Designing and implementing interdisciplinary projects in a Systems Engineering Master programme

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Abstract

Interdisciplinary projects (IP) carried out by teams of students have been recognized as an important approach for learning in several fields and at several levels of education. In higher education, it can be an important drive for student learning motivation and an advantage for students when entering the working marketplace. The experience acquired while developing IP gives students technical and transversal competences highly relevant for employment but above all give students confidence and a competitive advantage. This paper aims at describing and discussing an experience in carrying out interdisciplinary projects in the context of a System Engineering Master (SEM) programme. First we explore the SEM programme philosophy and organization focussed on IP-based learning and then, for a particular IP course unit of the SEM, the dimensions of project design and specification, project interdisciplinarity, teaching team organization, support to students, project evaluation and individual students' assessment. The authors argue that the IP learning model adopted in the case here reported is a good example of an IP-based learning at a master degree level.

Keywords: Interdisciplinary Projects; Design Projects; Project-Based Learning; Engineering Education; Systems Engineering.

1 Introduction

During the last years, there has been an increased interest in Active Learning in Engineering Education (Lima, Andersson, & Saalman, 2017). The educational approaches developed under the umbrella of Active Learning, promote the creation of an environment where the student has the opportunity of being engaged in the learning process, developing autonomy to select some paths of his own learning. This environment should give an adequate context for learning, aligned with professional needs. Such a context will contribute for giving a meaning for learning. In this way, students will understand the "why", and will reflect on "what" they are learning (Bonwell & Eison, 1991; Christie & de Graaff, 2017; Prince, 2004). These approaches have been evaluated as more effective for the learning process (Freeman et al., 2014).

Different approaches of Active Learning have been developed over the years and one of the most implemented in Engineering Education is Project-Based Learning (PBL) (Lima, Andersson, & Saalman, 2017). In project-based learning, teams of students develop a project during a predetermined period to solve open problems related to the professional practice. During this period, students simultaneously develop the project and the required competences (Edström & Kolmos, 2014; Graaff & Kolmos, 2003). In several setups of PBL, the technical competences related to a specific professional area are conceptually supported by courses on which they are enrolled in this period. During such period students develop an interdisciplinary project through the integration of the different courses' contents (Alves et al., 2016; Lima, Dinis-Carvalho, Flores & Hattum-Janssen, 2007; Powell & Weenk, 2003). Additionally, the students acquire transversal competences, e.g. teamwork, autonomy and creativity, intentionally required by the project work and the professional practice (Lima, Mesquita, Rocha, & Rabelo, 2017).

The number of works explicitly referring the development of interdisciplinary projects in master programs educational level is scarce. This work aims to contribute for the engineering education field, describing an interdisciplinary project approach implemented in a Systems Engineering Master programme. Additionally, the authors present a discussion about the main contributions of this approach.

The paper is organized in six sections, including this introduction where the paper objectives are also referred. The Systems Engineering Master programme is briefly presented in the second section. One of the interdisciplinary projects course units is overviewed in the third section, followed by the fourth section that presents the project design and specification developed by the students in the PBL context. Section five presents the students assessment criteria and process. Finally, section six presents some final remarks.

2 The Systems Engineering Master programme

The Systems Engineering Master (SEM) programme at University of Minho, Portugal is a two-year master programme, under the responsibility of the Department of Production and Systems. Table 18 represents the programme organization. The SEM is centred on several curricular units (courses) aimed at giving students competences required by the marketplace as Systems Engineering professionals and for being able to carry out with success the SEM master dissertation. This is carried out partially in the 1st semester of the 2nd year with full dedication during the 2nd semester. In the first semester of the 2nd year, students have also an intensive and focused education on research methodologies and tools. This is essentially concerned with ensuring that students learn to choose the right research methodologies and methods to carry out research projects and to access the right resources, including bibliography, that are necessary. Additionally, they learn and practice to fully develop and establish plans for industrial research projects that culminate with each student developing the project plan for his or her own master dissertation, under the guidance of a teacher on the technological domain of the dissertation and the teaching staff on research methodologies. Then, after project plan approval by the SEM programme direction, with the agreement of all teaching staff of the department, students carry out their projects under the guidance of one supervisor or, exceptionally, two, dependent on the technical skills required by the project. A typical case when two supervisors may be needed is when a project falling in a technological domain requires complex statistical analysis or computer simulation.

