees and their practical project

Table 5. University evaluation of industrial internship mentoring model implementation

Steps of Phase 4 – University evaluation of industrial internship mentoring model implementation
Step 1. Find out whether the mentoring implementation adds value to industrial engineering education from the mentee's point of view: Focus: effectively verify whether value was added to industrial engineering education during their internship period from the point of view of mentees through an individual interview to be held at the university itself.
Step 2. Consolidate the implementation results at the university from the mentor's point of view: Focus: check whether the mentee has achieved the expected results at the end of the model implementation from the mentor's point of view.

ment concerning industrial engineering skills and abilities from the point of view of the mentor.

- Step 10 – focus: monitor the mentoring implementation and its conclusion aligned with the pedagogical project of the industrial engineering course at the university itself in person.

4.4 Phase 4: University Evaluation of Industrial Internship Mentoring Model Implementation

The fourth, and last step of the model, is to evaluate the industrial internship mentoring model implementation and its results at the university. The main steps to be taken by the model coordinator are shown in Table 5.

Once these steps have been taken, it is consolidated the industrial internship mentoring model to be implemented in public universities for undergraduate industrial engineering education.

5. Industrial Internship Mentoring Model Implementation and its Results

5.1 People involved in Model Implementation

With regard to the people involved, it can be said that mentors have the profile features presented in Table 6. They are between 20 and 40 years old, mostly male postgraduate engineers occupying leading positions and undergraduates between 2008 and 2017, who have been working for 10 years in their respective companies.

As for the companies that participated in its implementation, their respective profile is shown in Table 7. They are mostly located in the city of Resende, rather large and belong to the automotive sector. Their mentors are mostly quality and industrial engineers.

As mentioned previously, mentees are industrial engineering students who work as interns in these industries.

Industrial engineering and human resource experts were consulted in order to verify whether the constructs of "industrial engineering education" and "mentoring" in combination are actually valid for generating the theoretical model. The profile of experts who participated in the interviews is summarized in Table 8. They are mostly women who are over 40 years old with 10 years of experience and having graduated in engineering over 20 years ago.

5.2 Implementation and Results of Industrial Internship Mentoring Model

The industrial internship mentoring model implementation takes into account the four phases presented from Tables 1 to 5. The main abilities and

Table 6. Profile of Mentors

Age range total %	**20–30**	**31–40**	**≥ 41**	
	38%	*47%*	*16%*	
Gender	**Masculine**	**Feminine**		
	85%	*15%*		
Academic degree	**Industrial Eng.**	**Mechanical Eng.**	**Chemical Eng.**	**Other**
	52%	*16%*	*13%*	*19%*
Year of completion (graduation)	**<1997**	**1998–2007**	**2008–2017**	
	10%	*41%*	*49%*	
Postgraduation	**Under postgraduate**	**Postgraduate**		
	30%	*70%*		
Position	**Engineer**	**Supervisor/Coord.**	**Manager**	**Other**
	45%	*25%*	*20%*	*9%*
Years of service total %	**1–10**	**11–20**	**21–30**	>;30
	73%	*19%*	*2%*	*6%*

Table 7. Profile of companies where interns and mentors work

Municipality	**Resende**	**Porto Real**	**Itatiaia**	**Cruzeiro**	**Other**
	52%	*23%*	*11%*	*6%*	*8%*
Number of employees	**>600**	**200 to 600**	**<200**		
	77%	*13%*	*11%*		
Sector	**Automotive**	**Chemical**	**Engineering**	**Other**	
	50%	*14%*	*5%*	*31%*	
Department	**Engineering**	**Quality**	**Production**	**Maintenance**	**Other**
	30%	*22%*	*19%*	*6%*	*23%*

skills chosen by mentors and mentees for the model implementation are shown in Table 9.

The results should be analyzed according to the opinion of those involved. So it is important to consider mentor's and mentee's point of view, as well as expert's opinion for constructs validation.

Thus, from the mentor's point of view, results have been investigated through a questionnaire, whose main question was:

- Have the results expected by the mentor as for areas of improvement been achieved? How can improvement be observed by you?

