Scientific Mapping of Project Management and Educational Perspectives for Industry 4.0

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Abstract

The research aimed to carry out a scientific mapping, in Scopus and Science Direct, about project management and educational perspectives for industry 4.0. For this was used the method Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). We conducted a systematic literature review on the topics Industry 4.0, project management, skills and engineering education. From the results found, it is highlighted that the project management theme will be very important in view of the new industrial revolution being considered a professional, methodological and operational competence. Authors highlight the importance of the theme for the information technology (IT) sectors facing the transformations caused by the fourth industrial revolution. However, in the area of education, there is a paradigm regarding the project management discipline as it is neglected in engineering courses, not arousing student interest. To minimize this problem, a partnership between governments, universities and companies is mentioned. Another possible solution to reduce this educational gap is the creation of Learning Factories, which enable the union between theory and practice, arousing greater interest of students and assisting in the development of skills required by industry 4.0.

Keywords
Engineering Education, Skill, Industry 4.0, Project Management.

1. Introduction

Projects bring development through the renewal of products and services, changing paradigms and generating sustainability for organizations (Almeida and Neto, 2015). Although, Koke and Moehler (2019) and Silvius (2017) mention that there are still challenges regarding the union between projects and sustainability. San Cristobal (2017) comment that over the years the projects have become increasingly complex. This complexity influences directly the modeling, evaluation and control, affecting time, cost, quality and safety.

The changes are directly linked to projects, and these are linked to the technical and behavioral skills that help in decision making. Balve and Ebert (2019) comment that project management is an area in which academics work only after completing a course. Radujkovic and Sjekavica (2017) claim that project management is inevitable in the current scenario, becoming a required subject in undergraduate (Raoufi et al. 2018). Vila et al. (2017) are concerned with how Project Management has been neglected in engineering courses. Kohdeir (2018) reports that project management at universities faces difficulties since the discipline does not answer the needs required by the industries and also why does not arouse interest of students.

Thus, this research aims to carry out a scientific mapping on project management and educational perspectives for industry 4.0. Finding possible gaps and opportunities in project management was also the focus of this research. The development this study was divided into 5 sections, and the first one was presented. Section 2 we describe the theoretical foundation for the better understanding of industry 4.0, project management, skills and engineering education. Section 3 comprises the research methodology. Subsequently the sections 4 and 5 are composed respectively by, results and conclusion.
2. Theoretical foundation

To better understand the topic, a theoretical research was conducted from the themes Industry 4.0, project management, skills and engineering training.

2.1 Indústria 4.0

The fourth industrial revolution, also called intelligent manufacturing, industrial internet or integrated industry, is an emerging theme that tends to affect industries internally changing the way manufacturing and product development, their processing, delivery and payment (Hofmann and Rüsch 2017). Lu (2017) reports that industry 4.0 was born in Germany and is related to new technological concepts. The study by Xu et al. (2018) mentions that information and industrialization techniques have leveraged the progress and evolution of manufacturing technologies. They also report that this whole package of technologies is intended to make Germany the leader of the integrated industry.

Although the literature disagrees on which emerging technologies are needed for Industry 4.0, we cite the most important according studied documents, these being: Internet of Things (IoT) (Zheng et al. 2018; Lu 2017; Zhong et al. 2017; Chen et al. 2017; Rüßmann et al. 2015), Cyber Physical Systems (CPS) (Zheng et al. 2018; Lu 2017; Zhong et al. 2017), Information and Communication Technology (ICT) (Lu 2017; Zhong et al. 2017), Enterprise Architecture (EA) (Lu 2017), Horizontal and Vertical System Integration (EI) (Lu 2017; Rüßmann et al. 2015), Cloud computing (Zheng et al. 2018; Zhong et al. 2017; Chen et al. 2017; Rüßmann et al. 2015), Big Data (Zheng et al. 2018; Zhong et al. 2017; Chen et al. 2017; Rüßmann et al. 2015) and Artificial Intelligence (AI) (Zheng et al. 2018).

Zheng et al. (2018) and Kipper et al. (2019) commenting on their research that implements Industry 4.0 requires the union of physical and virtual systems or that make manufacturing processes increasingly intelligent. Mrugalska and Wyrwicka (2016) add that Industry 4.0 will help build a smart network between machines, components, properties, people, production systems and information and communication technology (ICT) throughout the production process resulting in intelligent factories. Zhong et al. (2017) comments that the fourth industrial revolution brings a promise of flexible manufacturing aligned with large-scale personalization so that companies can meet the demands of individualized production of shorter lead times and higher quality. To this end, there should be concern about how project management will be done, considering that common project management practice should be based on 'flexible' projects where flexibility and tolerance for inaccuracy are required (Atkinson et al. 2006).