Table 18. University of Minho - Systems Engineering Master programme organization structure

	Curricular Unit (CU)	ECTS
Year 1		60
S1	Systems Simulation	5
S1	Manufacturing Planning and Control	5
S1	Integrated Project 1	5
S1	Option 1	5
S1	Option 2	5
S1	Integrated Project 2	5
		30
S2	Systems Analysis	5
S2	Logistics	5
S2	Integrated Project 3	5
S2	Option 3	5
S2	Option 4	5
S2	Integrated Project 4	5
		30
Year 2		60
S1&S2	Master Dissertation	45
S1	Research Methods	5
S1	Option 5:	5
S1	Option 6	5
	Total	120
ECTS – European Credit Transfer and Accumulation System. Si- Semester i		

The SEM programme has run now for 10 consecutive years having had a structure adjustment two years after starting in the school year 2008/09. This adjustment enriched the programme curricula through a larger focus on student teams' interdisciplinary projects with a consequent increase in the programme design configuration flexibility. This was achieved by increasing the number of interdisciplinary projects, reducing its duration from one year to one semester and by focussing each one of them on two, instead of four, related or complementary curricular units (CU). The range of CU for choice was carefully aligned with the overall learning objectives and planned learning outcomes of the SEM. The restructuring improved focus and control over the projects for students and teachers alike. The adjusted programme organization is shown in Table 18. This adjustment was driven by the perception that, on one hand, project oriented approaches seemed, and had been confirmed by previous research, more motivating for students and having positive impact on students learning (Fernandes, Mesquita, Flores, & Lima, 2014; Prince, 2004), and, on the other, giving students an advantage in the working marketplace resulting from its practical experience, working autonomy and transversal skills acquired from carrying out projects, developing reports and presenting work done and results, all of which are assessed by the teaching staff team.

The SEM programme design configuration flexibility, based on several specialization topics was a natural requirement faced with the diversity of jobs that students are called to fill in the marketplace and the somewhat diverse backgrounds of students enrolled at the SEM. Actually, SEM students are graduated young students and professionals, mostly from engineering, with a focus on computer science related engineering, but also from sciences and management. Students with bachelors in Mathematics and even in Physics have also joining the SEM. SEM students realize that the SEM competences offered, together with their previous acquired competences, give advantage edge in the working marketplace.

3 Interdisciplinary project overview

One of the CU of the SEM programme is called Integrated Project 1 (IP1). IP1 is a curricular unit in a form of an interdisciplinary project, with its own planned learning outcomes which depend on, complements and integrates learning outcomes of two other courses, namely Systems Simulation (SS) and Manufacturing Planning and Control (MPC). IP1 aims at the application of knowledge on these rather different domains that are necessary to put together when the objective is to apply and understand the workings and behaviour of different strategies and methods for managing manufacturing systems. This application and understanding is critical for practical implementation of such strategies and mechanisms and can be obtained by system simulation studies of manufacturing systems' operation. This project approach involving these three courses is a consequence of the interdisciplinary learning process model fomented by the main learning strategy adopted in the SEM, based on projects involving typically two complementary or interrelated domains and studied at advanced level in two curricular units.

In a summarized way, learning outcomes for the three courses, including IP1, are:

Systems Simulation:

- Understand the basic concepts of discrete-event simulation.
- Understand the nature and application of discrete-event simulation and know how to experiment with it.
- Use experimental design techniques and related statistical tests.
- Make appropriate modelling simplifications concerning the level of detail and the degree of abstraction.
- Develop a working knowledge of a discrete-event simulation software packages, such as SIMIO™ and Arena™.
- Interpret the meaning of simulation results, and make evidence-based recommendations for the design and operation of a system of interest.

