

# Evaluation of a Pilot Course of Project Management for Industry 4.0

Rui M. Lima<sup>1</sup>, Diana Mesquita<sup>1,2</sup>, André Luiz Aquere<sup>3</sup>, Cristiano de Jesus<sup>1</sup>

<sup>1</sup> Department of Production and Systems, ALGORITMI Centre, School of Engineering, University of Minho, Guimarães, Portugal

<sup>2</sup> CIEC—Research Centre on Child Studies, University of Minho, Portugal

<sup>3</sup> Department of Civil and Environment Engineering, Faculty of Technology, University of Brasília, Brasília, Brasil

Email: rml@dps.uminho.pt, diana@dps.uminho.pt, andre@unb.br, b12121@algoritmi.uminho.pt

## Abstract

The fourth industrial revolution created the need for the development of new competences for Industrial Engineering and Management. In order to address this need an Erasmus+ project, developed by a consortium of nine universities, has been engaged in Curriculum Development of Master's Degree Program in Industrial Engineering for Thailand Sustainable Smart Industry (MSIE4.0), co-funded by the European Commission. In the context of this project, there are 16 master level courses being developed and piloted. One of the courses is Project Management for Industry 4.0 (PM4I4). The objective of this paper is to present the evaluation of this course based on the perceptions of the enrolled students. This evaluation was based on written reflection of the course delivered at the end of the course by a total of twelve students. Most of students enrolled (10/12) provided a positive perspective about the course, considering that will contribute for their professional practice in the future and recommend it for other engineering students. Part of these students considered the project related to the development of a questionnaire of I4.0 in a company quite interesting and contributing for their formation and other students considered it less practical that they expected to. It is worthwhile to notice that most of the students really enjoyed the diversity of pedagogical experiences and teachers engaged in the process (a total of 4), and the development of transversal competences, but some of them would prefer to have contact with less teachers. Thus, as final contributions, it could be recommended to create better framework for the Industry 4.0 questionnaire project and create opportunities for the students to enrol in management of more practical projects related with that main theme.

**Keywords:** Project-Based Learning; Project Management; Industry 4.0; Industrial Engineering and Management.

## 1 Introduction

The mental and structural process of the efforts to systematize knowledge relating to the phenomenon called Industry 4.0 is widely known. It is known that this is a movement of reconfiguration of productive systems, which consists of the paradigm shift from mass production to product configuration plus the aggregation of value through services, digitization of operations and expansion of resources to support decision-making. All these transformations involve new technologies such as Internet of Things (IoT), Cloud Computing, Virtual Reality, Augmented Reality, Additive Manufacturing (or 3D Printing) and Autonomous Artificial Intelligence Systems (Machine Learning and Deep Learning). However, this description refers only to the first layer of perception of all the high proportion and range dynamics that are in process. The technological apparatus, therefore structural, presents in an almost obvious way its immediate implications, namely, the need for technological updating of productive systems and industrial management tools on the one hand and of the technical competences of human resources on the other. However, these new resources bring with them new possibilities of relationships among all agents involved, but they are only possible if the technology is not appropriated by all as just a new instrument to be operated. The new possibilities need to be explored. Within the discipline of project management, there is a wide range of frameworks that enable initiatives to update business models. However, doing the same as always, with a newer technology, technically and financially, is not a challenge, but taking advantage of new opportunities to deliver a product or service with added value and therefore differentiated, does require unprecedented efforts of reflection, strategy and action, which involve a perspective of progressive transformation guided by a maturity model with a continuous improvement approach (Agostini & Filippini, 2019; Crnjac, Veza, & Banduka, 2017; Gracel & Łebkowski, 2019).

According PMI-PMBOK (2017), Project Management is the application of knowledge, skills, tools, and techniques to project activities to meet project requirements. In this definition attention must be given to the expression “project requirements”. In any situation the project requirements – not only the product requirement - guide the way in which the project will be organized and executed. The new Industry 4.0 brings to project management a new set of requirements and a new challenge to this field of knowledge. With the emergence of organizations in Industry 4.0, “connected people” or “professionals 4.0” appear, who are distinguished by being more efficient, more flexible, faster and, consequently, more competitive, thanks to the total connectivity among machines, systems, and people (Cerezo-Narváez, Otero-Mateo, & Pastor, 2017).

So, how to work in an environment that demands agility to adapt to very dynamic requirements? How to make decisions in a constantly changing environment? How to communicate with teammates in a multicultural, geographically dispersed and, sometimes “nonhuman” teams? All these questions, among others, demand new competences from the workers in this new industrial model. Besides technical competences, transversal competences must be included in the background of the industrial engineer to the ID 4.0.

