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Mentoring model for undergraduate teaching in production engineering

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ABSTRACT
The goal of this thesis is to present a mentoring program for undergraduate teaching regarding Industrial Engineering in Brazilian public universities in industrial student training period. The proposed program is based on previous works available in specialized literature, regarding mentoring and industrial engineering teaching. The employed research methodology was of qualitative applied nature, through a research-action approach. To test the coherence of the questionnaire respondents, which was applied to mentors and mentees in the theme of mentoring in the industrial sector, the α-Cronbach test was adopted. And aiming to validate the proposed program it was applied a statistical test of comparison between proportions. Among protégés, 85% confirmed that the project has made a difference in production engineering education during their trainee period, while mentors reinforced that 98% of mentees had their industrial engineering competencies and skills developed. Amid program limitations, we identified that there is a lack of mentor's availability for formal training, and to minimize this problem, the proposed program has a detailed procedure to facilitate its use. The main contribution of this thesis regards its pioneer aspect in creating a mentoring program for production engineering teaching, bringing universities closer to manufacturing businesses, during the student training period.

Keywords: Mentoring program, Industrial engineering teaching, Training, Professional education.

1 INTRODUCTION

The word "mentor" represents an experienced person who advises and helps someone with less experience for a period [1]. In the study in question, mentoring is defined as an attempt to transfer specialized knowledge from an experienced professional (mentor) to a less experienced one (mentee) within an organization. It works as a "shortcut" in which the mentor supervises the activities and performance of the young colleague who must learn quickly [2].

Contemporary researchers in the field of business have been addressing the benefits of mentoring in studies since the 70s [3]. Mentoring has long been approached as an important resource for teachers in promoting the intellectual development of students [4].

The benefits of mentoring have been widely disseminated in journals. Some authors bring contributions.

For Booth [5], the mentor's attention to the mentee, as well as the satisfaction he gets in the program are among the advantages. For the mentee, the fact of having someone who donates part of his time and who transmits much of his knowledge is of fundamental importance to be able to see his professional future and deal better with people and problems of the most varied possible. On the other hand, the main advantage for the mentor is personal satisfaction in seeing the progress of the person being helped.

According to Stewart and Knowles [2], some of the advantages for mentees are support for professional development as engineers in technical and behavioral terms, the opportunity to show their skills and their potential for more advanced or complex activities in the future, and improved self-confidence. On the other hand, mentors can develop their leadership capacity for people development and feedback practice.

Mentoring as an activity provides positive benefits for both work groups and the organization. It improves self-esteem and increases the knowledge, skills and competencies of the people involved [6].

According to Gannon and Maher [7], mentoring is also recognized as a prosocial behavior in which individuals develop relationships that will benefit the person, group, or organization. This altruistic behavior is seen as beneficial for mentors, whether in the professional or personal area. An interesting fact of the text that the authors cite is that a part of the mentees still keep in touch with their mentor.

As for the main risks of failure and disadvantages in the application of a mentoring program, some authors present their view.

Gibb [8] cites the natural divergences (jealousy, insecurity, envy, in other words) that can occur, especially in higher ranking positions. Lack of training for mentors and mentees is another risk of mentoring failure [9]. Still addressing the theme of the training of the personnel involved, Scandura [10] addresses what can go wrong in a mentor-mentee relationship and proposes training to avoid this situation. Some relationships of orientation do not achieve their main objective, causing personal damage, feeding discontent, anger, resentment, distrust, and frustration [10].

Still with regard to risks, Rolfe's text [11] cites the seven fatal flaws for a mentoring program: strategic values without clarity, *insufficient lead-time* and planning, lack of resources, inadequate support, insufficient training, lack of structure and ineffective monitoring and monitoring, *feedback* and evaluation.

Through the authors mentioned above, it is seen that the initial training of mentors and mentees, as well as planning, monitoring and actions are essential for the success of a mentoring program. In addition, as stated by Stewart and Knowles [2] earlier, commitment, confidentiality and transparency on both sides are essential to minimize risks in the application of the program. As guidance to mitigate them, it is recommended preparatory training or training for mentors and mentees and preparation in advance of planning for the realization of the program.

Different foci and applications present themselves when it comes to the subject of "mentoring", as described below:

- Academic:
  - Mentoring of teachers for students in the first years of university studies, still with the objective of development and retention of students [12];
  - Mentoring applied to the first years of professional experience of university professors [13].
- Professional:
  - Mentoring in universities for cases of career guidance for young professionals with graduation already completed in different areas of activity [14];
  - Mentoring in areas such as nursing, medicine, social work and teaching of teachers [15].

Thus, this work was built based on the hypothesis that one can unite the concepts of production engineering teaching and mentoring to create a model for the teaching of production engineering.

From these concepts, the following questions motivate the research:

- How can mentoring be applied to undergraduate teaching in production engineering?
- How would it be possible to make the mentoring compatible with the pedagogical project of the production engineering course?
- How to use mentoring as a tool to expand the development of competencies and skills of production engineering recommended by ABEPRO and the MEC guidelines for engineering education?

Thus, the general objective of the work is to propose a mentoring model aimed at the teaching of undergraduate Production Engineering in public higher education institutions, linking the curricular guidelines for the teaching of production engineering, the competencies, and skills necessary for the profession in this area and the concept of mentoring.

The main expected contributions of the work are:

- Academic: councils of undergraduate courses of Production Engineering;
- Scientific: there is little scientific evidence that relates the concepts mentoring and teaching of production engineering, when approached together;
- Professional: learning and professional development of trainees based on the application of the mentoring model.

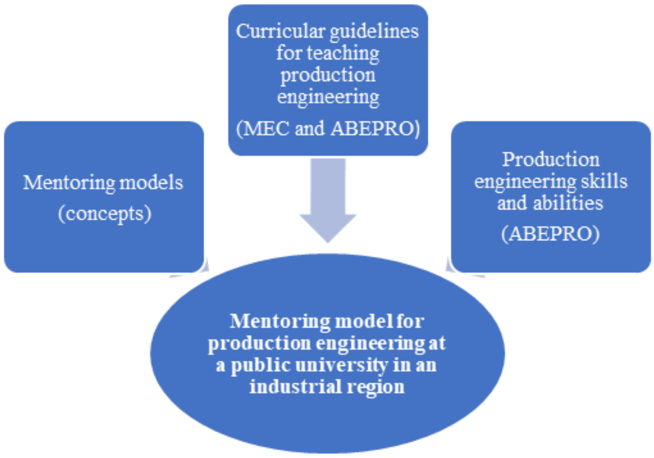
The work begins by reviewing the literature and steps for the creation of the model, followed by its construction. Through the application of the model, results are then provided, moving on to a discussion and its final considerations. Finally, the conclusion and the suggestion of future work are presented.

Among the limitations of the model, it proposes to be developed in internships in industries, not addressing, therefore, sectors such as services. Another point is that it does not aim to address or discuss the supervised internship, which is an element present in the curricula of the undergraduate course in production engineering.

2 THEORETICAL BASIS FOR THE MENTORING MODEL

To elaborate the theoretical model of mentoring, the elements illustrated in the concept map of Figure 1 were used. These constitute the theoretical framework upon which the model is founded.

Figure 1 - Conceptual map for the construction of the theoretical mentoring model



As for the mentoring models that served as the basis for the study, Vela [16] contributes his model in eleven steps distributed between the preparation, launch and evaluation phases. Alred et al. [17] collaborate with the model in three stages, which are exploration, new understanding and action plan. Poulsen [18], in turn, brings his "alliance in learning" model. To complement, we use a collection of different experiences in mentoring models in universities around the world. The choice of authors to guide the theoretical basis of this study is due to the contribution and quality that its contents contribute to the creation of the mentoring model presented.