Manufacturing Planning and Control:

- Correctly communicate, orally and by writing, in the technical language of MPC.
- Identify and describe the main functions of MPC in any manufacturing organization.

- Identify, describe and apply important manufacturing methods and techniques for managing manufacturing operations for different market demand environments.
- Identify, describe and use important measures of manufacturing performance and align them with market demand environments.

Integrated Project 1 (IP1):

- Identify methods and mechanisms for Manufacturing Planning and Control (MPC) in different production environments.
- Apply discrete event simulation to design, analyse and improve the performance of MPC methods.
- Build simulation models of manufacturing systems and the design experimental setup to study the systems' operation and the performance behavior of different MPC methods.
- Interpret and analyse the simulation results based on their validity, meaning and statistical significance, and draw conclusions about the systems' behaviour.
- Work in groups to solve problems cooperatively and communicate effectively.

As common in interdisciplinary projects, IP1 learning objectives are achieved based on projects that involves teams of students.

4 Project design and specification

One could go about several ways to specify students' projects (Gommer & Rijkeboer, 2010; Holgaard, Guerra, Kolmos, & Petersen, 2017; Moreira, Mesquita, & Hattum-Janssen, 2011; Powell & Weenk, 2003, Alves & Leão, 2015). Nevertheless, constraints related to objectives and learning outcomes must be taken in full consideration. To do that, in this case, to ensure that such objectives and outcomes could be delivered and that good control of project development and evaluation could be achieved, the teachers involved in managing and supervising the student's projects decided to elaborate themselves a project specification with variants for each team of students based on a common project specification framework.

4.1 A common project specification framework

There are a few constraints or requirements that should be considered for designing the project of each team of students that, in the case of IP1, are described below.

Firstly, probably the most important constraint or requirement is to ensure that the planed learning outcomes can be achieved. Another is to devise criteria and a process for student assessment that leads to a fair evaluation of student work and learning achievements. This must obviously be related with the student contribution for meeting project objectives and output requirements, such as for results discussion, work presentation, project report and communications or publications. A third constraint or requirement is ensuring that workload per team, and mainly per student, should be as identical as possible and compatible with the planned workload for the course. This include, 45 hours in the class room, i.e. simulation lab, with the support and guidance of teachers, and 95 hours of work that each student must manage according tasks allocated and needs for student individual study and interaction within the team, together with some complementary support of teaching staff. The intensity of interaction between teacher and students very much depends on the expressed needs and requirements of students during project development. The teacher can also, when thought required, ask for all students' attention to clarify issues thought to be critical or particularly important for the good understanding of the IP1 topics and for the development and progress of the IP1 projects.

The fourth and a logical constraint or requirement, based on the previous ones referred, is to think of projects that should implement the same learning process on a common framework, providing equivalent learning content and, at the same time, ensuring project differentiation for each students' team. Although an objective difficult to meet it can be made possible acting upon both, variables that characterize the production and operational environment and variables that can be experimental factors in systems simulation studies of manufacturing systems management. Suitable combination of these variables will lead to a diversity of projects based on the same learning process and framework, having a degree of modelling and analysis complexity very much equivalent and therefore requiring similar amounts of workload. Examples of experimental factors used in project specification are:

- The MPC mechanism. This has been the main experimental used in the IP1 factor and can be studied at several levels such as TKS (Toyota Kanban System) (Sugimori, Kusunoki, et al., 1977), DBR Drum-Buffer-Rope (DBR) (Goldratt, Fox, 1986) and CONWIP (CONstant-Work-in-Process) (Spearman, Woodruff & Hopp, 1990);
- The material flow control strategies. These refers to additional experimental factors that students may add to the problem, such as pool sequencing rules and the dispatching rules that govern the release of jobs into the systems and the work flow through the system, respectively.

Other variables for characterization of production system and operational environment, which generally make part of the problem description, include:

- The Manufacturing Approaches for Satisfying market Demand (MASD), i.e. Make-to-Order (MTO), Make to Stock (MTS) and hybrid MTO-MTS;
- The Manufacturing Systems Configurations (MSC): Job Shop; Flow shop; General Flow Shop, Flexible Flow Shop and flexible versions of these obtained by replicating all or some workstation types (Pinedo, 1995).