In the context of Industry 4.0, a consortium of nine universities has been developing a master program for Industry 4.0, co-funded by the European Commission (<https://msie4.ait.ac.th/>). One of the courses of this program is Project Management for Industry 4.0 (PM4I4). This course was designed to help students to develop competences related to Project Management in context of Industry 4.0. In order to accomplish this objective, the main pedagogical assumption is the need to use active learning (Christie & de Graaff, 2017; Freeman et al., 2014; Prince, 2004; Prince & Felder, 2006) approaches for competence development. In this course we propose to use a project-based learning approach to solve open problems, which is known as one of the main strategies to give autonomy to the student in the development of competences (Edström & Kolmos, 2014; Graaff & Kolmos, 2003; Lima, Dinis-Carvalho, Flores, & Hattum-Janssen, 2007; Lima et al., 2017). Additionally, we use this project as one of the ways of bringing Industry 4.0 into the content. Students will have to develop their knowledge and skills in this context developing a project related with I4.0 with companies. Another way to bring I4.0 to the content is through the use of agile approaches and collaborative and multicultural project management content in a new era of digitalization, which are the main requirements in this new era for project management.

The objective of this paper is to present the evaluation of a pilot version of this course based on the perceptions of the enrolled students. This paper will present the context of the course, followed by the methodology of evaluation and results and recommendations.

## 2 Context

In the new world of Industry 4.0, digitized connectivity may be considered the main driver of change that industries have to deal with. This change increases the opportunities to create new business models, exploring network of systems that will allow to increase the cooperation between and across companies and industries. It is expected an increase in customized services that ultimately can become a service for each customer. In this case, we will be dealing with a project service for each customer each time. These projects will be developed by interdisciplinary distributed teams using digital platforms.

This course aims to prepare graduates to perform in and manage projects and teams in the new highly agile digitized challenging smart industries. Thus, it was defined that students on the completion of this course should be able to:

CLO1 - Discuss Project Management relevance in the context of IND4.0 (Apply)

CLO2 - Evaluate the needs of an organization regarding IND 4.0, taking into account maturity / readiness models (Evaluate)

CLO3 - Plan, develop and manage projects in the context of IND 4.0, using frameworks of project management, such as PMI, IPMA and Agile/Lean (Create)

CLO4 - Support team decision making processes in accordance with the contingencies and uncertain environments of IND 4.0. (Evaluate)

CLO5 - Perform as a member of an extraordinary team, either distributed or co-located, using different tools and techniques, considering the team development phases (Create).

CLO6 – Develop a project within a real context, in interaction with an industry organization.

The course is structured in two modules. The first one, Management of Industry 4.0 Projects, has a higher focus in the project management frameworks and processes. The second one, Module 2 - Project Team Management for Industry 4.0, is more related to the need to develop people focused competences for project management in the context of industry 4.0. Along the two modules there will be a project to be developed in interaction with industrial companies. The objective of this project is to develop an instrument to measure the maturity level of the company in a specific dimension of industry 4.0, according to the acatech framework (Kagermann, Wahlster, & Helbig, 2013; Schuh, Anderl, Gausemeier, Hoppel, & Wahlster, 2017).

The choice for the creation of an instrument to evaluate the level of maturity of organizations for the concept of Industry 4.0 came from an expectation that consisted in (1) it was a concrete opportunity to clarify the complexity and multiple dimension of reconfiguration projects for Industry 4.0, that is, that it is not only about technological updating and technical competences, (2) it was expected that the instrument could show the progressive nature of a transformation process for Industry 4.0 where the strategic, systemic, project-based and focused on a perspective of continuous improvement is a critical factor of success, and (3) it was expected that the creation of an instrument to assess the level of maturity of organizations for Industry 4.0 would show the uniqueness of projects of this nature and therefore require unique strategies and actions.

### 3 Methodology

The evaluation of the pilot version of the course presented is based on narratives provided by the ten of the twelve students enrolled in the course. The narratives were delivered at the end of the course and aiming at to include a self-reflection about the course, in terms of the relevance of the contents and the activities developed during the course, teaching practice and interaction with teacher and students, amongst other issues, in which students were free to present. The narratives, as a technique of data collection, reinforce the authenticity of the information, because it is all about the voice of the participant in a specific context or situation, and not an abstract idea or assumption (Czarniawska, 2012). Thus, this study focuses on students' perceptions about this course, considering their personal experience, beliefs, and motivations.