Complementing the concept of "alliance in learning", Bozionelos et al. [19] highlight that one of the main characteristics of a mentor is the ability to listen to the professional in training, their positions, their judgments and their values. It should question it, seeking its justifications and encouraging the young learner to develop his capacity for critical reasoning. This is the main focus of the relationship, where one grows with the other. The authors also add that the role of mentor, therefore, relates to one of the essential concepts of the learning process: reflection. Reflecting allows you to analyze and evaluate one or more personal experiences, generalizing a certain thought. With this the young apprentice is better informed, acquiring more skills and being more effective than before [20, 21, 22].

Continuing the importance of reflection in the learning process, the Socratic method greatly collaborates in the development of mentoring.

This method, described by Lawrence [20], which dates from the era of Socrates, is a form of questioning and discussion, based on questions and answers in order to stimulate critical thinking and creativity, being, for this reason, one of the ways for the development of critical thinking skills. Effective mentors use the Socratic method, helping people grow personally and professionally.

Still talking about the Socratic method, Lawrence [20] addresses that instructing people on what to do or simply giving answers is the easiest way to do something. However, helping them solve the problems, using the Socratic method, is a more efficient approach, because by not solving the problem by that person (only helping them), it prevents the same problems from coming back to you to be corrected again. The mentee will be able to reflect and identify what needs to be improved.

The value of reflection is also found in Sweeny [21], where it is given as one of the main elements in the search for improving the performance and learning of professionals. Professionals need to always be analyzing their behavior, their relationship with the work team and their responsibilities.

In the text of Sweeny [22], the author lists strategies to facilitate professional growth based on the Socratic method, that is, through questions that lead the mentee to reflections.

Kram's model is another way of looking at mentoring. It was established by Kram [23] consists of two dimensions: career functions and psychosocial functions.

Career roles are those that provide advancement in the hierarchy of the organization. They accentuate the learning of organizational roles, career development and prepare the individual for good performance 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, building their self-esteem inside and outside the organization. These functions are performed through mutual trust and increasing intimacy in the interpersonal relationship. Emotional support, in this case, often affects the mentee's professional identity and can be instrumental in career advancement. These functions include role modeling, acceptance and confirmation, counseling, and friendship [23].

Career and psychosocial roles are not completely distinct. They are developed for what each one, mentor or mentee, seeks or offers [23].

On the other hand, over time individuals change and the importance given to functions also varies. The relevance of the functions performed can be affected by interpersonal skills and individual capacities. However, it is by adding these functions that individuals will be able to direct the objectives for each stage of the career [23].

As for the curricular guidelines for the teaching of production engineering, the National Council of Education [24] of the MEC has the prerogative to define the National Curricular Guidelines for the

Teaching of Undergraduate Engineering. The ENCEP [25] recommends the curricular guidelines for production engineering, as well as the topic related to the internship. To complement, one should consider the pedagogical project of the production engineering course.

The MEC is the body in Brazil that defines the educational guidelines of the country, including the curricular of engineering courses [24].

The National Curricular Guidelines for the Teaching of Undergraduate Engineering define the principles, foundations, conditions and procedures for the training of engineers of the Undergraduate Engineering Courses of the Institutions of the Higher Education System in Brazil. The profile of the graduate/professional engineer has generalist, humanist, critical and reflective training and is able to absorb and develop new technologies, stimulating their critical and creative performance in the identification and resolution of problems, considering their political, economic, social, environmental and cultural aspects, with an ethical and humanistic vision, in compliance with the demands of society [24].

As for the competencies and skills of production engineering, ENCEP [25] contributes with those that should be found in the egress of a Production Engineering course within the perimeter of Brazil according to ABEPRO (Brazilian Association of Production Engineering), knowing that this is the body in Brazil that clarifies the role of the production engineer in society and in its market of operation [25].

With regard to skill development, Locurcio and Mitvalsky [26] state that graduates need to acquire skills that are not part of the engineering curriculum, since academic programs should focus on technical content.

In this way, the constructs of a general mentoring model, the requirements to make it applicable to engineering education and, finally, the competencies and skills of ABEPRO are united, characterizing the model for production engineering.

Thus, a theoretical model is proposed that should be focused on including the development of the competencies and skills recommended by ABEPRO [25]. The role of the mentor, in turn, becomes a differential in the development and orientation of the mentee for these competencies and skills in the practice of production engineering as interns.

The meeting of the concepts proposed by the authors mentioned above, together with the applicability of research in universities and industries interested in the student of the undergraduate course in production engineering, in this work named mentored, and supported by the experienced engineer called mentor, make this work an unpublished, unique and useful work for professionals in the area and the academic environment.

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

A mentoring program practice is found in Hamilton-Jones [27]. The central idea of the article is to emphasize the position of mentor tutor, presenting the importance of the mentor's role in the learning of the mentees in the program. The text points out the great results and benefits of the application of this methodology through action research, taking into account the great pressure faced by young people who quickly suffer a change in their baggage of responsibilities, which are now referenced by academic responsibilities that already existed and more those of work.

In Richter et al. [13] another example of a mentoring program is presented, being applied to teachers in the first two years of their career. This mentoring is carried out by teachers who have a greater experience in the classroom, which includes pedagogical guidance, classroom observation, formative evaluation and support in difficulties. The results are mixed, but all show that there is an improvement in the teacher's way of teaching.

Santora et al. [28] advocate a progressive mentoring model as an increment of the educational process and present data from an international and interinstitutional research where mentoring in the field of science and engineering was observed, 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 the mentor for a long period. Therefore, according to Santora et al. [28] in progressive mentoring the student ceases to be passive and becomes active in the process, which leads to improved flow of information, more mastery of the student over the whole and freedom of decision making and relationship, where he can be mentor and learner and his official mentors serve more as a guide and an example and the institution more as a supporter to ensure the quality and effectiveness.

George and Mampilly [29] address mentoring in manager development schools. They cite that when it comes to the skills needed for good management, knowledge must be transferred experimentally, making the teaching of management an essentially interactive process between the teacher and the student. Therefore, mentoring is considered a stable intervention in the development of management and an important resource for learning and conducting organizational changes.

Examples of engineering-related mentoring programs can also be observed. One of them is given by Russell [14], where mentoring is recognized as a support provided by the professional engineer to engineering students who have recently entered the industry. The article talks about the gains for the mentee, the mentor and the company.

Beaty et al. [20] talk about an example of company-university contact in an engineering course. Industry professionals interact with students in a variety of ways, providing them with design advice, forming teaching partnerships, and participating in a student mentoring program, an advisory committee, an interdisciplinary design project, and an industry-based undergraduate student program.

Raber, Amato-Henderson and Troesch [31] show the implementation of the mentoring program at Michigan Technological University (USA) for engineering students, being applied within the college itself where the mentors were the professors themselves. One of the most surprising results was that the majority of students (about 91%) increased their grades after participating in the program. This improvement may have been due to the influence of the program, as the program's commitment coupled with the focus on solving "real world" problems and the teamwork structure impacted the studies at the college.

To achieve success in engineering, young engineers need role models and guidance. This is important so that the novice can face the challenges of a global interconnected world and encourage young professionals to stay in engineering instead of leaving the career and leaving for other areas [32].

According to Russell and Nelson [32], the real leaders in the profession are these experienced engineers who are mentoring the young graduates. They understand the value of cultivating the next generation and the importance of this in the permanent success of the professional and the company.

3 MATERIALS AND METHODS

3.1 SEARCH CLASSIFICATION

Initially it is defined how the research is classified.

The research is applied because it is the application of a mentoring model in an undergraduate course in production engineering, uniting the constructs mentoring and teaching of production engineering.