Table 19 shows, for two school years, according to the common project specification framework above referred, the several levels of the experimental factor, named mechanism for MPC, that were chosen by student teams for their project specification. This choice together with the choice of other variables for experimentation or system operation, lead to complete or partial differentiation of the project specifications of each team. Thus, e.g., when frequency of choice, in table 2, is larger than 1 (one) there is sharing of this experimental factor level by a number of groups equal to the frequency of choice. This information shows that there is a relative degree of freedom and autonomy of teams to define their own project, which make a contribution for the flexibility of the project.

Table 19. An experimental factor contributing for differentiating the student teams' projects.

Mechanism for MPC (experimental factor)	**Student teams' factor levels choices 2014/15**						**Student teams' factor levels choices 2015/16**						
	T1	T2	T3	T4	T5	Frequency of choice	T1	T2	T3	T4	T5	T6	Frequency of choice
BSS			1			1					1		1
CONWIP -MTS			1			1			1		1		2
TKS - Milkrun						0							0
TKS			1			1			1		1		2
MPR-CAP						0	1					1	2
POLCA				1	1	2	1	1					2
GPOLCA		1				1		1		1			2
GKS	1	1			1	3	1	1				1	3
WLC	1					1				1		1	2
CONWIP-MTO		1		1	1	3				1			1
Two Bin						0			1				1
DBR	1					1							0
Ti , i=1,...6 is the student teams representation.													

4.2 Organization of student's teams and project allocation

The size of students' teams on PBL are typically between 5 and 9 students depending on project complexity and size. Due to the controlled nature and size of the projects, in our case we realize that teams of five students meet several requirements including, expected workload per student, potential for collaboration among students and manageable number of teams in the class. So, as a basis for team organization we proposed teams of five students. The team size may vary slightly according the number of students attending the IP1 CU aiming, however, as much as possible, to teams of the same size, which are self-organized.

All teams develop system simulation models for evaluation of the performance of different manufacturing control systems (MCS) for operation of manufacturing systems. Each team carries out a different project, focussed on building a systems simulation model and using it for studying the application and performance behaviour of MCS. Each project is based on a common framework but resulting, as above said, from different combinations of system configuration and operation variables and experimental factors, used in the system simulation study related to each project. As a matter of easing control over and verification of simulation results some teams may carryout projects with partial interception of specifications and objectives. In this case independently of the modelling alternatives chosen and different models used, the teams that share the same specifications must arrive to the same simulation results. This partial sharing has a positive effect on the learning process since some teams can interact and compare their work solutions against those of other teams. Moreover, this makes easier the process of analysing and verifying of project results, both for students and teaching staff alike, and eases also the task of project evaluation. Additionally, we may also be concerned with studying manufacturing control influenced by the priority of order release and or order dispatching. So, using different manufacturing systems' platforms, formed by suitable combination of production and operational environment variables, such as those grouped under the headings of MSC and MASD above referred, we can develop experimental work on the performance of MCS methods and mechanisms using system simulation models developed by the IP1 course students' teams.

In this way we meet the third and fourth constraint or requirement identified in the previous section and pave the way for meeting the first and, at the same time, devising suitable student assessment criteria and process.

5 Students assessment criteria and process

This section describes the process of assessing both the project and individual students.

5.1 Assessing the project

Before going on describing the process and criteria for students' assessment we must describe the role of the teaching staff teams involved in the IP1 course and how projects themselves, not students, are evaluated. Thus, all the teachers responsible and collaborating on the student learning process, in both courses instrumental to IP1, are involved in helping and guiding students mostly, but not only, during course sessions, to achieve IP1 objectives, namely to develop successful projects, and achieve learning outcomes. Moreover, they are agents involved in assessing the achievement of the learning outcomes and student involvement and contribution for the development, output and quality of the projects.