2.2 Project management

To perform or structure any activity, a method is required (Kipper et al. 2013). Taking this thinking to the project area could not be otherwise, as this is an activity that manages resources, dates and technical requirements (Carvalho 2015, p.22). Having these needs in question, comes the Project Management Institute (PMI), that in the quest to better manage project management launches a document called “A guide to the Project Management Body of Knowledge - PMBOK®”. For the PMI (2013) the application of knowledge, techniques, tools and skills to handle a project is called project management. Management is applied and tuned to 47 processes divided into Initiation, Planning, Execution, Monitoring and Control, and Termination groups. Project management has, but is not limited to:

- Identify requirements, needs, concerns, and expectations that stakeholders regarding project planning and execution
- Establishment, maintenance, execution of efficient communications and project added value among stakeholders.
- Stakeholder management seeking to meet project requirements as well as delivery creation and constraint balancing.

The PMI (2013) says that leading a project brings great challenges for managers, for this reason a qualified leadership is essential. Leaders must meet the needs of activities, teams and individuals, set real and attainable boundaries, and ultimately be a facilitating link between the strategic area and the team. The important skills for a project manager go beyond specific. Skills such as management, performance, attitude, leadership and personality are part of the ideal professional. Another point that draws attention is the changes that occur in projects after the start, where all parts must be communicated. Therefore, communication is another essential competency for managers. When it is compromised, there may be
problems with delivering stakeholder needs. It is worth remembering that the professionals responsible for the projects must be trained in evaluating scenarios, in order to engage everyone for the proper execution of the work.

Atkinson et al. (2006) note that in project management more sophisticated efforts are needed to recognize and manage important sources of uncertainty. Such efforts need to cover organizational capabilities, including some aspects of the organization's culture and learning. For project management learning should focus on skills development (Drejer 2000; Thomas and Mengel 2008).

2.3 Skill and Engineering Education

Brandão and Bahry (2005) and Fleury and Fleury (2004) say that competence is the set of knowledge, skill and attitudes of an individual, thus making it stand out among the others. Fleury and Fleury (2001) associate competence with: know how to act, mobilize resources, integrate multiple and complex knowledge, learning, engagement, bear responsibility, strategic vision. Wilcox King et al. (2002) mention that most managers recognize the competencies of the company in order to generate competitive advantages. Thus, be aware of existing strengths, as well as areas for development.

De Souza Cruz and Moraes (2013) comment that with the competitive scenario it is necessary for the professional to have technical skills, expertise consistent with the designated and behavioral responsibilities. Dalenogare et al. (2018) recalls that companies need to rethink the way they work, so new skills will be needed, not just for the worker, but for the whole organization. For Fleury and Fleury (2001) skills add economic value to companies as well as social value to people. In this context when developing their skills the professional is investing in himself.

In relation to engineering education Crawley et al. (2014) comment that it is characterized by engineering practice (conception, design, implementation and operation) throughout the production chain. The job of the engineer is to create benefits for people by manipulating materials, energy and information, but for that they need to know beyond theory, what can be acquired through educational labs (Feisel and Rosa 2005). Although engineering curriculum have evolved to meet 21st century requirements, international organizations are still calling for changes to a knowledge-driven learning system and learning processes that support their development (Litzinger et al. 2011). Project based learning is an educational methodology that can assist with this change and skills development. De Los Rios et al. (2010) indicate advantages in the application of this methodology, such as the facilitation of training in technical, personal and contextual competences and that collaborative learning is facilitated by the integration of teaching and research.

3. Methodology

In order to analyze the scenario of the theme, a scientific mapping was carried out in the Scopus and Science Direct. These databases were chosen for their importance to academia. The Scopus database has 55 million records, more than 21 million titles and 5,000 publishers, and is the largest source for academic abstracts and citations. (Elsevier 2019). The Science Direct database, on the other hand, features a quarter of the world's scientific and technical content and includes nearly 2,500 journals and more than 30,000 books and an estimated 13,400,000 articles. (Elsevier 2019a).