Qualitative research is shown to be the most appropriate because it assumes an interpretative perspective of the data [33].

The qualitative research process is often much more interactive, while all the content cannot be well defined at the beginning (the case study can be seen as a good method for little-known areas). Instead, definitions and ideas are refined throughout the process recursively [34].

There are requirements for a research to be considered as qualitative. First, qualitative research, like all kinds of research, needs a research question. In some traditions, the term "problem(s)" is preferred to "question(s)". How and why something initially became a research question is a specific type of question. Different research traditions have different ideas about who owns the research question and how it develops. In all traditions, it can be seen that it evolves from the interaction between the objectives of the researcher (individual, ethical,...) and the theoretical frameworks of the researcher, which include all existing previous research, discoveries or theories on the topics to be studied mobilized by the researcher. A research question is something that, in this interaction, seems to be something in which more knowledge is expected.

What makes a research question qualitative is precisely the nature of this combination: qualitative objectives are different from quantitative ones, and qualitative questions are asked in a particular way, referring to qualitative contents. The peculiarity of qualitative objectives lies in the way the question is posed, having a need to describe, verify or understand. A qualitative research question has to be grounded in a qualitative argument [34].

Bryman [35] considers it an error to assert that the difference between the quantitative and qualitative approaches is the absence of quantification in the latter. The qualitative approach has no aversion to quantifying variables, and sometimes qualitative researchers quantify variables. "The distinguishing feature, in contrast to quantitative research, is the emphasis on the perspective of the individual being studied."

Action research is presented as the most appropriate research method, since the researcher takes advantage of the observations of mentors and mentees to interfere in the object of study, which is the mentoring model,

Regarding the data collection method, questionnaires and interviews were used.

Thus, the research is applied with a qualitative methodological approach, using a normative action-research, since it aims to create a norm through a model, supported by questionnaires and interviews for data collection.

3.2 RESEARCH POPULATION

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

Regarding the definition of the research subjects, the development of the mentoring model reached two distinct groups, namely:

- The undergraduate students in production engineering (group 1), who represented the mentees;
- The experienced engineers working in the industries (group 2), who acted as mentors.

The characteristics of these subjects of the application were:

1. Group 1: MENTEES or STUDENTS – student body of the undergraduate course in Production Engineering (higher education) of a Brazilian public university, attending the disciplines of supervised internship and acting as interns in industries, covering a total of 52 students.

2. Group 2: MENTORS or EXPERIENCED ENGINEERS – minimum of four years of work experience as engineers in industries. They are responsible for applying the mentoring model to students. The survey includes 52 engineers, who formed mentor-mentee pairs with students. It is

important to note that the minimum period of experience of an engineer to consider him as "experienced" for the program in question is four years.

3.3 DATA COLLECTION

The three cycles of application of the mentoring model were carried out with the objective of collecting data to consolidate the evaluation of the results of the application of the model.

Questionnaires and interviews were used in this data collection. First, two questionnaires were applied, the first, with the objective of observing, from the point of view of the mentor, the development of the mentee regarding the two points of improvement related to the competencies and skills of production engineering through the practical project carried out in the industry, as well as his vision of the model; the second, aiming to address the mentee's point of view on the mentoring model. These mentor and mentee points of view were addressed through open-ended questions, and served as the basis for the construction of the mentoring model. On the other hand, the development of the mentee from the point of view of the mentor used closed questions (it is limited to "yes" or "no" as an answer).

Access to mentors and mentees through questionnaires was made by the latter. These, as trainees, were responsible for answering their questionnaires and taking and bringing the questionnaires of their mentors at the end of the academic semester, returning them to the teachers of the disciplines.

Another instrument used was structured interviews, the first being called an interview with the mentees, in order to verify, from the point of view of the mentee, whether the mentoring model added value to the teaching of production engineering during their internship period through a closed question. In addition, the main positive points highlighted by the mentees, if any, were qualitatively addressed during the interviews. These interviews were conducted at the end of the academic semester during the presentation of the project developed by the mentee in the discipline of internship supervision, at the end of the presentation of the project and in the classroom.

The second interview, called interviews with specialists, aimed to validate the constructs of the theoretical model with specialists from the areas of production engineering and human resources, using open questions. Six specialists were chosen, being two specialists in the area of production engineering, three specialists in the area of human resources and one specialist in the area of production engineering and human resources. They received the material with the theoretical model and its bases, as well as the questions by *electronic e-mail*, and the interviews were obtained by telephone contact.

Then, the syntheses of the answers of questionnaires and interviews were made to present in the next phase the conclusions regarding the general objective and the questions of the research.

The data were recorded in electronic spreadsheets, using *Microsoft Excel*, and tabulated in order to be converted into information.

3.4 STATISTICAL VALIDATION OF THE RESEARCH

Action research should then be validated statistically. It should be based on reliability and validity, which are criteria for judging the quality of the research [36].

In the action research carried out, when it comes to reliability, it is about the reliability of the questionnaires used with mentors and mentees. When the validity is addressed, the answers to questionnaires and interviews of mentors and mentees are statistically verified. The typing and tabulation of the data relied on the use of an electronic spreadsheet in *Excel* for the conversion of the data into information.

Both the reliability and validity of the research were based on the Classical Theory of Measurement.

Reliability can be defined as the frequency with which the measuring instrument or questionnaire is producing the same result in repetitive situations [37]. It can be classified into four types: test-retest reliability, alternative forms of reliability, half-part reliability, and internal consistency reliability [38]. The most appropriate methodology to find the interrelationship between the elements or the reliability of the structure is the internal consistency test [39]. The main indicator of this test is the Cronbach-α value, which was used to validate the reliability of the questionnaires in the present study.

According to Cronbach [40], the α-Cronbach coefficient was presented by Lee J. Cronbach in 1951 as a way to estimate the reliability of a questionnaire applied in a survey. The α coefficient measures the correlation between answers in a questionnaire by analyzing the profile of the answers given by the respondents. This is an average correlation between questions. Given that all items in a questionnaire use the same measurement scale, the α coefficient is calculated from the variance of the individual items and the variance of the sum of the items of each evaluator through the following Equation (1):

$$\alpha = \left(\frac{k}{k-1}\right) \times \left(1 - \frac{\sum_{i=1}^{k} s_i^2}{s_t^2}\right) \qquad (1)$$

where:

- k corresponds to the number of items in the questionnaire;
- $s^2 i$ corresponds to the variance of each item;

- s^2t corresponds to the total variance of the questionnaire, determined as the sum of all variances.

Table 1 illustrates the step-by-step application of the coefficient, where each column indicates an item, each row indicates an evaluator and the encounter between an item and an evaluator (Xnk) indicates the response of this evaluator to this item, within the scale.

Table 1 - Data from the questionnaire to calculate Cronbach's α coefficient

Avaliadores	Itens						Total
	1	2	...	i	...	k	
1	X_{11}	X_{12}	...	X_{1i}	...	X_{1k}	X_1
2	X_{21}	X_{21}	...	X_{2i}	...	X_{2k}	X_2
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
p	X_{p1}	X_{p2}	...	X_{pi}	...	X_{pk}	X_p
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
n	X_{n1}	X_{n2}	...	X_{ni}	...	X_{nk}	X_n
	s^2_1	s^2_2	...	s^2_n	...	s^2_k	S^2_t

Source: Adapted from Cronbach (2004).

Each item must be independent. If the response to a certain item behaves similarly to the response to another item, it follows that one explains the other. Thus, in order to have a dimensionless value to represent the exemption of random errors of the observations (reliability), the estimator is divided by the total variability of the questionnaire, finally arriving at the formula presented by Cronbach in 1951 [41].

