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ARTICLE

UNIVERSITY-COMPANY INTERACTION FOR TEACHING BASED ON REAL CASES IN ENGINEERING[1]

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ABSTRACT The content of the Quality Management subject in Production Engineering courses tends to commonly be developed without relating theory with practical activities. Considering this issue, our study investigates the university-company interaction in teaching and learning processes in an Engineering course in a manner that contributes both to the teaching activities at universities and practical activities at companies. Action research was developed from a project that partnered with a company from the automobile segment and a public university to bring real-life problems that are related to the curriculum of the quality management subject in a bachelor's course in Production Engineering. Different resources and strategies were used: cases and training, which the company provided for in-classroom application; a final project that required student teamwork and constant contact with the company; and expository classes on the theoretical basis of Quality Management. Among the different results that were found, two factors were initially identified as barriers concerning the university-company logic, such as the execution time and the expected results of the project, and, in fact, they were facilitators of this dynamic. Another result was the increasing interest of students concerning the subject's content as they demonstrated autonomy and responsibility during the process of knowledge creation at the course's subject. We conclude, then, that the university-company interaction contributes to the creation of an environment that values that student as an active part that is inserted in a challenging scenario that, when enriched with constant feedback on the issues offered, promotes greater engagement and autonomy on students in regards to the learning process.

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Keywords: Teaching based on real-life cases, engineering teaching, learning methods, quality management.

INTERAÇÃO UNIVERSIDADE-EMPRESA PARA O ENSINO BASEADO EM CASOS REAIS EM ENGENHARIA

RESUMO: O conteúdo da disciplina de Gestão da Qualidade em cursos de Engenharia de Produção comumente tende a ser desenvolvido majoritariamente sem relacionar a teoria com atividades práticas. Considerando essa problemática, essa pesquisa objetiva investigar a interação universidade-empresa em processos de ensino e aprendizagem em um curso de Engenharia de forma a contribuir para o ensino nas universidades e para a prática nas empresas. Uma pesquisa-ação foi desenvolvida a partir de um projeto de parceria entre uma empresa da indústria automotiva e uma universidade pública com o propósito de trazer problemas reais relacionados à ementa da disciplina de gestão da qualidade de um curso de bacharelado em Engenharia de Produção. Diferentes recursos e estratégias foram utilizados: casos e treinamentos, que foram cedidos pela empresa para aplicação em sala de aula; um projeto final, que exigiu dos alunos trabalho em grupo e constante contato com a empresa; e aulas expositivas sobre a base teórica de Gestão da Qualidade. Entre os diversos resultados encontrados, dois fatores inicialmente previstos como barreiras à relação universidade-empresa, como tempo de execução e resultados esperados do projeto, na verdade se demonstraram facilitadores dessa relação. Outro resultado foi o elevado interesse pelos alunos em relação ao conteúdo da disciplina na medida em que estes demonstraram autonomia e responsabilidade durante o processo de criação de conhecimento na disciplina do curso. Conclui-se que a interação universidade-empresa contribui para criação de um ambiente de valorização do aluno como um integrante ativo que está inserido em um cenário desafiador que enriquecido de constantes *feedbacks* sobre os desafios propostos, promove maior envolvimento e autonomia dos alunos no processo de aprendizagem.

Palavras-chaves: Ensino Baseado em Casos Reais, Ensino na Engenharia, Métodos de Aprendizagem, Gestão da Qualidade.

INTERACCIÓN UNIVERSIDAD-EMPRESA PARA LA ENSEÑANZA BASADA EN CASOS REALES EN INGENIERÍA

RESUMEN: El contenido de las asignaturas de Gestión de la Calidad en la ingeniería de producción suele desarrollarse en su mayoría sin relacionar la teoría con las actividades prácticas. Teniendo en cuenta esta problemática, esta investigación tiene como objetivo investigar la interacción universidad-empresa en los procesos de enseñanza y aprendizaje en un curso de Ingeniería con el fin de contribuir a la enseñanza en las universidades y a la práctica en las empresas. Se desarrolló una investigación-acción a partir de un proyecto de colaboración entre una empresa de la industria del automóvil y una universidad pública con el fin de aportar problemas reales relacionados con el tema de la gestión de la calidad en un curso de licenciatura en Ingeniería de Producción. Se utilizaron diferentes recursos y estrategias: casos y formación, que fueron proporcionados por la empresa para su aplicación en el aula; un proyecto final, que requería un trabajo en grupo y un contacto constante con la empresa; y conferencias sobre las bases teóricas de la Gestión de la Calidad. Entre los diversos resultados encontrados, dos factores inicialmente previstos como barreras a la relación universidad-empresa, como son el tiempo de ejecución y los resultados esperados del proyecto, resultaron de hecho ser facilitadores de esta relación. Otro resultado fue el alto interés de los estudiantes en relación con el contenido de la asignatura, ya que demostraron autonomía y responsabilidad durante el proceso de creación de conocimiento en la asignatura. Se concluye que la interacción universidad-empresa contribuye a la creación de un ambiente de valoración del estudiante como miembro activo que se inserta en un escenario desafiante que, enriquecido con

constantes retroalimentaciones sobre los retos propuestos, promueve una mayor implicación y autonomía de los estudiantes en el proceso de aprendizaje.

Palabras clave: Aprendizaje Basado en Casos Reales, Enseñanza en Ingeniería, Métodos de Aprendizaje, Gestión de la Calidad.

INTRODUCTION

Students from universities face the great challenge of being prepared for the labor market nowadays. Requirements from companies concerning the professional curriculum of a recently graduated person, together with the important role that engineering has in economic, productivity, and innovation stand views in society (BLACKIE *et al.*, 2016), demand more attention from universities in this scenario.

Subsequently, teaching methods exerted by Higher Education Institutions (HEIs) directly impact the preparatory process of students to the labor market. Björck (2021) highlighted that teaching approaches integrated into the workplace could raise alumni employment, although these approaches present gaps that need to be filled. One of them is related to the fact that learning methods may not properly integrate the theory taught at university with the one that is indeed applied at the workplace given the lack of instruction on how to apply those theories in real-life experiences.

One may also observe that the discussion topic concerning learning and teaching methods, which have been one of the most central subjects on the overall agenda of HEI since the 1990s (LETTS, 2019), is shrouded in perspectives of change and transformation of teaching methods for them to become increasingly based on practical approaches. There is also a constant concern that the graduating student is not completely prepared for the labor market, given that their ability to assimilate new knowledge and apply it is not considered effective (BLACKIE *et al.*, 2016). In essentially theoretical curricular units, knowledge apprehension by students tends to be lower than in the ones that mix lectures with activities of theoretical application. A composition set between the purely expository model and the use of studies based on real data tends to raise students' interest and knowledge apprehension capacity (Glasser, 1999; Graham, 2010).

The research scenario regarding teaching methods with practical approaches in higher education institutions is poorly explored by academic initiatives of research according to Alzahrani *et al.* (2021) and Zarpelon and Resende (2020). Zarpelon and Resende (2020) carried out, at the Brazilian Congress of Engineering Education, throughout the 2010–2017 period, a survey of all publications related to the application of learning theories in the teaching of engineering, focusing on the Calculus 1 subject. The study revealed a very limited collection of articles, scarcely explored by the academic community compared to other themes approached at the congress. Alzahrani *et al.* (2021) showed that the number of published articles that linked current themes on quality (Quality 4.0–involving all concepts of Industry 4.0 Quality Management) with learning approaches in HEIs is inferior to the collection compiled by Zarpelon and Resende (2020), even when considering five global article databases (Google Scholar, Web of Science, Scopus, Ebsco, and ProQuest). This highlights that the number of works that bring practical approaches to teaching methods is even narrowed, oftentimes limiting itself to the replicability of approaches that involve games for executing practical instruction. In this light, this study aims to contribute to an answer to the following research question: how can we promote teaching based on real cases in the quality management subject in engineering majors?