Thus, the analysis of questionnaire responses shows that 98% of mentors confirm that the expected results in terms of improvement of skills and abilities have been achieved.

Still with respect to the opinion of those involved, an interview has been carried out with the aim of analyzing the mentee's opinion, whose main questions were:

- By comparing the internship period without the mentoring program implementation to the one in which it was actually implemented, has mentoring made a difference in industrial engineering education?
- If so, what were the positive points?

Thus, about 85% of mentees realize that the mentoring model has truly made a difference

Table 8. Experts profile

Age range total %	**31–40**	**≥ 41**		
	33%	*67%*		
Gender	**Masculine**	**Feminine**		
	17%	*83%*		
Academic degree	**Psychology**	**Mechanical Eng.**	**Chemical Eng.**	**Industrial Eng.**
	33%	*33%*	*17%*	*17%*
Year of completion (graduate)	**<1997**	**1998–2007**		
	67%	*33%*		
Master's Degree	**None**	**Holder**		
	33%	*67%*		
Doctor's Degree	**None**	**Holder**		
	67%	*33%*		
PhD's degree	**None**	**Holder**		
	83%	*17%*		
Area of expertise	**Industrial Eng. Education**	**Human Resources**		
	50%	*50%*		
Position	**Professor**	**Consultant**	**Manager**	**Other**
	58%	*8%*	*17%*	*17%*
Years of service total %	**1–10**	**11–20**		
	33%	*67%*		

Table 9. Abilities and skills chosen by mentors and mentees

Ability / Skill	Total %
Skill – Oral and written communication	18%
Skill – Ability to work in multidisciplinary teams	16%
Ability – Design, implement and improve systems, products and processes	13%
Skill – Identify, model and solve problems	11%
Ability – Allocate and integrate physical, human and financial resources	9%
Skill – Self-learning and continuing education initiatives	9%
Ability – Forecaste and analyze demands, and sort scientific and technological knowledge	5%
Ability – Use performance indicators, cost accounting systems, as well as evaluating the financial feasibility of projects	5%
Ability – Incorporate concepts and techniques towards quality improvement throughout the production system	4%

Table 10. Main highlights of the model obtained during interview with mentees

Highlights on what made a difference in the mentoring program	% answers by mentees
Improved mentor-mentored relationship	12
Feedback	11
Boosted confidence	7
Interpersonal and public communication	6
Better organization at work	6
Greater mentor's responsibility	4
Greater focus at work	4

during their internship period in industrial engineering education.

Qualitatively, the main positive points mentioned by mentees are shown in Table 10 by highlighting an improved mentor-mentee relationship and the practice of feedback.

In order to assess mentees and mentors' opinion about the internship mentoring model qualitatively, a questionnaire also had to be filled out, whose main questions were:

- What was important in the mentoring model? What was positive?
- What gains has the mentee acquired during the mentoring model?
- What gains has the mentor acquired during the mentoring model?
- What gains has the company acquired through the mentoring model?

The analysis of questionnaire responses given by mentees can also be seen in Table 11, along with the mentors' responses.

Tables 9 and 10 should be analyzed in conjunction. In Table 9, the "Oral and written communication" and "Ability to work in multidisciplinary teams" skills followed by the ability to "Design, implement and improve systems, products and processes" are those that must be mainly improved in the professional performance of interns involved in its implementation. On the other hand, the mentees emphasize in Table 10 that "interpersonal and public communication" is one of the strengths of the model. Thus, it can be observed a connection between the skills and abilities chosen by mentors for mentees to be developed and the mentee's perception as a strength of the model.

By analyzing Tables 10 and 11 together, it can be observed that the internship mentoring model, researched by different tools, contributes to the mentor-mentee relationship, the exchange of experience between them, greater feedback, transfer of knowledge from an experienced person to a less experienced one and better communication.