Many researchers consider that the α-Cronbach should have a value greater than 0.7, which is considered a good indicator of the internal consistency test [42].

With regard to validity, the main objective of its analysis is to provide a research instrument that allows researchers to find an answer to the research objective. Generally, researchers can conduct validity analysis by asking the number of questions and seeking answers from respondents or, in some cases, from other research papers [36].

The concept of "validity" brings subjectivity in itself, because when affirming that a measuring instrument is valid, the question arises: valid for what purpose? Validity is the degree to which a given instrument measures what it should measure [43]. Validity is, finally, the degree of accuracy or accuracy of the result of a measurement, that is, how close the result is to what is intended to be measured [44].

Thus, to confirm the validity of the mentor and mentee questionnaires, as well as the interviews with mentees, the statistical test of comparison between two proportions was used, as Costa Neto explains [45]. This test was chosen because it allows the comparison of the proportion of positive and negative responses in the questionnaires and interviews in a statistically valid way.

According to Costa Neto [45], it is often desired to test hypotheses regarding the difference between two population proportions, according to Equation (4):

$$H0, p1 - p2 = \triangle \quad (4)$$

against the convenient H1 alternative.

The test variable, of course, will be the difference between the relative frequencies of the two available samples, p1' and p2'. It is known that if $n1p1' > 5$, $n1(1\text{-}p1') > 5$, $n2p2' > 5$ and $n2(1\text{-}p2') \geq 5$, the distributions by sampling p1' and p2 ' can be approximated by normal distributions of means p1 and p2, according to Equation (5), and variance, according to Equation (6):

$$p1.\ (1-p1)/\ n1 \text{ and } p2.\ (1-p2)/\ n2 \quad (5)$$

$$\sigma 2\ (p1' - p2') = p1.\ (1-p1)/n1 + p2.\ (1-p2)/n2 \quad (6)$$

Therefore, hypothesis H0 could be tested, analogously to the previous cases, by the quantity given by Equation (7):

$$z = [(p1' - p2') - \triangle] / [p1.\ (1-p1)/n1 + p2.\ (1-p2)/n2] \quad (7)$$

As the values of p1 and p2 are not known (only a hypothesis as to their difference), the following steps are guided by Costa Neto [45]:

a) Its relative sampling frequencies are estimated, obtaining, by approximation, the value of z by Equation (8):

$$z = [(p1' - p2') - \triangle] / [p1'.\ (1-p1')/n1 + p2'.\ (1-p2')/n2] \quad (8)$$

b) Compare z to the absolute value $-z\alpha$ and $+z\alpha$, according to H1

c) When one wishes to test the equality of the two proportions, one assumes $\triangle=0$. So p1 = p2 = p and z is written according to Equation (9):

$$z = [(p1' - p2')] / \sqrt{[p'.\ (1-p').\ (1/n1+1/n2)]} \quad (9)$$

where p' is the estimate based on the fusion of the two samples, of the common proportion p.

d) P' is calculated, which is given by Equation (10):

$$p' = (n1p1' + n2p2')/(n1+n2) = (f1+f2)/(n1+n2), \quad (10)$$

where f1 and f2 are the frequencies observed in the two samples.

Thus, it can be stated that the frequency of responses f1 is higher or lower than the frequency f2.

4 CONSTRUCTION OF THE MENTORING MODEL

This item aims to present the method of construction of the mentoring model, enabling its replication in other universities / industries. A compiled schema of the model can be seen in Table 2 and the breakdown of the model follows in Phases 1 to 4 (Tables 2 to 6).

4.1 PHASE 1: PREPARATION OF MENTORING AT THE UNIVERSITY

The first step of the model consists of starting the preparation of the mentoring in phase with the pedagogical project of the production engineering course, by the leader of the model, who is the person of the institution that has an interest in the realization of the project. The main steps to be developed are shown in Table 3.

4.2 PHASE 2: PLANNING MENTORING AT THE UNIVERSITY

The second step of the model deals with the development of the details of the mentoring planning, in phase with the pedagogical project of the production engineering course by the coordinator of the model, who is the professor responsible for the internship discipline at the university. The main steps to be developed are presented in Table 4.

4.3 PHASE 3: APPLICATION OF MENTORING IN UNIVERSITY/INDUSTRY

The third step of the model focuses on applying the mentoring itself, according to the content defined in phases 1 and 2 of preparation and planning, by mentor, mentee, HR sector and model coordinator, in the university and in industry. The main steps to be followed can be seen in Table 5.

4.4 PHASE 4: EVALUATION OF THE APPLICATION OF MENTORING AT THE UNIVERSITY

The fourth and final step of the model is intended to evaluate the application of mentoring and its results at the university. The main steps to be performed by the model coordinator are shown in Table 6.

Table 2. Compiled schema of the mentoring model

Phases of the mentoring model
Preparation of mentoring at the university
• Structuring the mentoring model at the university
Mentoring planning at the university

• Definition of the mentor/mentee relationship • Detailed delineation of model shapes and participant profiles
Application in university/industry
• Effectiveness of the mentor/mentee relationship • Skills development
Assessment at the university
• Model evaluation

Table 3. Preparation of mentoring at the university

Steps of Phase 1 – Preparation of mentoring at the university
Step 1. Clarify the purpose of mentoring to develop the competencies and skills of production engineering
Focus: to make sense of why mentoring development is done and what is expected to be achieved with it in terms of mentoring development in terms of developing the competencies and skills of production engineering.
Step 2. Adapt the conditions of application adapted to the university
Focus: to put the application in phase with the pedagogical political project of the production engineering course. It should be verified if the pedagogical project of the course gives freedom to the leader of the model so that the mentoring is applied as an alternative activity within the context of the syllabus of the internship discipline.
Step 3. Define the role of the mentoring program coordinator at the university
Focus: coordinate the "customization" of the application to the pedagogical political project of the production engineering course, as well as its planning, development and evaluation at the university.

Table 4. Mentoring planning at the university

Steps of Phase 2 – Planning Mentoring at the University
Step 1. Define the roles of mentor and mentor
Focus: to give meaning to the mission of each one and its steps to follow, aiming at the development of the mentee as to the competencies and skills of the production engineering.
Step 2. Define the mentor profile
Focus: guide the mentee on the profile of the mentor to choose in phase with the objective of mentoring.
Step 3. Define the content of the training to be given to mentors and mentees
Focus: specify what knowledge and skills the mentor should put into practice and as a mentor and mentee should act, according to the roles already defined.
Step 4. Define how mentor-mentee pairs will be formed
Focus: define who will choose the mentor and how (mentoring coordinator or mentee).
Step 5. Define how the invitation to the mentor to participate in the application will be made
Focus: guide the mentee on how to approach the mentor, in addition to formalizing their commitment.
Step 6. Define how information will be made about the mentoring model to the mentor and the HR sector of the industry
Focus: to inform the mentor (experienced engineer) and the HR sector of the industry regarding the development of mentoring.
Step 7. Define the contract between mentor and mentee and set expectations in terms of points to improve on the part of the mentee
Focus: to ensure in a formalized way the confidentiality of the information exchanged between both parties and to define what is expected of improvement of the mentee regarding his development in the competencies and skills of the production engineering, through a practical project to be developed, and how this will be observed.
Step 8. Define the content of mentor-mentee meetings
Focus: guide what should be addressed by mentor and mentee in each meeting in order to contribute to the development of the mentee as to the competencies and skills of production engineering and how this should be done.
Step 9. Define the follow-up forms of the meetings between mentor and mentee
Focus: standardize and give quality to the application.
Step 10. Define how the mentee and their practical project will be monitored by the university
Focus: monitor the mentee, the development of your practical project and the completion of the application, as well as identify difficulties and suggest alternatives.
Step 11. Define how the analysis of the development of the competencies and skills of the mentee will be done

Focus: define how to observe at the end of the application, from the point of view of the mentor, the development of the mentee as to the competencies and skills chosen to be developed through the practical project to be carried out.
Step 12. Define how it will be observed if the application adds value to the teaching of production engineering from the point of view of the mentee
Focus: define how to observe, from the point of view of the mentee, if the application added value to their internship period for the development of competencies and skills of production engineering.
Step 13. Define the application schedule adapted to the university
Focus: to adapt the time of application of mentoring to the academic period of the university, aiming to enable the connection of mentoring to the internship discipline recommended by the curricular guidelines of MEC and ABEPRO.
Step 14. Prepare training material for the mentors, mentees and HR sector of the industry
Focus: explain about the beginning of the development of the same, give meaning to the objective of development of the mentee as to the competencies and skills of the production engineering, support the monitoring of the application, clarify possible doubts and explain the results to be obtained. All the content covered in this phase of mentoring planning will underpin this training.