Thus, IP1 projects assessment mostly results from the soundness of both model building and the simulation results obtained. The capability for written and oral presentations of the work and results, together with model verification and analysis of simulation results, are also important components for assessment of project quality and value, having into account the objectives and learning outcomes. Based on this, the assessment of the IP1 projects is determined by the two teaching teams responsible for each of the two instrumental courses, i.e. Systems Simulation and Manufacturing Planning and Control. All referred variables are weighed to reach a mark for the project itself. The weight of the view of each of the two teams on the projects assessment is 50%. This assessment is central to individual student's assessment on the IP1 course and is also used for assessing the Systems Simulation itself, but not the MPC. This is evaluated independently from IP1. These different views of using the project assessment on the assessment of the instrumental courses seem very logic to the teams, having into account their different instrumental nature to IP1.

5.2 Individual students' assessment

The actual method for individual student assessment on the IP1 CU is the result of a smooth evolution of the assessment process that has been implemented as an ongoing process of adaptation and adjustment aimed at improving individual assessment of students. Individual marks of students, based on project work and learning achievements must be fare. Achieving this is not easy with teams of five students or more working together in the same project and with the variety of assessment variables involved. So, mechanisms must be established that ensure fairness on individual student assessment. Although many strategies and approaches have been devised (Powell, 2004) in our case we use four dimensions of assessment:

1. The first one is based on the project assessment itself, as referred in previous section.
2. The second dimension is based on students' self-assessment.
3. The third results from the perception of the teaching teams relative to the contribution of each individual student in the team to the value of the project.
4. The final mark of the IP1 CU for the individual student is based on the assessment carried out under the scope of the instrumental courses of the project, namely in our case, SS and MPC, having into account the result from applying the three previous dimensions of assessment.

The first, second and third dimensions of student's assessment in the IP1 course are all concerned and related with the interdisciplinary project itself. The fourth is dependent on student individual performance on the two instrumental courses supporting the interdisciplinary project, is our case, MPC and SS. Thus, project assessment is first carried out by the teaching team, accomplishing the first dimension of assessment, who establishes the marks for the project, having into account several aspects related with the project development and results, as referred in the previous section. These marks, are multiplied by the number of students in the team to determine the size of the "cake" that the students, in a self-assessment process, must divide by themselves, in a fair and democratic manner, based on their perception of the contribution of each of the team members for the project value and for the work and ideas during project development. Limits are imposed by the teaching teams to the maximum and minimum marks, i. e. the size of the "piece of cake", which a student in the team can have. This results from a small, variation around the mean that the teaching teams, based on their experience and context, consider fair. For the student's self-assessment, in line with the experience of other authors (Alves et al., 2012), the teaching staff suggests, as a guidance to students, some criteria, such as degree of participation or involvement in carrying out the project and reporting the results and contribution to modelling or problem solving.

In the third dimension, if the teaching teams agree, based on their perception during project development and results presentation that the marks for a student are unfairly high, or low, they marginally adjust the marks of that student. Therefore, this may lead to the adjustment of the marks of other students in the team, since the "cake" size is unchangeable. Although this adjustment is formally part of the evaluation criteria our experience is that this rarely is necessary to apply.

The result of the application of the three first dimensions of individual student assessment results in the individual student marks, in the zero to twenty scale, related with the interdisciplinary project.

The application of the fourth dimension leads us to an individual assessment on the IP1 CU. Thus, having into account the result from applying the three previous dimensions of assessment, we establish the student individual marks for the IP1 based on the weight contribution of the student performance on the two IP1 instrumental courses and that for the interdisciplinary project. Thus, MPC individual assessment enters as a weight of 15%. The student performance on individual SS assessment tests and course work contributes with another 15% to the individual assessment of the IP1 course. Therefore, the individual assessment mark for each student, in the IP1 course, weights the result from the first three dimensions as 70% and the 30% remaining from the fourth, i.e. 15% from each of the two instrumental courses. This combination seems, to the teaching team, a good balance between the individual students work carried out as team members and the work carried out individually in the Manufacturing Planning and Control and Systems Simulation courses.