Some testimonials by mentors, mentees and human resources personnel at the industry are worth mentioning, as they highlight their perception about the model:

> "I found it fantastic because it greatly helps so as to have better professional education. I will talk to the interns' supervisors working at the company right away and I am sure they will get involved so that the program works effectively." (Testimonial from a human resource professional working at one of the industries involved)

> "I believe that the industrial internship mentoring program is of great value, both for companies and interns. Acquiring knowledge from more experienced professional is one of the key steps to become a competent professional." (Testimonial from a mentee)

> "The industrial internship mentoring program was very important in my career. Due to all past experiences of my mentor, besides discovering what were my mistakes and putting improvements into practice so that I can have a better professional future." (Testimonial from a mentee)

> "The program was very interesting. My mentor has helped me constantly in my day-to-day life. Through mentoring, the relationship was closer and I began to

Table 11. Questionnaire responses with open-ended questions asked to mentors and mentees

Category (asked question)	Main mentee's responses	Main mentors' responses
Positive points of the model	Exchange of information and experience between mentor and mentee	Exchange of experiences between mentor and mentee
	Development of relationship with mentors through meetings	Supporting/guiding the mentee through periodic meetings
	Feedback from mentor	Improved relationship between mentor and mentee
	Indication of what should be improved	Further feedback
Gains for the mentee	Feedback on operational and behavioral areas of improvement	Day-to-day problem solving
	Ability to acquire knowledge (including technical knowledge) from a more experienced person	Past mentoring knowledge and areas of improvement
	Better relationship with the mentor	Maturity and behavioral development by mentees
	Increase in strengths and weaknesses	Professional development
	Boosted self-confidence	Feedback
Gains for the mentor	Practice of people development and feedback	Professional experience exchange
	Satisfaction by imparting knowledge to those who are at the beginning of their career ("I am happy to impart my knowledge and I feel valued")	Side-by-side development, seeking to improve mentoring practices (teaching)
	Sense of contribution to develop mentoring practices	Feedback on operational and behavioral areas of improvement in daily problem solving
Gains for the company	Better results of internship work (clearer indicators with greater clarity)	Experience exchange
	Intern development	Train professionals according to the company's values
	Productivity gains (better result of working as an industrial engineering intern)	Improved intern performance
	Greater proximity between mentor and mentor	Integrating the company's reality into the university's

obtain feedback from my activities, which is essential for my professional development." (Testimonial from a mentee)

"I believe that the industrial internship mentoring program has much value to add to all participants, both students, professionals in the field and even professors. This first period served as experience, but for the next classes, there will be greater gains. Many students do not have this opportunity, perhaps because of company' culture or lack of time. However, when the proposal is from the university, there are greater chances of sensitizing professionals. However I believe that the industrial internship mentoring program will assist FAT (Faculty of Technology) in training future engineers with greater quality and professionalism." (Testimonial from a mentee)

"The industrial internship mentoring program was important so that the activities carried out during the internship period were directed towards fulfilling a specific objective. Internship is a professional training period when students obtain their first experiences and realize their career options. I believe that mentors are important for assisting mentees in their activities by indicating the areas that require improvement, sharing their own experiences and encouraging them to follow the path of continuous improvement. One of the difficulties found by me and my mentor was the lack of time for meetings." (Testimonial from a mentee)

"The program is very good. It uses the potential that already exists within the company, but involving the wisdom of a more experienced employee, thus fostering innovation and creativity of learners so as to make the company more competitive. Everyone wins." (Testimonial from a mentor)

"First of all, I appreciate the opportunity to share a bit of my experience with mentees, and the learning process from this practice is very important for any company's growth. It is not easy often due to our daily lives, but it is also important to take the time to prepare our substitutes, thus enhancing the results of the company." (Testimonial from a mentor)

"The industrial internship mentoring program went beyond my expectations because I was able to better understand the needs, difficulties and concerns of mentees, which generated greater trust and communication between students and the company in general. The program still has flaws that should be improved. Notwithstanding, it meets what has been proposed." (Testimonial from a mentor)

Regarding expert's point of view, interviews were applied, whose main questions were:

- As a HR or Industrial Engineering expert, what is your opinion about the model?