From the content analysis of the narratives, it was possible to identify three main categories, namely: 1) Course topics; 2) Teaching and learning approaches; 3) Project scope and activities. These categories were defined by the authors, who were engaged in the course and were able to provide and understand the meaning of the students' voices.

### 4 Results

The analysis of the narratives allowed to identify and categorise the main ideas the students have about the pilot course.

#### 4.1 Course topics

At the end of the course it was possible to obtain a view of the students on the topics covered in the discipline and to evaluate the effectiveness in reaching the objectives CLO1 to CLO6.

Four topics were mentioned most frequently by the students, having a similar weight among them: project management tools, teamwork and leadership, coaching and communication. Among the twelve students who

responded to the assessment, there are seven highlights to the themes of project management and teamwork / leadership, while the themes of communication and coaching appear prominently in six.

In the topic of project management, the management tools are highlighted:

*"In this course, it was possible to get to know and improve our knowledge of tools for successful team management, highlighting SCRUM, where it is possible to have a vision of the project and divide work tasks equally among the members of the group." (student 2)*

*"We learned to use management support tools such as PM Canvas, which is very useful for project planning and for clarifying objectives within work teams." (student 7)*

However, in addition to learning the management tools, another aspect highlighted was the Lean / Agile approach to project management, either by frequent reference to SCRUM, or by mentioning Lean principles:

*"It is important to understand very well what problems we intend to solve with our project so that tasks that do not add value and do not contribute to the success of its completion are not carried out." (student 7)*

Finally, it was possible to identify space for expansion of the project management approach with inclusion of new topics or deepening of others:

*"I wish there were more classes on project management methodologies, such as prince, pert etc. However, I understand that the time was short to address all topics related to project management." (student 3)*

Topics teamwork / leadership, communication appear together in many of the demonstrations, highlighting the growing importance of communication skills in a teamwork:

*"For me, the most important aspect in this course was to convey the importance of knowing how to lead and communicate." (student 7)*

*"Several leadership and communication styles were presented that, perhaps, if they had not been addressed, I would not think of them anytime soon." (student 4)*

*"We realize the importance of communication in a successful team. Often the way we communicate leads to totally different interpretations and that is why it is very important to think about the way we do communication as well as the barriers that may arise." (student 7)*

The concept of coaching appears in students' manifestations as a tool for personal growth and the development of transversal competences.

*"We were also introduced to a concept that is quite talked about in our day-to-day lives, but not clear, I mean the concept "Coaching", this concept is spoken, but few people know the true meaning, and in this class we can better understand ." (student 2)*

*"Some topics such as Coaching, Scrum and Communication were contents that, in my opinion, make perfect sense to be included in this UC and in which there was a lot of quality and effectiveness in the exhibition." (student 1)*

*"I think it was very useful to understand certain skills that we need to develop in order to be able to deal with differences within a work team. (...) With this class I realized that a coach simply gives us the tools and that all the work has to be done for us. I believe that Coaching makes us more and better!!!" (student 7)*

## 4.2 Teaching and Learning approaches

Regarding to the teaching and learning process, data point out the importance of the link between theory and practice. The teacher approach to present and deliver the content is a key-issue for student's engagement. In other words, the attractiveness of the content will depend on the teaching approach, in terms of communication, activities and resources used.

*"I think that all the practical activities added-value to understand the themes, as well as the videos and examples presented (...) However, certain classes were very theoretical, turning everything to much exhaustive, because each class had 4 hours." (student 12)*

*"Many of these topics were approached in a very theoretical way, which does not capture the students' attention (...) If the way that the topics do not get our attention, we just shut down until something or someone catches our attention. When we did exercises or group activities, everyone interacted, but when we had only one speaker, the group lowered their heads and everyone stayed in their own world." (student 4)*

It is not new that an active learning environment foster students' engagement and motivation through opportunities in which students need to mobilize knowledge in several activities. This process must be considered in the course planning, as well as in the teaching approach.

The course coordinator invited three teachers to collaborate in this course. This diversity enhances the expertise of each teacher, because they were responsible to deliver sessions oriented to specific topics (e.g. Coaching). At the same time, they are able to monitoring the project developed by the students, which is an added-value for student's support.

*"Everyone [teachers] was very helpful and always willing to help and answer any questions that arise in classes or projects." (student 12)*

However, in some cases this diversity might be considered a limitation in the student experience.