We are not sure that the weights here referred are the fairest. Recognizing that knowing what combination is the fairest is not an easy task, we believe that this is a reasonable combination of weights based on the considerations made above. However, we also recognize that further study should be done on the procedure for individual student assessment.

6 Final remarks

Interdisciplinary projects (IP) have been advocated as an approach that tends to advantageously favour students learning and the acquisition of transversal competences. This, are nowadays seen as an advantage to enter the working marketplace. Having this into account the Department of Production and Systems of the University of Minho, from Portugal, decided to implement a new SEM programme structure based on interdisciplinary projects. Within this structure we describe the implementation of an IP based SEM course, referred as Integrated Project 1 (IP1), and present a framework structure for students' projects design and evaluation adopted in this course. Moreover, we discuss the student individual assessment, based on four dimensions, including self-assessment and a share contribution from the instrumental courses to the IP1, namely Systems Simulation and Manufacturing Planning and Control.

One important remark is the required fairness of course workload, project complexity, project assessment and individual student assessment that interdisciplinary projects developed by teams of students need to meet. This is a difficult problem that nevertheless must be solved if the IP based learning process is to be adopted. The solution described, in the context of the IP1 course, we believe to be a good example that can be adapted to many other contexts, certainly in engineering courses. Probably the most sensible aspect to deal with is course individual assessment fairness. We present a methodology that we believe meets this fairness requirement. However, we think that there is still room for improvement and, therefore, we intend to make further adjustment and adaptation aligned with the dynamics of the learning and assessing requirements observed.

As a final remark we should emphasize that, under the interdisciplinary projects in the context of IP1, students were encouraged to publish work related with project development and results and, in the last few years, a few papers (André et al, 2014; Rocha et al., 2015; Gomes et al., 2016; Barros et al., 2016; Silva, et al., 2017) were presented to scientific events and published in conference proceedings, books and journals.

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7 References

Alves, A., Sousa, R. M., Fernandes, S., Cardoso, E., Carvalho, M. A., Figueiredo, J., & Pereira, R. M. S. (2016). Teacher's experiences in PBL: implications for practice. *European Journal of Engineering Education, 41*(2), 123-141. doi:10.1080/03043797.2015.1023782

Alves, A. C., & Leão, C. P. (2015). Action, Practice and Research in Project Based Learning in an Industrial Engineering and Management Program. In *ASME 2015 International Mechanical Engineering Congress and Exposition, Volume 5: Education and Globalization* (p. V005T05A013). ASME. http://doi.org/10.1115/IMECE2015-51438

Alves, A. C., Moreira, F., Mesquita, D., & Fernandes, S. (2012). Teamwork in Project-Based Learning: engineering students' perceptions of strengths and weaknesses. Proceedings of the Fourth International Symposium on Project Approaches (PAEE), S. Paulo, 26-27 July, pp. 23-32. ISBN 978-989-8525-14-7.

André, M., Dias, L., Pereira, G., Oliveira, J., Fernandes, N., Carmo-Silva, S., (2014). COMPARING MATERIAL FLOW CONTROL MECHANISMS USING SIMULATION OPTIMIZATION. In Proceedings of the 12th International Conference on Modelling and Applied Simulation, 25-27 September 2014, Athens, Greece

Barros C., Silva, C., Martins, S., Dias, L., Pereir, G., Fernandes, N. O., Carmo-Silva, S., (2016). Production Control: Are Card-based Systems Effective for Make-to-Order Production. *Romanian Review Precision Mechanics, Optics & Mechatronics, Supplement to issue* 49, pp 5-9 http://dx.doi.org/10.17683/rrpmom.issue.49

Bonwell, C. C., & Eison, J. A. (1991). *Active Learning: Creating Excitement in the Classroom*. Washington DC: ERIC Clearinghouse on Higher Education.

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

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

Fernandes, S., Mesquita, D., Flores, M. A., & Lima, R. M. (2014). Engaging students in learning: findings from a study of project-led education. *European Journal of Engineering Education, 39*(1), 55-67. doi:10.1080/03043797.2013.833170

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

Goldratt, E.M., Fox, R.E., (1986). *The Race*. North River Press, New York.