- Is the mentoring model valid for industrial engineering education? How?
- What are its strengths?
- What are its gaps or areas of improvement?

Among the interviewed experts, 83% consider the model valid for industrial engineering education. Besides the validity of concepts, some observations made by the interviewed experts should be taken into account by capitalizing them to design the mentoring model. Thus, this study should clarify that:

- The practical project, which is part of the practical implementation of the industrial internship mentoring model, is a context to develop skills and abilities.
- The mentee's role in choosing the mentor is acknowledged by experts as a possible facilitator of the model by a closer bond and greater trust between mentor and mentee.
- The industrial internship mentoring model is not and must not be intended to replace an internship model, but it may be part of it.
- The model should address feelings and emotions that must be shared between mentor and mentee.

Two strengths of the model were highlighted by the experts as the greatest gain obtained by mentees towards industrial engineering education, which are:

- The model translates into the opportunity to develop the mentees' (interns) behavior, ethics, learning and human relationships.
- It is a formal and structured process for the development of skills and abilities, regardless of the willingness or level of interest by university professors to do so informally.

So this topic was able to listen to mentees, mentors and industrial engineering/human resource experts about the industrial internship mentoring model.

Regarding reliability and validity evaluation for mentors and mentees questionnaires and interviews, statistical results are presented in Table 12.

Table 12. Levels of reliability and validity in synthesis of 3 cycles

Rated Item	Synthesis of 3 cycles
Sample size – number of mentor-mentee pairs	52
Reliability level – results of the Cronbach α coefficient test	0.72
Validity level – statistical hypothesis testing to compare two data sets	96% > 19%
Synthesis of interviews – mentees – statistical hypothesis testing to compare two data sets	71% > 22%
Questionnaire to analyze results – mentor – statistical hypothesis testing to compare two data sets	96% > 27%

With regard to Cronbach's α coefficient test, the overall result of the three cycles was greater than 0.70, which is the minimum value accepted [44].

As regards the research validity based on the statistical hypothesis testing, it is found that the null hypothesis (H_0) should be rejected, i.e. the one in which the sets of data on implementations renders the expected result is the same as that in which the expected result is not achieved. In fact, the data set of internship mentoring model implementation that generates the expected result is greater than the one which does not do so, as shown in Table 12, both from mentors' and mentee's opinion. Thus, it is observed that the null hypothesis (H_0) was rejected.

6. Discussions

6.1 Answers to Research Questions

With respect to the survey questions, it can be said that:

- Mentoring can be applied to undergraduate industrial engineering education for developing mentees' abilities and skills, which can be adapted to other cultural realities and contexts of engineering.
- According to the presented model, mentoring was compatible with the pedagogical project of the industrial engineering course as an activity within the programmed content of supervised internship, which is compulsory in undergraduate curricula of industrial engineering courses. It is not intended to replace the internship models in industries, but rather to complement them.

It should be considered that the practice of mentoring within the discipline of supervised internship is complementary to those within the traditional curriculum of an industrial engineering course, thus not being a replacement for any other discipline. It is seen as an opportunity to serve as an active learning practice, since the mentoring model is aimed to develop the student's career within an industry through the support of an experienced engineer.

This can be complemented by the results found by George and Mampilly [29], in which the authors discuss that universities should change their curriculum and ensure that students have appropriate knowledge, attitudes and skills to succeed in this turbulent social and professional environment nowadays.

6.2 Theoretical and Practical Contributions

The theoretical mentoring model brings both theoretical and practical contributions.

Talking about theoretical contribution, the model put together to "work as a team" constructs as industrial engineering education and mentoring.

With regard to practical application, it is possible to say that the model is effective due to an answer stating that the model makes a difference in 85% of its implementations from the opinion of students taking industrial engineering courses during their internship period, and 98% of the model implementations according to mentors' opinions. Its practical benefit is the added value of the model for the student's learning process of industrial engineering.