Table 5. Application of mentoring in universities and industries

Steps of Phase 3 – Application of mentoring in universities and industries	
Responsibilities of the model coordinator	Responsibilities of mentors and mentees
Step 1. Communicate with mentees about the application of mentoring	
Focus: communicate to mentees about the application details defined during the planning phase in the form of oral and face-to-face presentation at the university	
Step 2. Guide the mentee as to the mentor to be chosen and invited by him	Step 3. Invite the mentor to participate
Focus: to help the mentee still at the university to choose a mentor who can contribute to their development regarding the competencies and skills of production engineering. This choice should be based on the mentor's profile	Focus: already in the industry, commit the mentor to the application
Step 4. Communicate mentors and industry HR sector	Step 5. Enforce the mentoring agreement between mentor and mentee
Focus: communicate to mentors and HR about the application details defined during the planning phase in the form of electronic email	Focus: create the commitment of confidentiality between them in the industry regarding the information exchanged in the meetings and formalize the two points of improvement, to be addressed in the following topic
	Step 6. Define the two points of improvement of the mentee in terms of competencies and skills of production engineering
	Focus: define that two competencies and/or skills of production engineering need to be improved by the mentee during mentoring in the industry, as shown in Figure 2. The choice of the two competencies and/or abilities originated in the list of 10 competencies and 12 skills recommended by ABEPRO [25].
	Step 7. Define the practical project to be developed
	Focus: define the practical project with the two points to improve on the part of the mentee regarding the competencies and / or skills of production engineering in the context of project development in the industry. In addition, it should be defined how the two points of improvement will be observed at the end of the application, from

	the point of view of the mentor. With regard to the practical project, it should be made clear that it is only a means to create a context. Its main objective is to create the opportunity to develop competencies and skills related to the two points of improvement of the mentee in the practice of production engineering. Figure 2 shows the proposed model.
	Step 8. Conduct the meetings between mentor and mentee
	Focus: to hold the meetings in a face-to-face form in the industry. It is important to highlight that the meetings should address feelings and emotions, which should be shared between mentee and mentor.
Step 9. Observe the results of the application from the mentor's point of view	Step 10. Carry out the follow-up of the mentee and his practical project
Focus: to effectively observe, from the mentor's point of view, the development of the mentee regarding the two points of improvement retained relative to the competencies and skills of production engineering.	Focus: monitor the application of mentoring and its conclusion in phase with the pedagogical project of the production engineering course at the university itself in person

Figure 2 – Mentor-mentee contract model

Mentoring Model - Mentor Contract - Mented, Project and Expected Results

This agreement is established in ___ / ___ / ___ between __________

1. All planned mentoring sessions must be completed monthly, adding up to 3 hours over a maximum of 3 months.
2. The mentoring experience that is now beginning is the initial phase of the process, aimed at enabling the identification and realization of desired results for the professional development of the mentee.
3. The mentee agrees to communicate with all candor, to be open to receiving *feedback*, and to create the energy and time necessary for their full participation in the process.
4. The mentor and mentee agree to maintain full verbal and written confidentiality of all information arising during the process, unless both parties are permitted to disclose matters addressed in the mentoring meetings.
5. Due to the subjective nature of the work that is now initiated, the mentor does not guarantee that results will be achieved nor is he responsible for them.
6. The mentee understands that the mentoring process is not a psychological therapy and, therefore, does not replace it, if there is any need for it.

Points retained for the mentoring model over the 3 months

A. Among the competencies mentioned below, choose 2 to work on the development of the mentee during the application of the mentoring model. Describe the point to improve on the part of the mentee.

Knowledge and Skills recommended by ABEPRO	**Points to improve (fill 2 gaps)**
Scale and integrate physical, human and financial resources in order to produce, efficiently and at the lowest cost, considering the possibility of continuous improvements	
Use mathematical and statistical tools to model production systems and assist in decision making	
Design, implement and improve systems, products and processes, taking into account the limits and characteristics of the communities involved	

Predict and analyze demands, select scientific and technological knowledge, designing products or improving their characteristics and functionality	
Incorporate concepts and techniques of quality throughout the production system, both in its technological and organizational aspects, improving products and processes, and producing standards and procedures for control and auditing	
Predict the evolution of productive scenarios, perceiving the interaction between organizations and their impacts on competitiveness	
To keep up with technological advances, organizing them and putting them at the service of the demand of companies and society	
Understand the interrelationship of production systems with the environment, both with regard to the use of scarce resources and the final disposal of waste and tailings, paying attention to the requirement of sustainability	
Use performance indicators, costing systems, as well as evaluate the economic and financial viability of projects	
Manage and optimize the flow of information in companies using appropriate technologies	
Entrepreneurial initiative	
Initiative for self-learning and continuing education	
Oral and written communication	
Reading, interpretation and expression by graphic means	
Critical view of orders of magnitude	
Mastery of computational techniques	
Knowledge, at a technical level, of a foreign language	
Knowledge of relevant legislation	
Ability to work in multidisciplinary teams	
Ability to identify, model and solve problems	
Understanding of administrative, socio-economic and environmental problems	
"Think globally, act locally"	

B. Describe the small project that will be developed in these 3 months, aiming at the improvement of the points retained above in item A.

C. In the following action plan, describe the results that are intended to be achieved in relation to the 2 points of improvement of the mentee, through the realization of the small project, at the end of the model. How can improvement be observed by the mentee/mentor?

Point to improve	How will the improvement be observed in the mentee? What condition is the mentee expected to achieve?	Date

Mentor ____Date___/___/___
Mentee ____Date___/___/___

Table 6. Evaluation of the application of mentoring in the university

Steps of Phase 4 – Evaluation of the application of mentoring in the university
Step 1. To observe if the application of mentoring adds value to the teaching of production engineering from the point of view of the mentee
Focus: to verify effectively, from the point of view of the mentee through an individual interview to be conducted at the university itself, if it added value to the teaching of production engineering during its internship period.
Step 2. Consolidate the results of the application in the university from the point of view of the mentor
Focus: verify that the mentee has achieved the expected results at the end of the model

Once these steps have been accomplished, we have the mentoring model for application in public universities for undergraduate teaching in production engineering with internships carried out in industries.

5 APPLICATION OF THE MENTORING MODEL AND ITS RESULTS

This chapter aims to present the application of the mentoring model in a Brazilian university, as well as its results. This application takes into account the four phases presented in the model construction item.

Regarding the people involved in the research, it can be said that the profile of the mentors has the characteristics presented in Table 7.

As for the companies that participated in the application, the following profile is shown in Table 8.