From this issue, this research sought to investigate the university-company interaction in teaching and learning processes in an Engineering course through the application of an experimental and active teaching method in the Quality Management subject in the Production Engineering at the Federal University of São Carlos – Campus Sorocaba, through a partnership set with an Auto Parts Integrated Supplier, also located in Sorocaba, São Paulo State, Brazil.

FOUNDATIONAL CONCEPTS OF TEACHING-LEARNING

For Ginter and White (1982), learning is the result of observing the behavior of other individuals who belong to the same social context, copying everything that seems convenient (i.e., it is a learning in which individuals learn with each other). Kolb (1984) defined learning as the process through which knowledge is created through the transformation of experiences, and this learning construction is named experiential learning. For him, learning should be based on the following:

- One should focus on the adaptation and learning processes instead of content and the simple search for results: ideas are not elements arising from fixed, immutable thinking but formed and reformed through experience. Learning is an emergent process in which results only represent a historical register and not future knowledge;
- It should be a transformational process, continually created and recreated, and should not be seen as an independent entity to be acquired and transmitted, given that learning is a holistic process of adaptation to the world: learning is the pivotal process of the human being adaptation to physical and social environments, generating conceptual bridges through life situations–such as the ones experienced at school and work–therefore creating a continuous, permanent process of adaptation to the world;
- One should transform one's experience both objectively and subjectively: learning is the process of knowledge creation that approaches the more advanced scientific research and the simpler facts (e.g., a child's discovery that a rubber ball bounces). Learning is the result of the transaction between individual and social knowledge.

In addition, Kolb (1984) defended that learning construction obeys the following sequence of activities, which is called the Kolb Cycle:

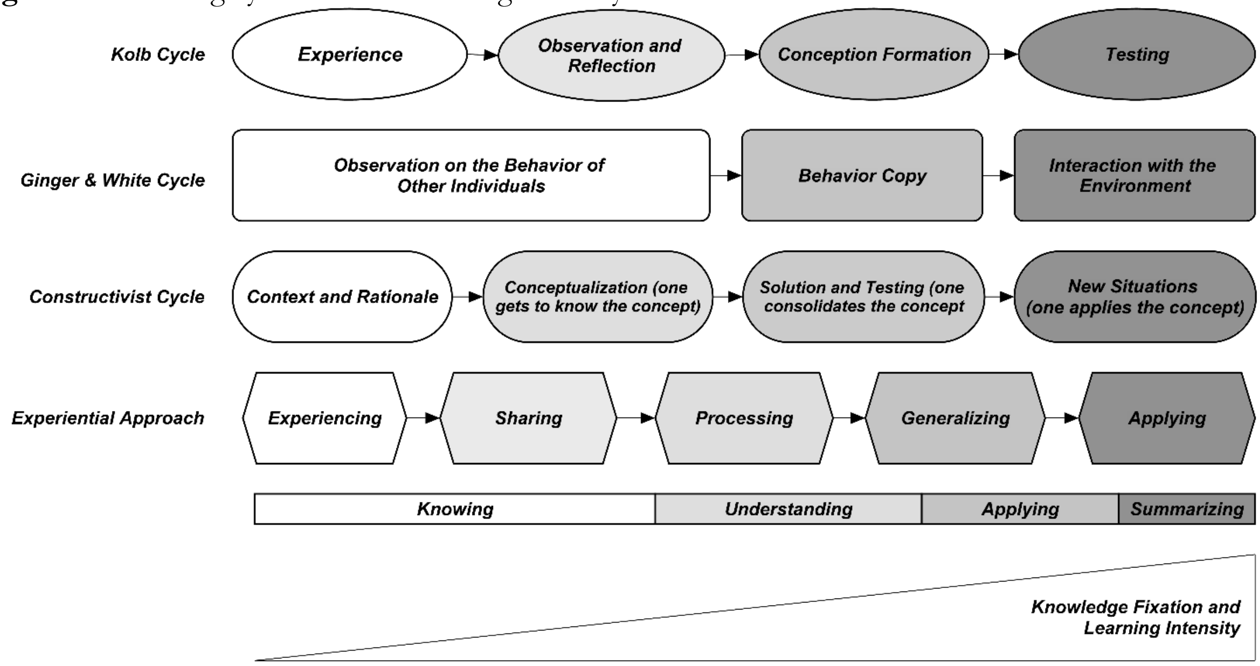
- The person is presented with a real-life experience, which is known and accepted as a concrete experience;
- The person analyzes the phenomenon and reflects on the fact, assuming a position of reflexive observation;
- The person abstracts the concept and generalizes ideas (abstract conceptualization);
- The person transforms these ideas into actions to be tested in real situations (active experimentation) and, if the generalized fact is significant for them, it will integrate them knowledge, solidifying learning.

Additionally, Carvalho, Porto, and Belhot (2001) put in evidence the learning cycle based on the constructivist logic, which is, according to them, the most adequate one when it comes to engineering education and comprises the following stages:

- Context and rationale: the individual is presented with the concepts that will be studied, the whys and wherefores for studying them, and their insertion on the context in the person's life. Also, issues related to them are presented, as well as the relevance of their solutions;
- Conceptualization: in this stage, all concepts linked to the matter are passed on and this is the point at which logic is valued, as well as deduction and ideas. The individual is kept in touch with new concepts that are related to previously acquired ones;
- Resolution and testing: in this stage, previously presented concepts are solidified through practical exercises and the application of related issues. The development of abilities and creativity is stimulated in individuals;
- New situations: in this stage, the individual applies solidified concepts in real-life situations, developing confidence in decision-making processes, and experience, providing the person with conditions for checking the application of acquired conceptions in the first stage.

Concepts on learning cycles and processes by Ginter and White (1982), Kolb (1984), and Carvalho, Porto, and Belhot (2001) are summarized as shown in Figure 1.

Figure 1 – Learning cycles and the learning intensity.

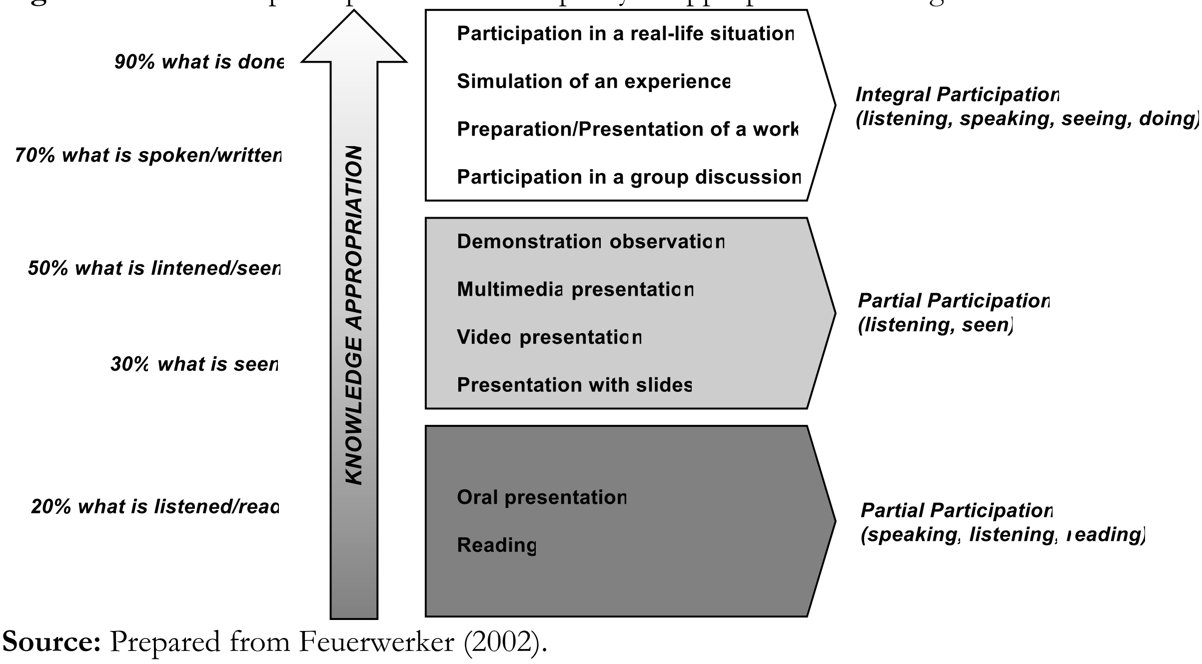


Source: Prepared by Ginter and White (1982), Kolb (1984), and Carvalho, Porto, and Belhot (2001).