The search was conducted on August 29, 2019. In the search field the following expression was used: "Engineering education" AND "skill" AND "Industry 4.0" AND "Project management". These research was made in “all fields”. Only articles published from 2015 to 2019 were selected. The bibliometric research used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Moher et al. 2015; Stewart et al. 2015; Mcinnes et al. 2018; Liberati et al. 2009). The method PRISMA It is divided into four phases, concentrating on the way in which the authors perform a systematic analysis of the literature: identification, screening, eligibility and inclusion (Liberati et al. 2009). Second Moher et al. (2009), using this methodology helps authors facilitate readers understanding of how systematic reviews and meta-analyses are performed.

4. Results and discussions

The Figure 1 shows the research flow and results according to methodology PRISMA.
In the first search conducted with the research themes was located at the databases Scopus and Science Direct, 25 documents (Appendix 1). In the screening process it was found that there were no duplicate documents. The content was analyzed and it was identified that 5 of these documents did not contribute to the research problem. With the help of Software VOSviewer a word interconnection map was produced for readers to get a better understanding of the topic. Van Eck e Waltman (2009) consider that the VOSviewer is a software which allows the construction, visualization and interpretation of bibliometric maps. The results will be presented in the next item.

From the 25 documents found, Figure 2 was constructed. For this we use the software VOSviewer. Following we will present the themes with the most interconnected words.

Figure 1. Protocol PRISMA and search results
Caruso (2018) mentions in his research that Project Management follows coded formulas and planning and technical and behavioral areas. Revolution, we can say that the Learning Factories contribute directly to the professional development in technical and behavioral areas.

Caruso (2018) adds that project management incorporates all activities in order to achieve a goal, and that the skill set for managers are: vision, software techniques, quality vision and team autonomy. The Project Management is considered a professional competence (Müller-Frommeyer et al. 2017; Bender et al. 2015, apoud Heyse and Erpenbeck 2009), methodological (Buth et al. 2017; Müller-Frommeyer et al. 2017; Bender et al. 2015, apoud Heyse and Erpenbeck 2009) and operational (Lanz et al. 2018).

Vila et al. (2017) comments on the importance that Project Management brings, such as functionality related to business objectives, work breakdown structure definition, task assignments, resource allocation, workflow definition, approvals, configuration and change management, requirements and plan control project. In addition, the Project Manager needs to map the entire collaborative platform plan for ease of use. In conjunction with business management, proper Project Management provides a multicultural and multinational business landscape for technical aspects (Gordon et al. 2018). Pejic-Bach et al. (2019) contributes to research by addressing that project management and supply chain appear together in the area of continuous improvement, lean manufacturing and operational excellence.

A study in India found that industries expect students (professionals) to have knowledge in Project Management as they undergo constant transformations in pursuit of greater competitive advantage (Buth et al. 2017) highlighting the importance this skill (Pejic-Bach et al. 2019). Pejic-Bach et al. (2019) highlighting the Project Management importance for Industry 4.0 implementation. This revolution will bring many robots into the process, which reinforces the thinking of Benesová and Tupa (2017) that programmers will need to possess this skill in their qualification. It is also emphasized that this competence is more expected in information technology (IT) sectors than in other sectors (Siddoo et al. 2019). Kleinschmidt (2019) highlights the importance of this skill for engineers. To develop this skill, Louw and Droomer (2019) speak of the inclusion of Learning Factories could help develop the skills of engineering student. Kemény et al. (2016) reinforces too that Learning Factories simplify or reduce complex, large-scale production processes and provide safety for activities and learning.

Nyemba et al. (2019) comments that training in projects in the industry, brings an increase in problem solving skills, helps in the development of functional skills (Lanz et al. 2018). Bilge and Severengiz (2019) mention the importance of qualifying industrial engineering courses and the implementation of a game methodology and integration between company-school (student-professionals). This integration is one way to design sustainable factories and transform processes using Project Management. Ahmad et al. (2018) say that the Learning Factories improve students knowledge by connecting theory and practice, helping to bridge the educational gap about lean manufacturing. The account of Alberta Learning Factory (AllFactory), discusses that project-based experiential learning environment facilitates student development in interdisciplinary Project Management.

Block et al. (2018) in their research comment that Learning Factories approach knowledge in a practical way for students as well as instigate creative thinking through holistic approaches. Salah and Darmoul (2018) in their case study present complex design tasks and reconfigurable manufacturing system operations (RMS). From this Project Management methodology, students are urged to design, implement, evaluate performance, and operate a reconfigurable manufacturing, which means opening their minds to complex topics, modular, flexible systems, and interoperability in the design and operation of fabrication computer systems. Müller-Frommeyer et al. (2017) conclude that the union of Learning Factory and
didactic concepts promote professional/methodological, social and personal skills, enabling autonomous but goal-oriented development. Buth et al. (2017) report that gap between academia and industry can be minimized through Learning Factories.