Based on the mentor-mentee contract model presented in Figure 2, the main competencies and skills chosen by mentors and mentees for the application of the model are shown in Table 9.

The results in the perception of those involved deserve to be explored. Also in Figure 2, two points of improvement were chosen, in terms of competencies and skills of production engineering, to be developed by the mentee through the realization of a small project. Thus, from the mentor's point of view, his perception of the results was explored through the questionnaire presented in Figure 3.

Thus, the synthesis of the answers to the questionnaire presented in Figure 3 shows that 98% of the mentors confirm that the expected results in terms of improving competencies and skills have been achieved. The answers to the open questions will be presented in Table 12 later.

Still observing the perception of those involved, the interview presented in Figure 4 addresses the point of view of the mentees.

Through the synthesis of the answers of the interview presented in Figure 4, it is observed that 85% of the mentees perceive that the mentoring model made a difference in their internship period for the teaching of production engineering (including the partial results of each application cycle), as shown in Table 10. In a qualitative way, the main positive points cited by them are addressed in Table 11.

In order to address the perception of the mentees about the mentoring model in a qualitative way, the questionnaire presented in Figure 5 was applied.

The synthesis of the answers of the questionnaires applied to mentors (Figure 3) and mentees (Figure 5) can be seen in Table 12.

Table 7. Mentors profile

Idade (anos)	20 - 30	31 - 40	> 41	
	38%	47%	16%	
Sexo	Masculino	Feminino		
	85%	15%		
Graduação	Eng. Produção	Eng. Mecânico	Eng. químico	Outros
	52%	16%	13%	19%
Ano de conclusão (graduação)	<1997	1998-2007	2008-2017	
	10%	41%	49%	
Pós-graduação	Não possui	Possui		
	30%	70%		
Cargo	Engenheiro	Supervisor/coord.	Gerente	Outros
	45%	25%	20%	9%
Tempo na empresa (anos)	1-10	11-20	21-30	>30
	73%	19%	2%	6%

Table 8. Profile of the companies where the interns and mentors work

Município	Resende	Porto Real	Itatiaia	Cruzeiro	Outros
	52%	23%	11%	6%	8%
Nº empregados	>600	201 a 600	<200		
	77%	13%	11%		
Ramo	Automotivo	Químico	Engenharia	Outros	
	50%	14%	5%	31%	
Departamento	Engenharia	Qualidade	Produção	Manutenção	Outros
	30%	22%	19%	6%	23%

Table 9 - Key improvement points retained by mentors and mentees

Competência / Habilidade	% Total	% Acumulado
Habilidade - Comunicação oral e escrita	18%	18%
Habilidade - Capacidade de trabalhar em equipes multidisciplinares	16%	33%
Competência - Projetar, implementar e aperfeiçoar sistemas, produtos e processos	13%	46%
Habilidade - Capacidade de identificar, modelar e resolver problemas	11%	58%
Competência - Dimensionar e integrar recursos físicos, humanos e financeiros	9%	67%
Habilidade - Iniciativa para auto-aprendizado e educação continuada	9%	75%
Competência - Prever e analisar demandas, selecionar conhecimento científico e tecnológico	5%	81%
Competência - Utilizar indicadores de desempenho, sistemas de custeio, ...	5%	86%
Competência - Incorporar conceitos e técnicas da qualidade em todo o sistema produtivo	4%	90%

Figure 3 – Questionnaire to verify the expected results from the mentor's point of view

1. Have the expected results of the mentee in relation to the improvement points been achieved? Resume the points retained in the mentoring model contract. How can improvement be observed by the mentor?

Point to improve	How will the improvement be observed in the mentee? What condition is the mentee expected to achieve?	Status of achievement? **S/N**

2. Was the mentoring model effective, in your opinion? What makes you have this opinion?
3. What could be improved in the mentoring model? Please cite at least 3 main points.
4. What was important about the mentoring model? What was positive?
5. What were the gains of the mentoring model for the mentee?
6. What were the gains of the mentoring model for you as a mentor?
7. What were the gains of the mentoring model for your company?

Figure 4 – Interview made by the professors to the mentee at the end of the program at the university

1. Comparing the internship period without the application of the mentoring program with the internship period in which it was being applied, did the mentoring make a difference to the teaching of production engineering?

2. If so, what were the positives?

Table 8 - Summary of interview responses

Answer	Response in percentage numbers			
	1st cycle	2nd cycle	3rd cycle	Total
Yes	82%	80%	94%	85%
No	18%	20%	6%	15%

Source: the author herself.

Table 11 - Main points highlighted in the model by the interview applied to the mentees

Pontos destacados sobre o que fez diferença no programa de mentoring	% pontos destacados	% acumulado dos pontos destacados
Aproximação mentor - mentorado	12	27%
Feedback	11	27%
Maior confiança	7	35%
Comunicação interpessoal e em público	6	42%
Melhor organização no trabalho	6	49%
Maior responsabilidade ao mentorado	4	54%
Trabalho com mais foco	4	59%

Figure 5 – Questionnaire about the mentoring model from the point of view of the mentee

1. Was the mentoring model effective, in your opinion? What makes you have this opinion?
2. What could be improved in the mentoring model? Please cite at least 3 main points.
3. What was important about the mentoring model? What was positive?
4. What were the gains of the mentoring model for you as a mentee?
7. What were the gains of the mentoring model for your mentor? How did you realize this in practice?
8. What were the gains of the mentoring model for your company?

Table 12 - Answers to the open questions in the three application cycles

Category (question asked)	**Top responses from mentees**	**Key responses from mentors**
Positives of the model (what was important in the mentoring model?)	Exchange of information and experience between mentor and mentee	Exchange of experiences between mentor and mentee
	Approach with mentor through meetings	Support/direction to the mentee through periodic meetings
	Mentor feedback	Rapprochement between mentor and mentee
	Score what to improve	More *feedback*
Gains for the mentee (what were the gains of the mentoring model for the mentee?)	*Feedback* of points to improve operational and behavioral	Everyday problem solving
	Being able to absorb the knowledge (including technical) of a more experienced person	Knowledge passed by the mentor and points to be improved
	Approach with the mentor	Maturity and behavioral development of the mentee
	Improvement of strengths and weaknesses	Professional development
	Increased self-confidence	*Feedback*
Gains for the mentor (what were the gains of the mentoring model for the mentor?)	Practice of developing people and *feedback*	Exchange of professional experience
	Satisfaction regarding the passage of knowledge to those who are starting their professional life ("I am happy to be able to pass on my knowledge and feel valued")	Develop the development side of people, seeking the improvement of the mentee (teach)
	Perception of contribution to the development of the mentee	*Feedback* of points to improve operational and behavioral for the resolution of problems in everyday life
Earnings for the company (what were the gains of the mentoring model for the company?)	Higher results in the trainee work (presents indicators with greater clarity)	Exchange of experiences
	Trainee training	Train professionals with the values of the company
	Gain in productivity (higher result in the work of the production engineering intern)	Better performance of the trainee
	Proximity between mentor and mentee	Integration of the reality of the company with the university

Tables 9 and 11 can be analyzed together. In Table 9 the skills of "Oral and written communication" and "Ability to work in multidisciplinary teams", followed by the competence of "Design, implement and improve systems, products and processes" are the main ones to be improved in the professional performance of the trainees involved in the application. On the other hand, the mentees highlight in Table 11 the "interpersonal and public communication" as one of the positive points of the model. Thus, it is seen, therefore, a relationship between the competencies and skills chosen by mentors and mentees and the perception of mentees as a positive point of the mentoring model.