Figure 1 shows the learning processes according to the Kolb Cycle (existential learning), Ginter & White Cycle (social learning), the Constructivist Cycle, and the Experiential Approach. The student's experiences through their learning processes are fundamental to developing the abilities on required critical analyses for the exercise of their future professions (RUSNAKOVA and BACHAROVA, 2001).

According to Feuerwerker (2002), the student internalizes knowledge primarily through practice rather than with the traditional learning processes that take place only through reading, lectures, and visual presentations (Figure 2).

Figure 2 – Student's participation and the capacity to appropriate knowledge.



Source: Prepared from Feuerwerker (2002).

As reported by March (2005), expertise has become increasingly extensive, with more fragmented and specialized kinds of knowledge produced rapidly each day, consequently reaching obsolescence in shorter times. The same author indicates that these traits demand some changes in the teaching-learning process, as follows:

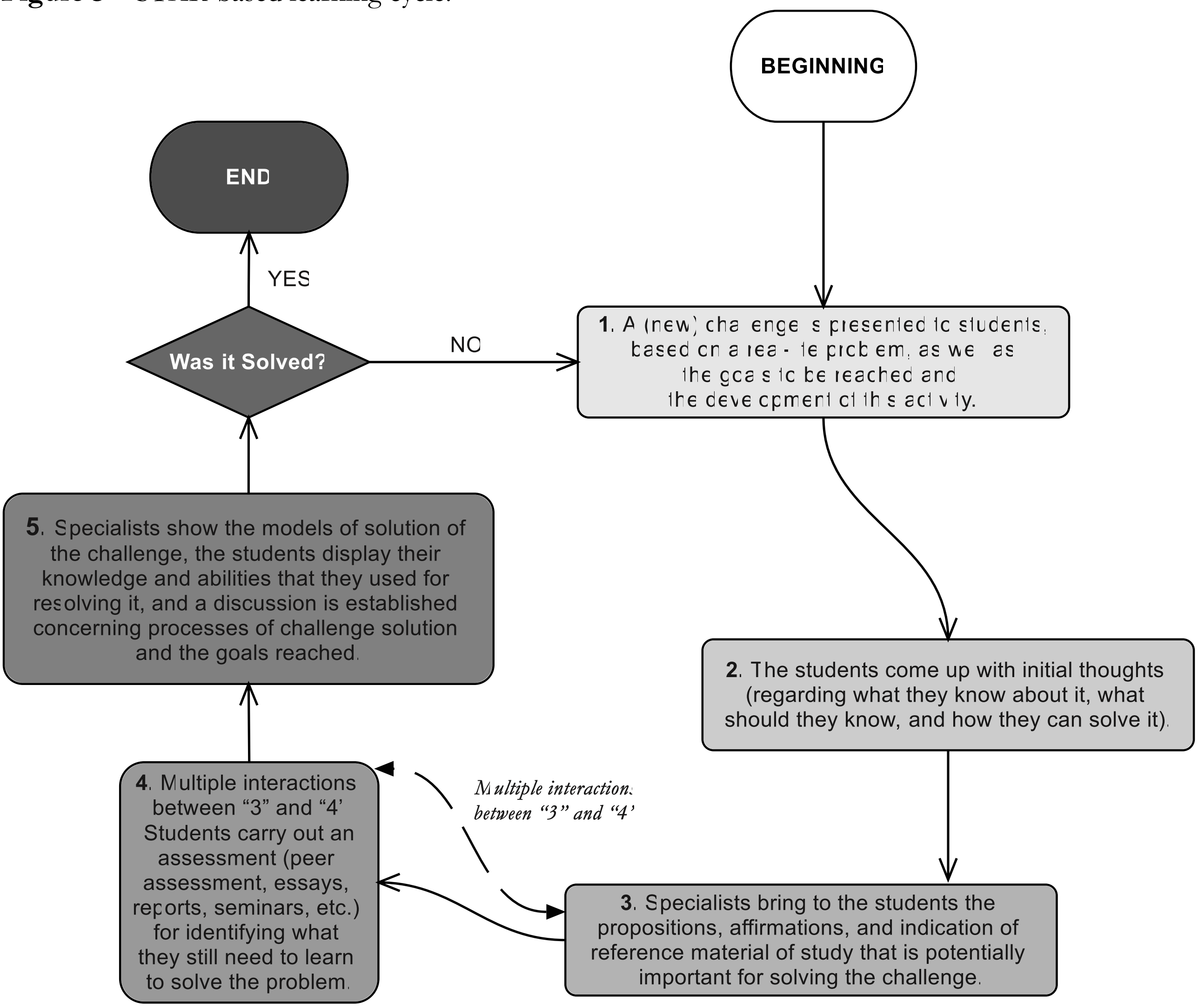
- Teaching centralization: teaching the student to continually learn;
- Student's autonomous learning: the professor takes up the function of tutor;
- Result-based learning: learning unfolds both in generic and specific competencies;
- Cooperation: teaching and learning processes are based on cooperative work between students and professors;
- Fluid and heterogeneous knowledge: the curricular matrix should consider spaces for working multi and transdisciplinarity;
- Strategic assessment: assessments should be integrated with learning activities, therefore valuing formative, continuous assessment over a certifying final assessment;
- Valuing Information and Communication Technologies (ICTs): using multifunctional platforms and data transmission infrastructures to improve learning processes, as well as research and assessment, such as providing real-time assessments, enabling the performance of shared projects, etc.

A learning method that uses these characteristics is problem-based learning, which, according to Benjamin and Keenan (2006), is a strategy that promotes active learning type of way given that the student has control over the process. One uses open-ended and non-structured problems for triggering the learning process. Students analyze the problem, decide on what they should know, and acquire knowledge when developing appropriate solutions. Teamwork is an integral part of this strategy in which learning sharing and assessment constitute an essential element in developing solutions (BENJAMIN and KEENAN, 2006). Overall, problem-based learning:

> "[...] aims, conjoint with other constructivist educational methods, to answer some dilemmas that emerged in contemporary vocational training, including the impressive increase in the volume of scientific and technical knowledge that should be taught to students during the graduation course, as well as its accelerated obsolescence rhythm. It seemingly satisfies some aspects that the literature commends for higher education (i.e., a course that integrates theory to practice and the academic world to work one, promoting — in addition to the domain of specific knowledge — the development of professional and civic abilities and behaviors)" (RIBEIRO, 2008, p. 13).

Prince and Felder (2006) approach inductive learning methods that, overall, can be analyzed as methods organized as learning cycles. All around, these cycles' stages may be summarized according to actions described in the modules of Software Technology for Action and Reflection (STAR) developed under the Vanderbilt University Learning Technology Center (PRINCE and FELDER, 2006) and presented in Figure 3.