5. Conclusion

This research aimed to carry out a scientific mapping on project management and educational perspectives for industry 4.0. Such an approach has raised important findings.

The Project Management is directly linked to industry 4.0 as it will transform the entire production process. Transformations require projects, and knowing how to manage them is of paramount importance at a time when change is a constant. This brings us to a critical point, because as addressed the Project Management discipline is neglected in undergraduate courses, not meeting industry requirements and not arousing the interest of universities and students, which goes against expectations and requirements of industry.

Finally, authors suggest the implementation of Learning Factories as a learning facilitator, working on Project Management in a real environment. Changes in academic curricula in search of skill-cutting, such as problem-solving skills, functional, professional/methodological, social and personal skills development, are also required. A didactic methodology with practices tends to arouse more interest from students than just classroom theory.

The authors also suggest partnerships between universities (with the application of active learning methodologies), with government that should provide funding, and with companies by training students to meet the required needs. Applying serious games in sustainable manufacturing areas via digital transformation can also be a study factor.

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References


program Master in Industrial Systems and in the research line of Monitoring, Simulation or System and Process Optimization. During this period been produced documents focused on skills management for Industry 4.0.

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## Apendix 1. Articles located in Scopus and Science Direct databases

<table>
<thead>
<tr>
<th>Article</th>
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<tbody>
<tr>
<td>A systems thinking approach to collaboration for capacity building and</td>
<td>Nyemba et al. (2019)</td>
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<td>sustainability in engineering education</td>
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<td>Development of a low cost machine vision based quality control system</td>
<td>Louw and Droomer (2019)</td>
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<td>for a learning factory</td>
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<td>Analysis of industrial engineering qualification for the job market</td>
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<td>Development of an agile development method based on Kanban for</td>
<td>Hofmann et al. (2018)</td>
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<td>distributed part-time teams and an introduction framework</td>
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<td>a New Profession and a Case Study in Providing the Required Skillset</td>
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<td>Based on Graduates Feedback</td>
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<td>Holistic approach for teaching IT skills in a production environment</td>
<td>Block et al. (2018)</td>
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<td>Alberta Learning Factory for training reconfigurable assembly process</td>
<td>Ahmad et al. (2018)</td>
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<td>A Method for Improving Production Management Training by Integrating</td>
<td>Yang et al. (2018)</td>
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<td>an Industry 4.0 Innovation Center in China</td>
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<td>Engineering Technology Education Based on the Reconfigurable</td>
<td>Salah and Darmoul (2018)</td>
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<td>Manufacturing Paradigm: A Case Study</td>
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<td>A concept and local implementation for industry-academy collaboration</td>
<td>Lanz et al. (2018)</td>
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<td>and life-long learning</td>
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<td>Engineering Design and Manufacturing Education through Research</td>
<td>Zhu et al. (2018)</td>
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<td>Experience for High School Teachers</td>
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<td>Evolution of SMEs towards Industrie 4.0 through a scenario based learning factory training</td>
<td>Wienbruch et al. (2018)</td>
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<td>Benchmarking Undergraduate Manufacturing Curricula in the United States</td>
<td>Raoufí et al. (2018)</td>
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<td>Project-based collaborative engineering learning to develop Industry 4.0</td>
<td>Vila et al. (2017)</td>
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<td>skills within a PLM framework</td>
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<td>Requirements for Education and Qualification of People in Industry 4.0</td>
<td>Benesová and Tupa (2017)</td>
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<td>Introducing Competency Models as a Tool for Holistic Competency</td>
<td>Müller-Frommeyer et al. (2017)</td>
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<td>Development in Learning Factories: Challenges, Example and Future Application</td>
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<td>Bridging the Qualification Gap between Academia and Industry in India</td>
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<td>Complementary Research and Education Opportunities—A Comparison of</td>
<td>Kemény et al. (2016)</td>
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<td>Learning Factory Facilities and Methodologies at TU Wien and MTA SZTAK1</td>
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<td>Learning Factory 2.0 – Integrated View of Product Development and</td>
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<td>Teaching internet ofthings for engineering courses: A project-based</td>
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<td>An exploratory study of digital workforce competency in Thailand</td>
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<td>Digital innovation and the fourth industrial revolution: epochal social</td>
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<td>An interpretive structural modeling of teamwork training in higher</td>
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