Gommer, L., & Rijkeboer, M. (2010, 01-02 July 2010). *Designing Project Assignments; Experiences and RecommeCamparing Material ndations from PLE-practice in Engineering Education.* Paper presented at the Second Ibero-American Symposium on Project Approaches in Engineering Education (PAEE'2010): Creating Meaningful Learning Environments, Barcelona - Spain.

Gomes, C., Ribeiro, A., Freitas, J., Dias, L., Pereira, G., Vieira, A., Fernandes, N. O., Carmo-Silva, S. (2015). Improving Production Logistics Through Materials Flow Control and Lot Splitting. Paias, A., Ruthmair, M., Voβ (Eds), Lecture Notes in Computer Science 9855/Computational Logistics, Springer, 2016.

Graaff, E. d., & Kolmos, A. (2003). Characteristics of Problem–Based Learning. *International Journal of Engineering Education, 19*(5), 657-662.

Holgaard, J. E., Guerra, A., Kolmos, A., & Petersen, L. S. (2017). Getting a hold on the problem in a problem-based learning environment. *International Journal of Engineering Education, 33*(3), 1070-1085.

Hopp, J. W. & Spearman, M., L., (2008). *Factory Physiscs*, Waveland Press, Inc. USA.

Lima, R. M., Andersson, P. H., & Saalman, E. (2017). Active Learning in Engineering Education: a (re)introduction. *European Journal of Engineering Education, 42*(1), 1-4. doi:10.1080/03043797.2016.1254161

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.

Lima, R. M., Mesquita, D., Rocha, C., & Rabelo, M. (2017). Defining the Industrial and Engineering Management Professional Profile: a longitudinal study based on job advertisements. *Production journal, 27*(spe), 1-15. doi:10.1590/0103-6513.229916

Pinedo, M., (1995). Scheduling – Theory, Algorithms and Systems, Prentice Hall Inc.

Moreira, F., Mesquita, D., & Hattum-Janssen, N. v. (2011, 01-02 October 2011). *The importance of the project theme in Project-Based Learning: a study of student and teacher perceptions.* Paper presented at the International Symposium on Project Approaches in Engineering Education (PAEE'2011): Aligning Engineering Education with Engineering Challenges, Lisbon – Portugal

Olhager, J., Selldin, E., (2007). Manufacturing planning and control approaches: market alignment and performance. *International Journal of Production Research*, 45 (6) 1469-1484

Powell, P. C., & Weenk, W. (2003). *Project-Led Engineering Education*. Utrecht: Lemma.

Powell, P. (2004) Assessment of team-based projects in project-led education, European Journal of Engineering Education, 29:2, 221-230, DOI: 10.1080/03043790310001633205.

Prince, M. (2004). Does Active Learning Work? A review of the Research. *Journal of Engineering Education, 93*(3), 223-231.

Rocha, F., Silva, E., Lopes, A., Dias. L., Pereira, G., Fernandes, N. O., Carmo-Silva, S., (2015). Materials Flow Control in Hybrid Make-to-Stock/Make-to-Order Manufacturing. Corman, F., Voβ, S., Negenborn, S. V. R. R., (Eds), Lecture Notes in Computer Science 9335/Computational Logistics, 2015, Springer.

Silva, C., Reis, V., Morais, A., Brilenkov, I., Vaza, J., Pinheiro, T., Neves, M., Henriques, M., Varela, M. l., Pereira, G., Dias, L., Fernandes, N. O., Carmo-Silva, S. (2017). A Comparison of Production Control Systems in a Flexible Flow Shop. *Procedia Manufacturing*, 2017, Elsevier.

Spearman, M.L., Woodruff, D.L., Hopp, W.J., (1990). Conwip: A pull alternative to Kanban. *International Journal of Production Research* 28 (5), 879–894.

Sugimori, Y., Kusunoki, K., Cho, F., Uchikawa, S., (1977). Toyota production system and Kanban system materialization of just-in-time and respect-for-Human system. *International Journal of Production Research* 15 (6), 553–564.