Figure 3 – STAR-based learning cycle.



Source: Prepared and adapted from Prince and Felder (2006, p. 126).

Behrens (2006) points out that, as for projects' methodology, from problematic situations, the student investigates for producing individual knowledge. Thus, they reunite "[...] the actions for reflecting, dialoguing, arguing, and creating the possibility of taking up the problem for developing and complex, in-context view of reality" (BEHRENS, 2006, p.173). This also includes, in addition, the problematic technique, the problem-based learning method, according to the same author, enabling the development of activities that involve the engagement of individuals in collective, critical, and reflexive discussions. The author understands teaching through a complex lens that makes students coexist with different opinions, converting methodological activities into rich, significant situations for producing knowledge and learning directed to one's own life (BEHRENS, 2006).

In problem-based learning, students start from a real-life scenario that has no unique, certain answer. From a problem analysis, they research an alternative and present a recommended solution. This experience replicates the situation the students shall face when inserted in the labor market (HSIEH e KNIGHT, 2008). According to Postholm (2008), teamwork, project-directed works, and problem-based learning are set amongst learning methods directed at substituting or complementing more traditional expository classes. When aligned with an interdisciplinary idea, these learning methods have been present in discussions involving contemporaneous teaching and learning practices.

Still according to Richter and Paretti (2009), when participants identify and integrate different perspectives through a conjoint work toward the resolution of a problem in a manner that ensures that everyone learns and have the chance to remodel their behaviors and practices, interdisciplinarity occurs.

This, considering project-related work, according to Grant *et al.* (2010), also contributes to developing important abilities to insert the student into the labor market.

For Farias *et al.* (2015), educators use problematic methods to induce the student into the practical context, making them face real or simulated problems and minimizing the occurrence of fragmented instruction. These objects, called Active Methods of Education (AME), in order to be considered adequate, must be (FARIAS *et al.*, 2015, p. 146):

- Constructivist: based on significant learning;
- Collaborative: favors the construction of knowledge through a group dynamic;
- Interdisciplinary: proposes activities integrated into other disciplines.
- Contextualized: allows the student to understand the real-life application of this knowledge;
- Reflexive: strengthens ethical principles and moral values;
- Critical: stimulates the student to search for deepening to ensure the understanding of the limits the pieces of information face when reaching them;
- Investigative: awakens one's curiosity and autonomy, enabling the student to have the opportunity to learn how to learn;
- Humanistic: it is concerned and integrated into the social context;
- Motivational: it promotes the working and valuing of emotions;
- Challenging: it stimulates the students to search for solutions.

It is worth emphasizing that, when considering the AME, two roles gain prominence: both the professor and the student. Indeed, as stated by Farias *et al.* (2015) regarding the usage of AME, one should highlight

> "[...] the professor, who leaves behind the function of teaching, embracing the task of facilitating the process of knowledge acquisition, as well as the graduate, who ends up receiving denominations that refer to the dynamic context, as student or scholar. It all highlights the active, dynamic, and constructivist environment that can positively influence the perception of educators and students" (FARIAS *et al.*, 2015, p. 145).

Therefore, for all modes of learning, environment, and experience, observation, followed by the reflection on what is real to the construction of concepts and its posterior application, constitutes the primary way to construct knowledge and solidify knowledge. In other words, knowledge fixity and the intensity or capacity of learning apprehension increases in compliance with the way one follows the sequence "learning – comprehending – applying – summarizing": one perceives what happens around oneself, in addition to knowing what one whats to learn; therefore, a process of comprehension is initiated through the understanding of the process of adequate, appropriate information from external sources; after the issue is apprehended and comprehended, one should plan and apply a solution; and, lastly, if the application testing is satisfactory, one should adopt the model that was transmitted onto the environment, when one interacts with the environment and summarizes what was learned.

Thus, observation- and reflection-based learning construction on real-life experiences is fundamentally important for the formation of qualified alumni. An educational movement initiated around 1990, and primarily known as STEM, put the AME in evidence, especially those based on projects. It is the STEM Education movement, which, around the year 2008, became known as STEAM Education. In the following section, this movement is detailed.

THE "STEM" AND "STEAM" MOVEMENTS

The STEM abbreviation is formed by the initials of the words Science, Technology, Engineering, and Mathematics; It is presented as an innovative proposal for the teaching of natural sciences, given it is composed of a set of methods and tools that substitute merely expository teaching for an interdisciplinary one, which is project based (PUGLIESE, 2017). More recently, the integration of the STEM movement with the Humanities was sought, especially in the Arts area, originating the STEAM term (Science, Technology, Engineering, Arts, and Mathematics).

Interdisciplinary, project-based teaching: Pugliese (2017) stated that the Arts area in the STEAM movement should not be a merely entertaining accessory but should be accessed in its sensitive, teaching, creative, critical, and aesthetic functions, and quotes Radziwill *et al.* (2015) who defends the integration of significative experiences and the promotion of a rich environment for learning through an approach of participatory art. For Blackley and Howell (2015) apud Pugliese (2017), the "Arts" field includes Sociology, Psychology, History, Visual Arts, Philosophy, and Education in the search for more effective, substantial learning. Still following Pugliese (2017), when approaching STEM, this movement can be dealt with through four different formats of teaching in Sciences, including:

- Exclusively as an Approach or Method: learning would occur through the interaction of the object of study, linked with the manner of teaching natural sciences based on Problem Based Learning (PBL) and prototyping, therefore possessing a smaller and more restrictive dimension to one approach of teaching natural sciences
- As an increment to a natural sciences curriculum: in this case, the STEM-based curriculum incorporates Programming and concepts from Engineering and Design, still possessing a smaller and more restrictive dimension to one approach of teaching natural sciences;
- Public Policy: it aims to create a contingency of STEM professors and professionals and direct students to these areas. It may or may not be linked to the choice of a new educational model, i.e., it would be an educational public policy with the influence of other domains, such as the school curriculum, or restricted only to actions of STEM professors training. For Pugliese (2017), as a public policy, it ends up encompassing the two other representations: it acts modifying the curriculum and the method for attaining certain endpoints; and
- as a Model of Natural Sciences Teaching: It may assume the Traditional, Rediscovery-related, Technicist, Constructivist, Sociocultural, or Science-Technology-Society model, considering that Educational Models are formulations from interpretative charts based on theoretical assumptions used for explaining or exemplifying educational ideas and serve as a reference to refer to the educational phenomenon in its totality (PUGLIESE, 2017).

However, for Zeidler (2017) and Pugliese (2017), the STEM model lacks the worry with ethical and social issues of Natural Sciences, as well as the worry with scientific literalness and the construction of knowledge about the nature of Science, lacking central sociocultural and socio-scientific aspects for the formation of a sense of scientific identity that necessarily implies on the promulgation of moral responsibility.

QUALITY MANAGEMENT TEACHING IN PRODUCTION ENGINEERING

Silva and Cecílio (2007) point out that the necessity of continuous learning for one to maintain oneself updated on the labor market directly requires, from professors and educators, the same posture of "reviewing knowledge, researching, and keeping in touch with extra-scholar environments, in the face of in-context teaching (SILVA and CECÍLIO, 2007, p. 76). They indicate the necessity of nearing the engineering students' formation to the necessities of society and stimulate their capacity to develop broad competencies that surpass the classroom environment. For Sigahi, Ferrarini, and Borrás (2017), it seems important to narrow the relation university-company to nurture the perfection process of a decisive teaching-learning developed by graduation courses by minimizing the difference between what is taught and what is asked for in the labor market.