*"Regarding to teachers, I consider that there is no need to have so many in a course because it confuses students and we end up not realizing who to address when doubts arise". (student 11)*

Thus, teacher' role is a key-dimension for an effective and meaningful teaching and learning approach. Considering the data from this study, it is possible to highlight three main elements that influences the teacher role: 1) the teaching approach in terms of balance between theory and practice; 2) the importance of support, encouraging and inspiring students in their own learning process, providing interesting opportunities and contact with different professionals in Project Management (experts and/or practioners); 3) the close relation between teacher and students, in terms of communication: to align and clarify expectations and to provide feedback.

*"Every week the classes were very dynamic and interactive. The teacher, and guests, knew how to captivate the students' attention and encouraged the critical spirit of the class." (student 6)*

### **4.3 Project**

The actions related to the theme of Industry 4.0 in the discipline of Project Management were guided from the following trajectory: (1) awareness of the students regarding the dimension and complexity of the theme, (2) choice of an action applicable in reconfiguration projects for Industry 4.0, and (3) orientation of an exercise of operationalization of the construction of the instrument.

The first stage foreseen in this design was carried out through a lecture type class in which the fundamental characteristics of the model now called Industry 4.0 were presented, including its structural and technological configuration, the change of paradigm regarding products and services as well as the transformations that this requires in the concept of productive system, in the consequences imposed on business models, and in the demands for new competencies of human resources. An effort has been applied to provoke reflection on the initiatives related to the reconfiguration projects for Industry 4.0 in which they frequently present strategies focused on technological updating.

The operationalization of the planned actions presented positive and other challenging aspects. If on the one hand the students had the opportunity to deepen researches and readings about the Industry 4.0 theme and at the same time observe in companies the applications of these concepts, on the other hand, the construction of an evaluation instrument involves foundations and techniques independent of the Industry 4.0 theme and Project Management. The requirement to develop critical knowledge about the construction of evaluation instruments, especially in a short period of time, proved to be a source of discomfort for students, as can be seen in student comments:

*"(...) themes that turned out to be very theoretical (...) as was the case with our theme 'Self-evaluation instrument of the maturity of Industry 4.0 in Resources' (...), I was a little disappointed, since Industry 4.0 is a theme that I have a lot of curiosity and interest." (student 1)*

*"I found the work quite constructive, as I learned a lot about it, but honestly I did not think it had a great impact in terms of people management and teamwork (...), is a very interesting and useful topic because it will be the future of the industry and in this way we have already understood the basic concepts for its implementation." (student 4)*

*"(...) forced us to waste a lot of time investigating on the subject (...), it was initially difficult to apply project management and team management". (student 11)*

It became clear in the comments that the students have a great interest in the subject and that they understood about the multidisciplinary range of projects of this nature, as can be observed in the following comment in particular:

*"The industry 4.0 approach was also very useful to learn the basic concepts of this subject (...), through the tool for assessing the level of maturity of the companies that we develop in the work we realized that most companies are still in a very early stage. I don't think it's an easy task due to the investments needed not only in technology but also in people's training. Perhaps the most complicated job will be to implement the changes in people's mentality and culture, and in that sense we realize the importance of unconditional support from top management". (student 7)*

## 5 Recommendations and Final Remarks

Most of the students (10/12) wrote that the course was good or very good and above their expectations, reinforcing that idea by telling that this elective course should be delivered in the following years. A good summary for the perceptions of the students could come from the excerpt that summarizes a student's overview of the course:

*"I consider the topics covered very interesting, starting with Industry 4.0, PM Canvas and SCRUM, to some more related topics with our soft skills such as teamwork, leadership, communication and coaching. The soft skills have been increasingly important in the labor market and will be for the Accenture, one of the most important requirements in the "jobs of the future." These are areas that cannot be learned, where there is no magic formula, but only trained and cultivated. I think it is very important to start instilling this in students from an early age, in order to be more prepared for the "future" market and even for the "now" market." (student 4)*

Despite the fact that the majority of the students really enjoyed the diversity of pedagogical experiences, some of them would prefer to have contact with a lower number of teachers in this course. It should be noted that this is not unanimous and some students told that they enjoyed the opportunity to interact with several teachers during the classes. Thus, as final contributions, it could be recommended to create better framework for the Industry 4.0 questionnaire project and create opportunities for the students to enrol in management of more practical projects related with that main theme.