Still approaching Tables 9 and 11 together, it can be observed that the mentoring model, researched by different instruments, contributes to the mentor-mentee approach, exchange of experience between mentor and mentee, greater *feedback*, transfer of knowledge from one experienced professional to another with less experience and better communication.

Some testimonials made by mentors, mentees and HR in the industry deserve to be cited:

> "I thought the mentoring program that you are developing was fantastic, because it helps students a lot to have a better professional training. I will talk to the supervisors of the interns we have today in the company and I am sure that they will engage to make the program work!" Testimonial of an HR professional from one of the participating industries (1).
> "I believe that the mentoring program is of great value, both for companies and for interns. Absorbing knowledge from more experienced professionals is one of the first steps to becoming a competent professional." Testimony of a mentee (1).
> "Very important mentoring program in my professional life. For all the experience passed by my mentor, as well as seeing where my mistakes were and putting the improvements into practice so that I have a better professional future." Testimony of a mentee (2).
> "The program was very interesting to me. My mentor has already helped me constantly in my day-to-day life. Through mentoring, the relationship was strengthened and I started to get *feedback* on my activities, which has been essential for my professional evolution." Testimony of a mentee (3).
> "I believe that the mentoring program has a lot to add to all the participants, both students, professionals and even teachers. This first period served as an experiment, but for the next classes, the gain will be greater. Many students do not have this opportunity, perhaps because of the company's culture or lack of time. However, when the proposal comes from the faculty, the chances of sensitizing professionals is much greater. However, I believe that the mentoring program will help FAT train future engineers with more quality and professional vision." Testimony of a mentee (4).
> "The mentoring program was important so that the activities developed in the internship period were directed to the fulfillment of a specific objective. The internship is a period of professional training, where the student will acquire their first experiences and will realize their career options. I believe in the importance of the mentor to assist the mentee in their activities, indicating the points that should be improved, sharing their next experiences and encouraging them to follow the path of constant development. One of the difficulties encountered by me and my mentor was the availability of time for the meetings." Testimony of a mentee (5).
> "Very good program. It utilizes the potential that exists within the company, with the wisdom of a more experienced employee, driving innovation and creativity of the learner to make the company more competitive. Everyone wins." Testimonial of a mentor (1).
> "Initially I appreciate the opportunity to share some of my experience with the mentee, as well as learn and record that this practice is very important for the renewal of any company. A fact that is not easy often due to everyday life, but it is important to take the time to prepare our replacements, enhancing the company's results." Testimonial of a mentor (2).
> "The mentoring program exceeded my expectations, as I was able to better understand the needs, difficulties and concerns of the mentee, which generated greater trust and communication between the student and the company, in general. The program still has flaws that should be improved. Despite this, it meets what is proposed." Testimonial of a mentor (3).

Evaluating the process of development of action research, each cycle the model was statistically tested in relation to reliability, through the Cronbach's α coefficient test, and validity, through the statistical test of comparison between two proportions. The results of these tests are presented in Table 13.

Table 13 - Levels of reliability and validity in the three application cycles

Rated item	1st cycle	2nd cycle	3rd cycle	3 cycles together
Sample size – number of pairs of mentors and mentees	30	8	14	52
Test of independence of opinions of mentors and mentees	Independent			
Level of reliability – Figures 3 and 5 – result of the Cronbach's α coefficient test	0,74	0,48	0,84	0,72

Validity level – Figures 3 and 5 – statistical test of comparison between two proportions	100% > 25%	100% > 39%	86% > 34%	96% > 19%
Summary of the interviews - Figure 4 - mentees - statistical test of comparison between two proportions	65% > 28%	60% > 51%	88% > 45%	71% > 22%
Results verification questionnaire – Figure 3 – mentor – statistical test of comparison between two proportions	-	-	-	96% > 27%

Source: the author herself.

The test of independence of opinions of mentors and mentees was performed, confirming that the samples are independent (Table 13).

With regard to the Cronbach's α coefficient test, the overall result of the three cycles was higher than 0.70, which is the minimum level of acceptance [42].

Regarding the validity of the research, relying on the statistical test of comparison between two proportions, it is seen that the null hypothesis (H0) that the proportion of applications that gives the expected result is equal to the proportion of applications that do not give the expected result is not true. In fact, the proportion of applications of the mentoring model that gives the expected result is higher than the one that does not give results, as shown in Table 13, both from the point of view of the mentor and the mentee. Thus, it is seen that the null hypothesis (H0) was rejected.

In order to verify whether the concepts "production engineering teaching" and "mentoring" together are valid for the creation of the theoretical model, experts in production engineering and human resources were consulted. The profile of the experts who participated in the interviews can be summarized in Table 14.

This consultation was made through the application of an interview aimed at them.

The questions asked in the interview applied to each specialist individually can be seen in Figure 6.

Table 14 - Expert profile

Idade (anos)	31 - 40	> 41		
	33%	67%		
Sexo	Masculino	Feminino		
	17%	83%		
Graduação	Psicologia	Eng. Mecânica	Eng. Química	Eng. Produção
	33%	33%	17%	17%
Ano de conclusão (graduação)	<1997	1998-2007		
	67%	33%		
Pós-graduação Latu Sensu	Não possui	Possui		
	33%	67%		
Mestrado	Não possui	Possui		
	33%	67%		
Doutorado	Não possui	Possui		
	67%	33%		
Pós-doutorado	Não possui	Possui		
	83%	17%		
Área de atuação	Ensino Eng. Produção	Recursos humanos		
	50%	50%		
Cargo	Professor	Consultor	Gerente	Outros
	58%	8%	17%	17%
Tempo na empresa (anos)	1-10	11-20		
	33%	67%		

Figure 5 – Interview with experts

Questions to be answered through <u>a telephone interview</u>:

1. As an expert in the field of HR or Production Engineering, what is your opinion about the model?
2. Is the mentoring model valid for teaching production engineering? In what sense?
3. What are your strengths?
4. What are your gaps or your points of improvement?

Among the experts consulted, 83% consider the model valid for the teaching of production engineering. In addition to the validity of the concepts, one can take advantage of some observations made by the experts during the interviews, capitalizing on them to compose the mentoring model. Thus, this study should make it clear that:

- The practical project, which is part of the practical application of the mentoring model, is a context for the development of competencies and skills;
- The role of the mentee in the choice of mentor is seen by experts as a possible facilitator for the model by increasing the bond and also in the growth of the feeling of trust between mentor and mentee;
- The mentoring model is not and does not propose to replace an internship model, and may be part of it;
- The model should address feelings and emotions that should be shared between mentee and mentor.

Two strengths of the model were highlighted by the experts as, according to them, the great "gain" for the teaching of production engineering of the mentee. They are:

- The model translates into the opportunity to develop behavior, ethics, learning and human relationships for the mentee (intern);
- It is a formal and structured process for the development of competencies and skills, regardless of the availability or interest of professors at the university in doing so informally.

In addition, because the content of the supervised internship disciplines leave the traditional molds of learning in the classroom, it is common even a reaction of discomfort on the part of the students. However, as cited by Pedro [46] in his work, not being limited to traditional classroom spaces allows an interdisciplinarity between disciplines, as well as limits of less rigid classroom spaces, more permeable borders and knowledge that intermingle as in real life.

Thus, the model presented is proposed as a form of active learning. Some authors contribute with their studies in this area with the present work.

According to Bonwell and Eison [47], institutional strategies for active learning can be defined as an approach that "engages students doing things and thinking about what they are doing." Thus, active learning is strongly characterized by student engagement in the learning process [48, 49], an attitude that clearly contrasts with traditional reading in which students passively receive information from an instructor but are rarely able to convert theoretical information into practical knowledge [50].

One type of active learning instruction strategy has gained popularity in operations management training, which is the use of games and manual activities [50].