Indeed, the National Curriculum Directives of Engineering courses that are registered by CNE/CES Resolution no. 2 of 04/24/2019 (BRASIL, 2019), and CNE/CES Resolution no. 1 of 03/06/2021 (BRASIL, 2021), Art. 6 ensures the Engineering Pedagogical Course Projects to

> "[...] stimulate activities that simultaneously articulate theory, practice, and application context necessary for developing competencies established for the alumni profile, including extension areas and the **university-company integration**.
> Paragraph 3 Students' works should be encouraged, both individual and group ones, under the effective guidance of the professor.
> Paragraph 4 Since the beginning of the course, interdisciplinary activities that promote integration should be implemented coherently regarding curricular development to integrate technical, scientific, economic, social, environmental, and ethical dimensions. (BRASIL, 2019, p. 3-4, our emphasis).

Martins, Abreu, and Simon (2018) described an evolution scale of higher education from the current one toward a future level in which characteristics allow students to acquire greater autonomy in developing their competencies. In these future moments of teaching, there would be practices of, among other activities, the student's search for content based on tutored challenges, the approximation of companies during the student's graduation along with the development of professional challenges and the student's assessment by society, labor market, and regulatory entities (MARTINS, ABREU, and SIMON, 2018).

Likewise, it is worth considering what is indicated by the Brazilian Association of Production Engineering (ABEPRO), which is that one of the fundamental competencies of the production engineer is comprehending concepts linked to the area of Quality Engineering, being:

> "The Production Engineering area is responsible for the planning, project, and control of quality management systems that consider the management of processes, the factual approach for decision making, and the use of quality tools." (Commission of Graduation and referenced in the GT of Graduation of Encep 08 and Enegep 08 - 10/16/08).

Overall, production engineering courses follow the instruction in addressing all concepts related to Quality Engineering in compliance with ABEPRO's guidelines. These concepts are related to quality engineering and may be organized into the following subareas:

- Quality Systems Management: "[...] a set of planned and executed actions throughout the production cycle (from the conception of a product toward its post-sale), and which is extended to the productive chain (suppliers and clients), to grant the required and planned quality for the product, ensuring the lowest cost possible." (TOLEDO *et al.*, 2017);
- Quality Planning and Control: the process through which quality aims are established, as well as the respective means for one to reach them. Likewise, definitions of what should be controlled and the means to measure and assess the performance, along with their respective targets and contingency actions (JURAN, 1991).
- Normalization, Auditing, and Quality Certification: the adoption of approaches that are pointed toward a standard for processes regarding the development, implementation, and improvement of the efficacy of a Quality Systems Management (QSM), which are recurrently validated and certified by a regulatory organ or even a client, to ensure the product's quality (ABNT, 2015);
- Metrological Quality Organization: for Toledo *et al.* (2017), this topic consists of the understanding of the planning, as well as the execution of metrological measures to ensure quality and replicability in productive processes. To ensure product quality, and therefore comply with requirements and specifications from the client, always aiming at reducing variables in measuring and manufacturing methods;

- Reliability of Processes and Products: all quality characteristics from the project, the involved processes, and the final product, including the client's own perspectives, which, when aligned, constitute the total quality of a product and compose a reliability parameter (TOLEDO, 1994 apud TOLEDO *et al.*, 2017).

Linked to these concepts, there are still methods that seek to operationalize learning principles that enable students to fixate on all of this knowledge, therefore allowing them to replicate it in the future in practical situations. These principles are directly linked to the fundamental concepts of teaching and learning, to solidify this knowledge in the student. Some applications seek to operationalize learning theories in the context of quality management teaching, as presented below.

The method of using games is approached by Fuzeto *et al.* (2017). They highlight the possibility of the students themselves acting on the development of board games as part of the learning process. This approach demanded a broader comprehension of the content that was ministered throughout the course's subject, which, in addition to topics related to Quality Management and its respective tools, also contemplated all of the theoretical frameworks behind the conception and development of a game.

An adaptation of PBL with the method of corporate games in the Control Tools and Quality Management subject was presented by Martinez (2018) when addressing the teaching of quality in compliance with the conjoint union of the learning method and related theoretical database. The approach by Martinez (2018) was structured in periods of teamwork discussion right after the presentation of theoretical content, which occurred weekly that followed the schedule presented in Chart 1. Each group chose a product, which would be, in a simulative manner, produced in the classroom, and it required the handling of evidence on the use of quality tools that contemplated a complete dossier on relevant information concerning the production and use of these tools.

Chart 1 – Schedule of classes of the study of case subject elaborated by Martinez (2018).

Class	Theoretical Content	Practical Content
Class 1	Subject presentation and introduction to the management processes and quality management	-
Class 2	Quality management basis – Structured approach for the resolution of quality management problems: MASP	Constitution of teams and product choice
Class 3	Lean Manufacturing, 5S System, Kaizen, PDCA Cycle, TPM, Muda	Definition of the workplan based in PDCA, TPM, and Muda
Class 4	The seven basic tools of quality: verification sheet, control letter, Pareto's graphic, stratification	First production batch (initial data collection, definition of specification and productive capacity)
Class 5	The seven basic tools of quality: cause-effect diagram, histogram, and correlation diagram	Verifying errors in the process and their causes with Ishikawa's diagram
Class 6	Presentation of the quality management norms (ISO, TS, QS, GMP)	Second production batch (data collection)
Class 7	The seven new tools of quality: affinity diagram, relation diagram, tree diagram	Verifying errors in the process and their causes with the affinity, relation and tree diagrams
Class 8	The seven new tools of quality: matrix diagram, prioritization matrix, PDPC diagram, and arrow diagrams	Constructing the PDPC diagram of the process of product obtaining and the GUT matrix with the problems verified in the prior class
Class 9	TQM and metrology	Third, last production batch (data collection)

Source: Martinez (2018).

Results referring to the general median of the class were reported as satisfactory by Martinez (2018). As for the perspective of the students on the method, registered through a questionnaire, was positive for the learning and a better understanding of the practical applicability of concepts. These results by Martinez (2018) are aligned with the approach by Feuerwerker (2002). A very similar approach to the one by Martinez (2018) is presented by Fabricio *et al.* (2018), but this time, focusing on learning the Just-in-Time philosophy. It explored concepts related to productivity, which encompasses Quality without deepening on the Quality Management theme in compliance with guidelines by ABEPRO (2021). The professor still plays the responsible role of conducting the theoretical exposition on the subject's matters and planning all of the applied methods. The approach by Fabricio *et al.* (2008) proposes more active participation on the part of students, given that the simulation of productive systems is their responsibility of them themselves, and it all ends up with an exercise of collective reflection regarding the philosophies involved in the activity.

Lastly, Santos *et al.* (2020) report a familiar approach to using games as a learning method. In this case, the applied game was inserted in the Role Playing Game (RPG) genre, aimed at making the most out of the traits related to flexibility and creativity of the gamification process, used for the employment of the active teaching method in the Quality Management subject. It highlighted the student's position as the protagonist of their own learning, resulting in a satisfactory project performance. The approach by Santos *et al.* (2020) is coherent with the proposal by Farias *et al.* (2015), which puts into evidence the importance of each alumnus receiving customized care and summarizes the role of the professor and the student. It is directly linked to other relevant points presented by the work: a specific modality of RPG was sought, named FIASCO, to bring the logic that the player is also the narrator of their own history. Given that the professor would not have the capability to individually narrate the histories of the entirety of participating students, this professional can assume the role of a consultant and doubt clarifier.

METHOD

This study has an exploratory character and is also action research because it applies a dynamic of teaching and learning processes in an interactive university-company context. The chosen subject for applying this dynamic was quality management, and it took place in the 1st semester of 2019 and the 5th term of the production engineering course at the Federal University of São Carlos - campus Sorocaba. As for the partnered company linked to the university, an Auto Parts Integrated Supplier was chosen, also located in Sorocaba.