No doubt the theme on Industry 4.0 arouses interest in students, however, the planning of a short time for the presentation of the general aspects and fundamentals on the theme, so as to imply an over-expositive approach, generates discomfort in students who expect more opportunities for interaction, more examples

and practical actions. It is also a hypothesis that the greatest expectation of the students regarding Industrial 4.0 are the new possibilities offered by new technologies such as artificial intelligence, additive manufacturing, virtual reality, etc. If this is true, a work focused on maturity level assessment may generate some disappointment. The requirement to develop critical knowledge about the construction of assessment tools, although it is relevant to the understanding of the need for a judicious procedure for surveys of this type are valid, has proved to be a critical point and requires a new approach. The proposal is that this content should be approached as a topic of one or more classes so that it results in an application structure for the students and thus they can dedicate more time in the construction of the instrument and in the interaction with the companies.

As a final remark we would like to share a general comment from student 7:

*"In general, I think this course will be very important for my professional career and my personal development. It gives us the basis for what will be our job as engineers and the skills we need to develop in order to be successful."*

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## 7 References

- Agostini, L., & Filippini, R. (2019). Organizational and managerial challenges in the path toward Industry 4.0. *European Journal of Innovation Management*, 22(3), 406-421. doi:10.1108/EJIM-02-2018-0030
- Cerezo-Narváez, A., Otero-Mateo, M., & Pastor, A. (2017). *Development of professional competences for industry 4.0 project management*.
- Christie, M., & de Graaff, E. (2017). The philosophical and pedagogical underpinnings of Active Learning in Engineering Education. *European Journal of Engineering Education*, 42(1), 5-16. doi:10.1080/03043797.2016.1254160
- Crnjac, M., Veza, I., & Banduka, N. (2017). From concept to the introduction of industry 4.0. *International Journal of Industrial Engineering and Management*, 8, 21-30.
- Czarniawska, B. (2012). *Narratives in social science research*. London: Sage Publications.
- Edström, K., & Kolmos, A. (2014). PBL and CDIO: complementary models for engineering education development. *European Journal of Engineering Education*, 39(5), 539-555. doi:10.1080/03043797.2014.895703
- Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences*, 111(23), 8410-8415. doi:10.1073/pnas.1319030111
- Graaff, E. d., & Kolmos, A. (2003). Characteristics of Problem-Based Learning. *International Journal of Engineering Education*, 19(5), 657-662.
- Gracel, J., & Łebkowski, P. (2019). The Concept of Industry 4.0 Related Manufacturing Technology Maturity Model (Manutech Maturity Model, MTMM). *Decision Making in Manufacturing and Services; Vol 12 (2018): No. 1-2*. doi:10.7494/dmms.2018.12.1-2.17
- Kagermann, H., Wahlster, W., & Helbig, J. (2013). *Recommendations for Implementing the Strategic Initiative INDUSTRIE 4.0*. Berlin: Industrie 4.0 Working Group of Acatech.
- Lima, R. M., Dinis-Carvalho, J., Flores, M. A., & Hattum-Janssen, N. v. (2007). A case study on project led education in engineering: students' and teachers' perceptions. *European Journal of Engineering Education*, 32(3), 337 - 347. doi:10.1080/03043790701278599
- Lima, R. M., Dinis-Carvalho, J., Sousa, R. M., Alves, A. C., Moreira, F., Fernandes, S., & Mesquita, D. (2017). Ten Years of Project-Based Learning (PBL) in Industrial Engineering and Management at the University of Minho In A. Guerra, R. Ulseth, & A. Kolmos (Eds.), *PBL in Engineering Education: International Perspectives on Curriculum Change* (pp. 33-52). Rotterdam, The Netherlands: Sense Publishers.
- PMI-PMBOK. (2017). *A guide to the project management body of knowledge (PMBOK guide)* (6th ed.). Pennsylvania, USA: Project Management Institute (PMI).
- Prince, M. (2004). Does Active Learning Work? A review of the Research. *Journal of Engineering Education*, 93(3), 223-231.

- Prince, M., & Felder, R. M. (2006). Inductive Teaching and Learning Methods: Definitions, Comparisons, and Research Bases. *Journal of Engineering Education*, 95(2), 123-138.
- Schuh, G., Anderl, R., Gausemeier, J., Hompel, M. t., & Wahlster, W. (2017). *Industrie 4.0 Maturity Index – Managing the Digital Transformation of Companies*. Retrieved from [https://en.acatech.de/wp-content/uploads/sites/6/2018/03/acatech\\_STUDIE\\_Maturity\\_Index\\_eng\\_WEB.pdf](https://en.acatech.de/wp-content/uploads/sites/6/2018/03/acatech_STUDIE_Maturity_Index_eng_WEB.pdf)