An example of this type of strategy is presented by Arenas-Márquez et al. [51]. They address how teaching method based on information communication technologies (ICT) can significantly affect students' perceptions of the learning process. The results of the study they present also confirm the pedagogical effectiveness of the *software* that was designed and that methods based on information communication technologies (ICT) are an alternative to traditional methods used in operations management education. The results of the research can be considered positive with regard to the use of ICT in the teaching and learning of OM.

According to the European Commission [52], the use of information communication technologies (ICT) is a trend in Europe, which proposes to change teaching focused on learning rather than on teaching itself. The authors highlight that, more important than the use of technology, is how the student interacts with it and how learning is done from it [51]. This study shows that interactive *software* can be well suited for learning in operations management. The designed *software* supports the study of content with numerous interactions that facilitate the learning process, turning it into a very active experience. The *software* also formally analyzes the relationship between the teaching-learning method and students' attitudes towards their learning process [51].

Another example was also used by Santos et al. [50], based on the teaching methodology following the philosophy of active learning for operations management. The applicability of the method was proven during exercises in class. The results were proven with positive *feedback* from the students involved in the exercise, which was obtained by a survey after some applications. Using simple, low-cost materials, students were involved in order to create a real process of a fictitious product.

Current social changes and the intensification of the flow of information are changing the profile of university students and, as a consequence, the way they learn. This new context demands different teaching approaches and justifies the growing interest in improving the teaching-learning relationship through innovative classroom activities [50].

Another example of active learning is presented by Yalabik et al. [53], through a tool called "The Innovation Game", which aims to demonstrate the challenges of developing an effective innovation strategy in the context of the development of a new product. Specifically, the paper presented explores the impact of choices made on capability, capacity management, and product portfolio management. At the end of the exercise, students are invited to present their learning qualitatively to each other in the classroom through transparencies.

Another example of an active learning exercise is presented by Lambrecht et al. [54]. The dice game is a powerful exercise that focuses on the impact of variability and dependence on the production capacity and intermediate stock level of the production line. A product-based view is used at work, but the game can be used for application in services as well as manufacturing. It can be applied on a manual production line or by means of a simulation tool. Student interference can help optimize the production line. The game addresses understanding the relationship between process variability and its production capacity in an environment with dependent stations and limited inventories. While conceptually this is not new to students, they typically underestimate the impact of variability on production capacity.

According to NGUYEN et al. [55], when using active learning, instructors should choose activities with the appropriate difficulty, clearly explaining what is expected with it and its associated benefits. It is also important to be sure of the time needed, as well as to encourage the student to commit to carrying out the activity.

In all of these examples, students are invited to practice outside the classroom, collaborating with learning that goes beyond books. It is at this point that the present study weaves its relationship with active learning.

6 DISCUSSIONS

6.1 ANSWERS TO SURVEY QUESTIONS

Regarding the research questions, it can be said that:

- Mentoring can be applied to undergraduate teaching in production engineering for the development of the competencies and skills recommended by ABEPRO in the mentee.
- The mentoring, in the model presented, was compatible with the pedagogical project of the production engineering course as an activity within the programmatic content of the supervised internship discipline, mandatory in the curricula of the undergraduate program in production engineering. It does not propose to replace the models of internship in the industries, but rather to complement them;
- The mentoring was placed as a tool to expand the development of competencies and skills of production engineering standardized by ABEPRO and the MEC guidelines for engineering education through a theoretical model to be applied to undergraduate trainee students in production engineering. These competencies and skills and guidelines constituted the main theoretical bases for the creation of the model in question.

Therefore, through the above statements, the research questions were answered.

It should be considered that the practice of mentoring within the internship discipline is complementary to those traditional ones of the curriculum of a production engineering course, not being a substitute for any other discipline. It is seen as an opportunity to use it as an active learning practice, since the mentoring model is sought to develop the student in professional life within an industry with the support of an experienced engineer.

This can be reinforced by the article by George and Mampilly (2012), where the authors address that colleges must alter their curriculum and ensure that students have the appropriate knowledge, attitudes and competencies that bring success in this turbulent social and professional environment.

6.2 THEORETICAL AND PRACTICAL CONTRIBUTIONS

In addition, the theoretical model of mentoring brings contributions to both theory and practice.

The contribution of the present work to the existing theory is the union of the theoretical concepts about the teaching of production engineering and about mentoring, which previously "navigated" separately and now "work in a team" in a pioneering way in a mentoring model for the teaching of undergraduate production engineering, put into practice through students of this course who also act as interns in industries. Once again, the novelty of the work should be highlighted. Thus, it is understood that the work contributes both to the research environment and to the scientific production for the academic experience.

With regard to practice, it is possible to say that the model worked, relying on the answer that the model makes a difference in 85% of its applications from the point of view of the student of the production engineering course during the internship period, and in 98% of the applications of the model from the point of view of the mentors. The practical benefit of the work is the added value of the model for the learning of the production engineering student.

To date, no similar example of publication has been found, which characterizes the unpublished theoretical contribution of this work to the academy. Therefore, it is this "gap" that this study proposes to fill.

6.3 LIMITATIONS OF THE RESEARCH

However, there are limitations in the present research, such as the difficulty of training mentors and the possible confusion between mentoring model and internship content in the industry.

Regarding the training of mentors, in order to minimize the risks of failure of the model, it was necessary to seek alternatives in the planning of the model. This study communicated the model to mentors in little depth due to the difficulty of having personal contact with them in the classroom. The availability of mentors for training falls short of the needs of a traditional model for this stage. With this, the present model had to look for an alternative to form them or inform them about the steps of the application of the model. The form found was the standardization of the content to be addressed in each of the mentor-mentee meetings.

As a complement, it is important to highlight that, according to the experts' observations, the mentoring model is not intended to be or replace an internship model. That is part of the internship only as a means of active learning for collaboration in the teaching of production engineering. Thus, although it is possible, contributions from the internship to the mentoring model are not expected, as well as separating what is the result of mentoring and what is the result of the internship. The model does not propose to delve into this direction.

As a conclusion, despite these limitations, the results observed by mentors and mentees show the model as valid for the teaching of production engineering in the conditions established through the development of students with respect to competencies and skills.

7 CONCLUSION AND FUTURE WORK

The aim of this study was to present a mentoring model for undergraduate teaching in production engineering in public universities with internships in industries in Brazil. Interviews and questionnaires that were previously developed and validated were used to collect data from 52 students from a Brazilian public university and their respective mentor-engineers. The results were analyzed using the Cronbach's α coefficient test to validate the reliability, and the statistical test of comparison between two proportions in order to verify the validity of the model.

The most important conclusion of this study is that the mentoring model is valid for undergraduate teaching in production engineering. This finding should serve to reinforce that active learning methodologies, such as this model, should be used as a complement to traditional teaching curricula. This is reinforced by the testimony of mentors and mentees that the model adds value to teaching through the development of competencies and skills of production engineering in students. In addition, the finding corroborates the literature review that presents characteristics of mentoring.

In future work, one can study how applicable the mentoring model is in other undergraduate courses in production engineering, including private universities, and involving a larger sample of mentors and mentees. With this, one could ratify its applicability with more sophisticated statistical analyses and more generalizable results.

In addition, the development of the mentoring model could be expanded not only to courses that rely on industry as support for internships, but also to be carried out in the service sector. Production engineering extends its field of action to several areas and the service sector is a possible and wide field of development for the mentoring model adapted to its reality, where it deserves to be tested.

Finally, it would open up an opportunity to find new theoretical and practical contributions of the mentoring model not mentioned in the present work. The continuous improvement of the model would go forward in an enriching way, since it would be expanded to new horizons.

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