Considering the aim of this study (i.e., investigating the interaction set between the university and the company in teaching and learning processes in an engineering course), two propositions were elaborated to develop conjoint actions of these two entities. The first proposition deals with the lack of success of the partnership for educational application due to the labor market's lack of interest or incomprehension for the execution time with the result that is based on the formation and not the creation of an asset that the market could explore by the involved parties. The second proposition, in contrast, was that students would be more interested in the subject's content if it were to be applied in real-life cases during the theoretical learning itself.

The action study was conducted according to the recommendations of Gil (2002). As elaborated by this author, this type of research consists of the conception and performance of a narrow association of action along with the solution of a problem, in which researchers and representative participants of the situation in question are involved in a cooperative, participative manner. One should note that the essence of the action research method presented by Gil (2002) is consistently aligned with the STAR method of Prince and Felder (2006). Thus, considering the stages of the action research and adapting them to the research scope, we developed the following work stages:

- exploratory stage: in this stage, we set the interest in narrowing the approximation between the university and the company, and, therefore, we defined the representatives for the initiative;
- problem formulation: we sought to understand the simpler, more solidified way for inserting inexperienced students into the complex labor market environment by identifying the opportunities of providing them with practical and real experiences and, in the specific case of this work, with an emphasis on the supply chain of auto parts;
- construction of propositions: at this point, the representative parties suppose that an extension project set between the university and company, in which students would be involved as project performing parties, would analyze and provide solutions to real cases, in addition to being presented to the whole theoretical basis of Quality Management and being capable of promoting the percentage increase of knowledge fixity and apprehension of them;
- performance of a seminar: representative parties define the project's guidelines;
- sample selection: we defined the class of students involved in the project and the company's team available to bring cases to be analyzed, in addition to considering the participation in analyses that would present everyday challenges that are faced in work;
- data collection: data collection and monitoring in compliance with the project's guidelines, including the development of questionnaires for each group of participants, seeking to capture the post-project perspective of each involved party;
- data analysis and interpretation: assessment of the students and the ongoing involvement in the development of the project and study, weekly, transforming all of the collected data into relevant information for this research;
- plan of action elaboration: the means were defined, in which everything planned would be executed, among procedures, routines, and forms of control to ensure the success of the research;
- results dissemination: partial results were disseminated to the involved members as they were reached to obtain their involvement.

Students' development assessment was carried out progressively and consisted of ten assessment activities related to three types of activities. The first type involved theoretical and expository classes (Theoretical class I, Theoretical class II, and Theoretical class III). The second type involved three cases (Case I, Case II, and Case III) of the partnered company itself on real situations (Project preview, Project partial, and Final project). Except for the final project, the other nine activities were simultaneously assessed by the professor and the assistant, and deviations from the expected elements in the reports delivered were made explicit in the form of feedback to the students. The assessment of the Final Project activity was carried out through the application of a questionnaire from the partnered company's team. The questionnaire presented three affirmations concerning the perception of the quality of the projects developed by students, as follows: i) the project positively contributed to promoting the students' learning and development; ii) the students reached the goals of the project, and iii) the products obtained through the project were satisfactory. The respondents were required to present their degree of agreement with these affirmations that offered a liker-type scale with options ranging from complete disagreement to partial disagreement, partial agreement, and complete agreement.

UNIVERSITY-COMPANY INTERACTIVE CASE IN QUALITY MANAGEMENT TEACHING

Seeking to promote the approximation of students to the real-life work environment, as well as a better relationship between theory and practice, we aimed at defining a dynamic in the subject of quality management in a course of Product Engineering at a public educational institution and measuring the contribution of this dynamic in the learning process from the point of view of the students and the participating company.

The participating company was a large-sized transnational in the metal-mechanic sector, which actively participated in the dynamic, both in the planning and in the execution with the supply of real cases and enabling students to present the result of the work to the company's management at the end of the graduation semester.

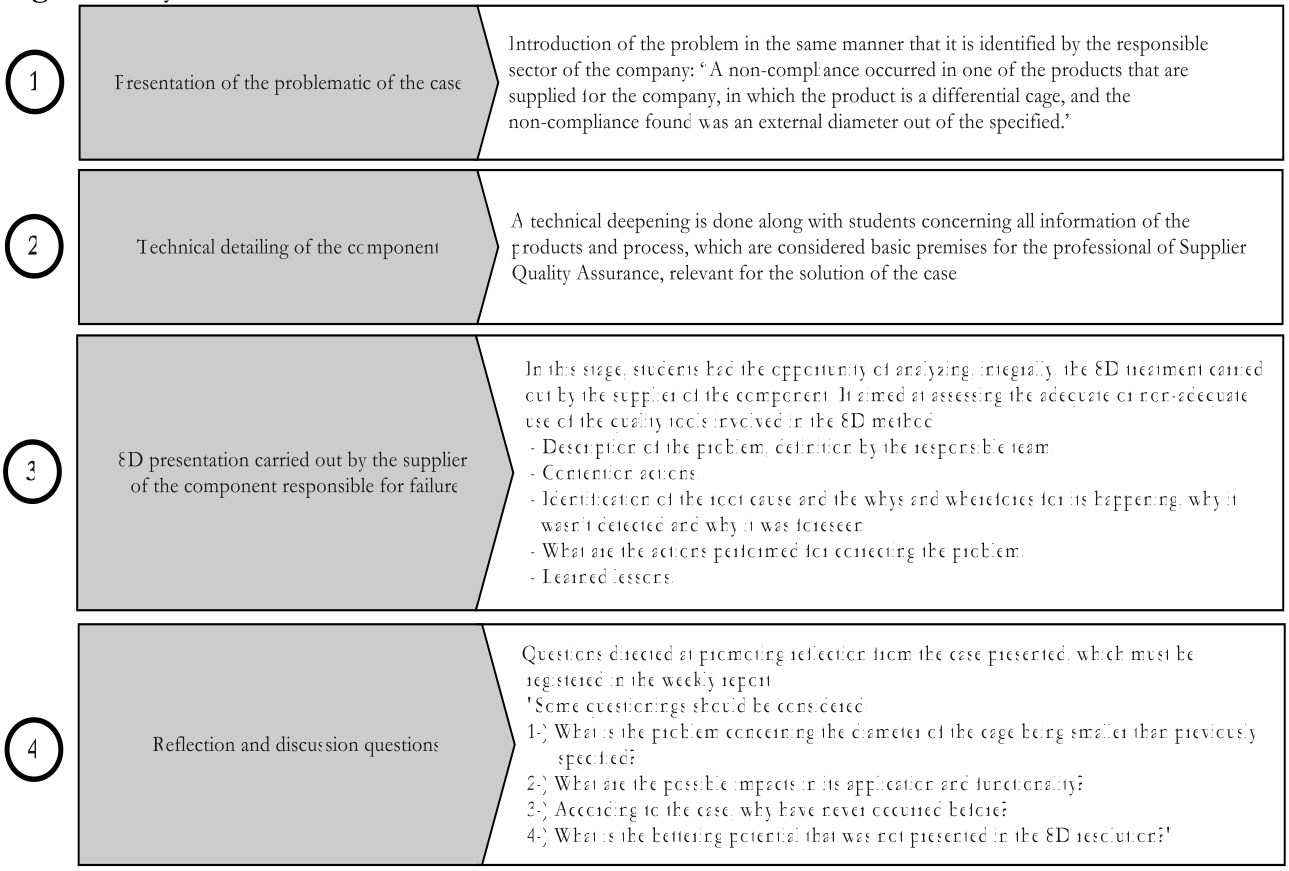
Initially, we elaborated an activities plan that sought, through the composition of expository and practical classes, the ongoing follow-up of the student and their respective evolution regarding learning. The working groups were required to formulate weekly reports whose content should address specific issues addressed to the themes of each class, the evolution of the final work project, the monitoring of the schedule, an analysis of each member of the group that their respective leader should perform, and, finally, report the progress between the motivations for the approach between the members of each team. As the assistant was responsible for carrying out the follow-up of each report and directing each group regarding the final project, the professor of the subject was responsible for monitoring the whole process.