Another point to be highlighted in terms of contribution is skills and abilities development for mentees. As shown previously by Tables 10 and 11, they are largely listed by mentors and mentees. But one main practice should be emphasized because is cited sometimes in these tables is the feedback practice. By receiving feedback, mentees have the opportunity to be openminded, listen to a more experienced professional about their gaps to be improved and how to do so and change their behavior. It is the continuous improvement in practice because the mentee really aim to be a better engineer and use the internship mentoring model for this main goal.

6.3 Relation between Industrial Internship Mentoring Model and Active Learning

Regarding model implementation, because it is outside the scope of traditional classroom learning methods, students commonly feel a certain amount of discomfort. However, as cited by Pedro [47], not keeping to traditional classroom teaching methods allows interdisciplinarity, as well as less severe classroom environments, more patent boundaries and knowledge that can be applied in real life.

Thus, the presented model is proposed as a form of active learning. Some authors have made significant contributions through their studies.

Bonwell and Eison [48] define institutional strategies for active learning as an approach that compels students to do things and think about what they are doing. Thus, active learning is strongly characterized by student engagement in the learning process [49, 50], an attitude that is in marked contrast to traditional reading methods in which students passively obtain information from an instructor, but are rarely able to translate theoretical information into practical knowledge [51].

A type of active learning instruction strategy that has achieved popularity in operations management training is the use of games and manual activities [51].

An example of such strategy has been presented by Arenas-Márquez et al. [52]. They address how a teaching method based on information communication technologies (ICT) can significantly affect students' understanding of the learning process. Their results also confirm the pedagogical effectiveness of the software, and that methods based on ICT are an alternative to traditional methods used in operations management (OM) education. These results are considered quite positive in teaching and learning OM.

Another instance that is worth mentioning was provided by Santos et al. [51], which is based on a teaching method according to the philosophy of active learning for operations management. Current social changes and increased information flow are changing the profile of college students and, as a consequence, the way they learn. This new context requires different approaches to teaching and justifies the growing interest in improving the teaching-learning relationship through innovative classroom activities [51].

Another example of active learning has been presented by Yalabik et al. [53]. The authors explore the impact of the choices made about capacity, capacity management and product portfolio management. At the end of the exercise, students are invited to present their learning qualitatively in the classroom using transparencies.

A further example of active learning exercise has been presented by Lambrecht et al. [54] through a game that evaluates the understanding of the relationship between process variability and its production capacity in an environment with dependent working stations and limited inventories. Although it is not new to students conceptually, they usually underestimate the impact of variability on production capacity.

According to Nguyen et al. [55], when using active learning, instructors must choose activities at appropriate level of difficulty by clearly explaining what is expected from it and its benefits. It is also important to be certain about the time required for such an assignment, as well as encourage students to commit to the activity.

In all these examples, students are invited to engage outside the scope of the classroom, collaborating with a learning process that goes beyond reading books. It is at this point that the present study shows its relation to active learning.

7. Conclusion and Suggestions for Further Research

This study aimed to present an industrial internship mentoring model for undergraduate industrial engineering education at public universities. Interviews and questionnaires were previously developed and validated to collect data from 52 students of a

Brazilian public university and their respective mentors-engineers. The results were analyzed using Cronbach's α coefficient test to validate its reliability, and the statistical hypothesis test of comparison between two sets of data in order to verify its validity.

The most important finding of this study is that the industrial internship mentoring model is valid for undergraduate industrial engineering education. It should serve to emphasize that active learning methods, such as this model, can be used as a complement to traditional teaching curricula. This can be confirmed by the testimonials of mentors and mentees that the model adds value to teaching through the development of students' industrial engineering skills and abilities.

In addition, the contribution of the present work to current literature is the combination of theoretical constructs about industrial engineering education and mentoring, which previously "flown solo" but now "act as a team" in a pioneering way through an internship mentoring model for undergraduate industrial engineering education to be put into practice by its students who are also industrial interns. Once again, its novelty should be highlighted. Therefore, it is understood that the present work contributes both to a research environment and to the scientific production towards broadening academic experience.

However, the present research contains a few limitations, such as the difficulty in training mentors and a possible misunderstanding between the mentoring model and the internship content at the industry.