For the elaboration of the cases, the company provided all materials and content duly protected by a legal agreement set between the parties, and it all had a direct relation with the content dealt with throughout the subject. The systematic adopted for elaborating each case is exemplified by Figure 4, in which Case I is addressed, the Case of the "Differential Cage," where a real case for applying the 8D method to the investigation and solution of problems was applied. It was based on the work that the partnered company has as treatment of problems in Quality, nine sequential steps to exercise an efficient deployment of Quality tools (5W2H, Process Diagram, 3x5 Whys, Ishikawa, FMEA, among others).

> "8D is a method of problem analysis and solution that allows integrating quality tools to a teamwork perspective." (Primary conception of the training offered by the partnered company on the extension process.)

Among the other methods for the application of Quality tools, 8D was selected not only for integrating the philosophy of the partnered company but also for instigating investigative and analytical abilities in students in a more agile way that did not require other, more advanced abilities (such as the Six Sigma).

Figure 4 – Systematic elaboration of cases.

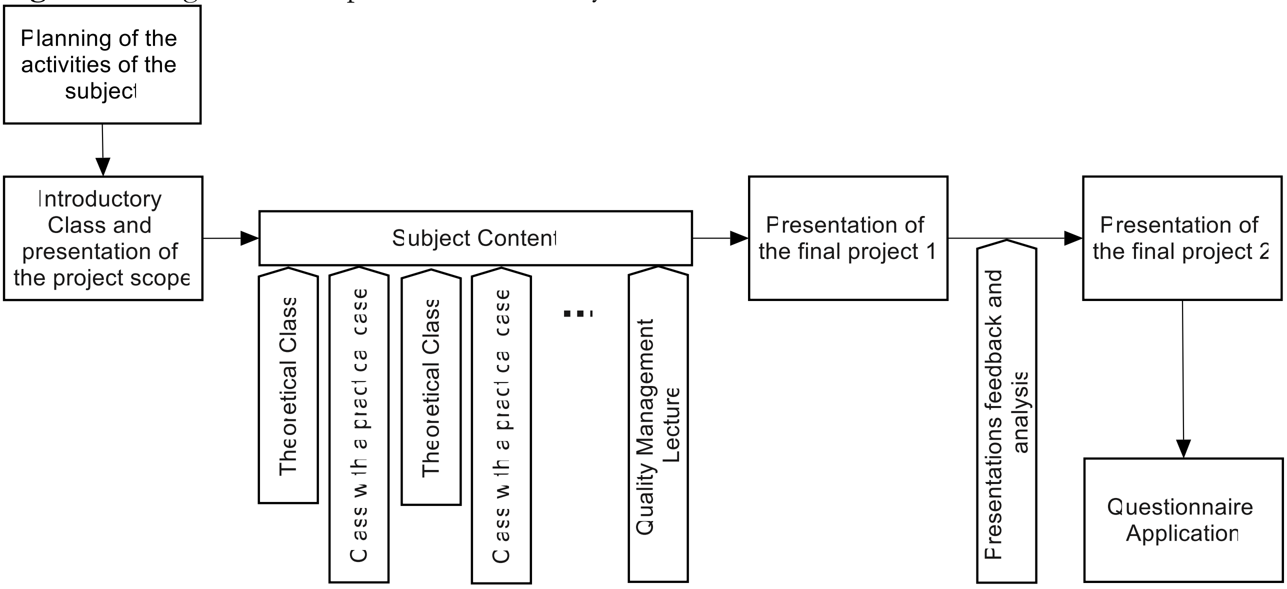


Source: Prepared by the authors.

Two other cases were made considering real data from the suppliers of the company: "Case of the 'Pipe'" (Case II) – an auto part with stains on the galvanized surface and the "Case of the Planetary Carrier Gear" (Case III). The first one addressed the finishing processes and surface treatment of a shaft fitting auto part that followed the same systematic in Figure 4, but with matters of reflection and discussion directed to this specific case. As for the second one, despite following the same systematic line, it was made during the class and with the assistant to test the acquired knowledge by students on previously studied cases.

An important point is that practical cases were adjusted to promote a very near experience to the one provided by the company's reality to their Supplier Quality Assurance (SQA) team. In the group, one person is responsible for the problem studied, and they should investigate the problem through quality management tools. After the root cause of the problem in question is identified, the group should be capable of making decisions that promote the correct execution of the tools for the issue to be indeed solved. For a better understanding of the structure of this project, Figure 05 illustrates all planned and executed activities.

Figure 5 – Stages of development of the activity.



Source: Prepared by the authors.

By the end of this flux, a questionnaire was applied for the students and another one for the company's quality team, aiming at the collection of qualitative information in regards to the extension project under different perspectives: from the ones that elaborated the performed work, as well as from the ones that received the work.

Each questionnaire had distinct approaches, for it was necessary to highlight distinct perspectives related to the aim of analyzing the entirety of the project regarding the study expectations. Therefore, the questionnaire directed toward the students addressed the following themes:

- Learning stimulus and professional engagement.
- Motivation stimulus to learn the content of the discipline.
- Openness in regards to the applied teaching method.
- Content replication capability.

As for the questionnaire that was applied to the company's quality team, we offered them a descriptive space concerning the observed benefits that the project provided for the company, in addition to highlighting the following themes:

- Degree of preparation for the labor market environment that the project provided for the students.
- Level of satisfaction of student deliveries.

Right after the subject planning, which was conjointly elaborated by: The assistant of the Quality Management subject, the professor of the Quality Management subject, and the manager of the sector of Supplier Quality Assurance of the Auto Parts Integrated Supplier, we elaborated the following schedule for the execution of the extension project throughout 10 weeks (Chart 2).

Chart 02 – Stages of development of the activity.

Applied activities	Activities demanded and weights on the final average	Activity date	Class' Average per Activity (Ma)	Class' Total	Variation Tax
Introductory class	-	03/21/2019	-	-	-
Theoretical class I	Report – 5.0%	03/28/2019	*5.50*	*5.50*	-
Case I	Report – 5.6%	04/11/2019	*7.85*	*6.68*	*17.60%*
Theoretical class II	Report – 6.2%	04/18/2019	*8.19*	*7.18*	*7.03%*
Case II	Report – 6.8%	04/25/2019	*8.23*	*7.44*	*3.53%*
Quality Management Lecture	Report – 7.4%	05/02/2019	*8.87*	*7.73*	*3.69%*
Project Preview Presentation	Report – 9.5%	05/09/2019	*6.02*	*7.44*	*-3.82%*
Case III	Report – 8.0%	05/23/2019	*4.69*	*7.05*	*-5.58%*
Theoretical class IV	Report – 9.5%	05/30/2019	*9.20*	*7.32*	*3.67%*
Partial delivery of the final project	Final Project – 17.5%	06/06/2019	*5.69*	*7.14*	*-2.54%*
Presentations at UFSCAR of the final project	Final Project – 24.5%	07/04/2019	*8.39*	*7.26*	*1.72%*

Source: Prepared by the authors.

An important point to mention is that making the schedule some months in advance in relation to the beginning of classes was essential for avoiding schedule conflicts between the involved parties: the company and the university.

RESULTS

Throughout the subject's duration, we followed up on the students' performance, monitoring the grades they obtained for each activity. As shown in Chart 2, one may observe that the class, overall, obtained a good performance throughout the activities. It is noteworthy to observe the level of complexity and difficulty of the deliveries, which directly impacted the global performance of the class. As, for example, in the first presentation (dated 05/09/2019), when many corrections were asked on the works that were presented as a way of preparing the students for the level of demand that appraising members of the company were going to ask in the final presentation.

Many points require attention in Chart 02, such as the performance of activities related to the Lecture on Quality Management, Case III, and the Partial delivery of the final project. The drop in performance of the students on the activity of Project Preview Presentation was justified by a preliminary, unsatisfactory result (we required a demonstration of a sketch of an idea of the product, and the majority of groups had not yet defined which idea would be used), given that the groups ended up dedicating themselves to the project with more diligence only at the end of the term. The second drop occurred because some groups had not yet delivered the weekly report due to a lack of organization and ended up having a zero grade on the activity (Referring to Case III). This result was discussed with the students, who, in this process of reflection, revealed discomfort along with the moral responsibility they assumed when they used the autonomy granted to them. After this event, results revealed a collective recovery, even considering the bigger exigence of the delivery of the Project partial. Lastly, as for the Partial delivery of the final project, a high level of the requirement was set (concerning the project's content, design, and adherence to the initial scope of it), which resulted in numerous corrections on the works presented as a way of preparing the students for the required level that the appraising members of the company would demand at the final presentation. By the end of the project, it was possible to analyze the answers to the questionnaires conjointly with the performance of the groups of students, and this data is shown in Chart 3.

Chart 3 – Subject assessment by students.

Student's Questionnaire				
Questions	**Percentage that completely agreed**	**Percentage that partially agreed**	**Percentage that partially disagreed**	**Percentage that completely disagreed**
Compared to a traditional expository class, the new class method and the project contributed for a bigger stimulus to learning of the content and professional growth.	100%	-	-	-
I felt motivated to dedicate more when compared to the traditional teaching method (assessments and expository content, only).	50%	50%	-	-
It was possible to acquire the new knowledge offered throughout the subject in more instructional ways than the traditional method (assessment and expository content).	50%	50%	-	-
It was possible to understand the subject's content and transmitting a great part of that acquired knowledge to other person.	25%	75%	-	-
The learning positively collaborated to the market labor's preparation and growth, as well as to the professional life.	100%	-	-	-
Knowledge acquirement was significant to the student.	100%	-	-	-
The experience of applying the theory in practical dynamics was significant for learning.	100%	-	-	-

Source: Prepared by the authors.

In turn, Chart 4 shows the data obtained that referred to the perception of the quality of works developed by students and expressed by the partnered company's team. We highlight two observations made by employees of the company on the benefits of the subject, developed as it was, brought to the company:

> "The project can make access available, more easily, to the information inherent to the tools for managing problems of non-compliance both with the supplier and with the Auto Parts Integrated Supplier team. It will enable a better understanding among parties for a better and more rapid solution." (Intern of the SQA sector of the partnered company.)

> "Diffusion and standardization of knowledge of the quality tools of the supply chain, in addition to centralizing it and providing rapid access to tools." (Senior Engineer of the SQA sector of the partnered company.)

Chart 4 – Assessment of the results of the work by the team of the partnered company.

SQA Questionnaire				
Questions	**Percentage that completely agreed**	**Percentage that partially agreed**	**Percentage that partially disagreed**	**Percentage that completely disagreed**
The project positively contributed to promoting the students' learning and development	100%	-	-	-
The students reached the goals of the project	60%	40%	-	-
The products obtained through the project were satisfactory	60%	40%	-	-

Source: prepared by the authors.

Thus, this work obtained positive results under very diverse perspectives, in addition to promoting a good overall in-class performance in the Quality Management subject. The most pivotal points raised after a complete analysis of the results complied with the challenges of motivation and self-incentive of the student so that they would be capable of reaching these project goals and bringing better results on the conception of the final product. The averages of the groups on the activities put this point into evidence, given the drop in performance in activities where the weights in the assessment method were higher in the items of proactivity and critical analysis of the participants.

FINAL REMARKS

This research performed action research on the teaching and learning processes of the quality management subject in the product engineering course in the investigative context of the interaction set between the university and the company. The study provided the opportunity of nearing students with everyday practice in the quality sector of a company belonging to the automobile industry. The observations of the professionals in this area show the experiment's effectiveness to this end. Labor market expectancies generated regarding the students' domain on the subject were satisfied.

Our findings allow one to conclude that it is possible to enable university-company partners that lead to beneficial actions in the environment of the graduation teaching in Engineering throughout the development of these conjoint actions. Still, in regards to the propositions presented in the methods section, the company revealed to be open to the above-mentioned partnership that focused on the formation of Production Engineering alumni and aspects related to the possibly existing barrier related to the time of execution and expected results were aspects of encouragement and not a barrier. Additionally, the students became increasingly interested in the content of the subject, revealing their growing autonomy and responsibility as people accountable for the creation and construction of knowledge throughout the term. Below, we present other contributions reached during the action research and go beyond previously presented propositions.

Other contributions reached, such as the summary of the results of this action research during the development of the action research, were also identified and presented. The valuing of the student as an active part of the teaching-learning was highlighted, and it was accomplished when considering the student as the builder of their knowledge, as well as the builder of the collective knowledge in the class, especially in the bachelor's in Engineering and Production Engineering, in which interaction between theory and practice has gained prominence due to the new National Curriculum Directives for Engineering courses (BRASIL, 2019; BRASIL, 2021). This contribution is also in compliance with the proposal by Rusnakova and Bacharova (2001) concerning their position on how the student's experiences during the learning process contribute to the exercise of their future professions.

The challenging scenario presented by the cases, which demanded an interface between Mechanical and Production Engineering, promoted students' increased interest and commitment as a thought-provoking scenario of problem resolution based on practice was solidified. The cases and the final project also contributed to the creation of this challenging scenario. The involvement of these professionals, already inserted in the labor market and the learning process, along with deliveries of data, information, context, and real problems, encouraged students the search for solutions to the proposed problems, generating a virtuous cycle and resulting in the search for more theoretical knowledge on the subject's theme.

Delivery of feedback by the assistant, the professor, and the partnered company's professionals over each one of the works that were handled revealed itself as an encouraging practice for the bettering of deliveries made by students. This ongoing bettering process of study methods and case analysis allowed that method and conceptual considerations, as well as reflections that had not yet been considered in previous deliveries of the partial report, could be applied and considered in the following delivery. Additionally, the autonomy and dedication of the students in the subject were encouraged with the permission given to them to raise constant questions about the project proposals of each group and to actively engage in answering the various questions, stimulating reflection on their work developed so far.

The partnered company considered that the nearing and sharing processes of expectancies before the beginning of in-classroom activities were decisive for the partnership between the university and the company. Lastly, it was possible to experience the challenges that involved the conception of innovative learning theories in higher education. Nevertheless, given the limitations of the action research method in regards to its capacity for generalization, future research could be performed in the sense of assessing the broadening of the findings of this research to another engineering, in addition to other related courses. Additionally, one can observe and indicate public policies that encourage the university-company interaction in a manner that seeks diverse ways for stimulating the theoretical and practical relation throughout graduation courses in a reality of professors that may not possess the adequate formation of insertion in this type of reality. Moreover, future research may also investigate virtual teaching in the university-company interaction environment from the perspective of learning methods developed for using virtual technologies.

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Author 1 – Project coordination, conceptualization, data analysis, method design, validation, and drafting.
Author 2 – Conceptualization, data collection, validation, and drafting.
Author 3 – Reviewing.

DECLARATION OF CONFLICT OF INTEREST

The authors declare that there is no conflict of interest with this article.