As regards training mentors, in order to minimize the risks of failure posed by the model, alternatives were sought for planning it. The model was badly presented to mentors due to the difficulty of having personal contact with them in the classroom. The mentors' availability for training is insufficient if compared to the needs of a traditional model in this phase. Thereby, the present model had to seek different alternatives to present the steps to implement the model to them. It was found that a standardization of content ought to be mentioned in each of the mentor-mentee meetings.

Moreover, it is important to highlight that the industrial internship mentoring model does not propose to be or to replace an internship model according to experts' observations. It is serves only as an active learning medium for collaboration in industrial engineering education. Thus, despite being possible, internship contributions are not expected by the mentoring model, as well as the identification of what are the results of mentoring and what are the results of internship. The model does not propose to go any further in this respect.

As future research, one should study how applicable the mentoring model is in other undergraduate industrial engineering courses, including in private universities and ranging a wider variety mentors and mentees. Thus, its applicability could be confirmed by using more sophisticated statistical analysis methods and more generalizable results.

Another point is that the development of the mentoring model could be expanded not only to courses that rely on industry as a support for internships, but also in the service sector. Industrial engineering extends its field of application to several areas, but the service sector is a possible and broad field of development for the mentoring model to be adapted to its reality in which it can in fact be tested.

Ultimately, there would be an opportunity to find new theoretical and practical contributions of the mentoring model that have not been mentioned herein. Applying continuous improvement concepts to the model would make significant and insightful improvements, since it would broaden its horizons.

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Maria da Glória Diniz de Almeida has been an Industrial Engineering Professor at Rio de Janeiro State University, Brazil, since 2001. She was awarded with her BS and MS degrees in industrial engineering at Rio de Janeiro State University, Brazil, in 1999, and Rio de Janeiro Federal University, Brazil, in 2002, respectively, and her PhD degree in mechanical engineering from Sao Paulo State University, Brazil, in 2017. She is quite active in both research and applications on account of her complementary industrial experience. Her current research interests are focused on people's development regarding engineering education, mentoring and productivity.

Fernando Augusto Silva Marins received the BS degree in mechanical engineering from Sao Paulo State University, Brazil, in 1976, the MSc Degree in Operations Research, in 1981, from Technological Institute of Aeronautics, Brazil, and the PhD degree in Operations Research, in 1987, from University of Campinas, Brazil. He was a post-doctorate fellow at Brunel University, London – England, in 1994–1995. From 1977 to 2019, he has been working at Sao Paulo State University, and since 2010 he is a Full Professor in the Operations Research and Logistics Area. He is author/coauthor of twenty-three books and books chapters, 69 papers in scientific journals, and 198 papers published in proceedings of scientific congress and conferences. His research interests include operations research applications on logistics and supply chain management, as well as multiple criteria decision methods. In Brazil, he is member of the Editorial Board of Production Journal and of the Online Production Journal, and he is member of the Technical Council of the Electronic Journal on Production & Engineering.

Andreia Maria Pedro Salgado is a Professor of Mechanical Industrial Engineering at São Paulo State University, Brazil. She graduated in Psychology from Santa Catarina Federal University, Brazil, in 1998 and at the same university got a DS in Industrial Engineering in 2007 and a MS in Industrial Engineering in 2003. She has been working for São Paulo State University, Brazil, as a professor since 2012. Her current research interests are focused on Knowledge Management regarding industrial engineering and psychology.

Rita de Cássia da Silveira Marconcini Bittar holds a PhD in Mechanical Engineering from the State University of Campinas (2014), a MSc. in Mechanical Engineering from the State University of Campinas (1993) and a degree in Mechanical Engineering from the Federal University of Itajubá (1987). She is currently a professor and coordinator of the Industrial Engineering course at the Faculty of Technology of the Rio de Janeiro State University, working in the areas of teaching, research and extension programs. She has experience in the field of Industrial Engineering, with focus on Planning, Design and Control of Production Systems, working mainly on the following topics: Extended Business Management, Business Process Management and discipline of supervised internship. She also actively participates in groups of extension projects and research on the area of Active Learning Methodologies and Creative Learning. Member of G3E – Group of Experts in Entrepreneurial Education at UERJ.

José Glênio Medeiros de Barros holds a PhD in Industrial Engineering from the Federal University of Rio de Janeiro (1999) and is an Associate Professor at the Rio de Janeiro State University, who has also been an Assistant Professor at the University of Taubaté for over 13 years. He has been working for more than 20 years in the field of Industrial Engineering, especially focused on Manufacturing Management, Statistical Process Control, Quality Management, Productivity and Production Management. With researches and works developed in various companies and institutions, he has particularly worked in the following sectors: automobile, metal-mechanic, chemical, naval and aeronautical industries, as well as at universities. He is also an evaluator of INEP/MEC undergraduate courses and higher education institutions.

Antonio Henriques de Araújo Junior is a transportation engineer who has graduated at Bergische Universitaet Wuppertal (Germany) with a Master's degree in Finance (FEA/USP) and a PhD in Industrial Engineering (EPUSP). He carried out post-doctoral programs at the Technological Institute of Aeronautics (ITA) and at the Engineering School of the University of Minho (EEUM), Portugal. He is Adjunct Professor at Level IV of the Rio de Janeiro State University and is a reviewer of national and international journals in the fields of Production and Management Engineering, as well as being an Editor of the Journal of Air Transport and Management. He has 25 years of experience in the automotive industry (Mercedes-Benz Germany and Mercedes-Benz Brazil) and aeronautics (EMBRAER). Main areas of research: Industrial productivity and air transport, quality management and environmental economics. He has also published scientific and didactic books about industrial productivity and scientific methodology.

Nilo Antonio de Souza Sampaio got a PhD in Mechanical Engineering at the Universidade Estadual Paulista (UNESP-FEG), a Master's Degree in Mechanical Engineering at the University of Taubaté (UNITAU) and a university graduate in Chemical Engineer at the University of São Paulo (EEL / USP). He is Adjunct Professor I of the Rio de Janeiro State University and he teaches in the graduation of the courses of Industrial Engineering, Mechanical Engineering and Chemical Engineering. He works with Mathematics and Statistics, with emphasis on Applications of Statistics and Mathematics in Sciences, Planning of Experiments and Monitoring of Processes. It has several articles published in periodicals and Proceedings of Brazilian national and international scientific events.

Bernardo Bastos da Fonseca got a PhD in Industrial Engineering at the Luiz Alberto Coimbra Institute for Graduate Studies and Engineering Research at the Federal University of Rio de Janeiro – PEP / COPPE / UFRJ. He develops his research in the area of ergonomics, human factors, security, environment and health. He got a Master in Industrial Engineering with emphasis in Ergonomics and Complex Systems at the COPPE / UFRJ and a MBA in Ergonomics at the COPPE / UFRJ. He is graduated in Industrial Design at the UFRJ and he develops studies in the area of ergonomics with emphasis on complex systems, design, product development, health and safety at work. He developed ergonomic evaluation studies in chemical laboratories, health insurance offices and in a manufacturing company. Currently he teaches and investigates in the Industrial Engineering the State University of Rio de Janeiro.

Andresa Deoclidia Soares Côrtes received the bachelor's degree in Physics from the São Paulo State University (2004) and the MSc. Degree in Applied Physics from the same university at the Physics Institute of Rio Claro (2007), a PhD degree in Mechanical Engineering from the State University of Campinas (2011) and postdoctoral by this same university in the Semiconductor Center (2012). She is currently a collaborator at the State University of Campinas, a full professor at the Paulista University and a lecturer at the Centro Universitário Herminio Ometto de Araras. She has experience in the area of Materials Engineering and Metallurgy, working mainly on the following topics: teos, xerogéis, sleep-hydrolysis, sol-gel process and gettering.

Gessica Naira Diniz Baronto is an Industrial Engineering student at Rio de Janeiro State University and has supported the mentoring program as an intern.