Chapter 10
Lean Education at University of Minho: Aligning and Pulling the Right Requirements Geared on Competitive Industries

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10.1 Introduction

The University of Minho is a modern university located in the northern region of Portugal. The University ranks 64th, on the ranking of the top 100 universities under 50 years old (The Times Higher Education 100 Under 50 Rankings 2015). The region holds a human capital of over 100,000 students in higher education, is responsible for about 40 % of the exports of the country, and is considered the 5th most industrialized region of the European Union, with an overall share of exporting companies located in the region of about 44 % of the country total (CCDRN 2015). The authors of this book chapter pertain to the scientific area of Industrial Management (IM) of the Department of Production and Systems (DPS), of the School of Engineering of University of Minho. The DPS main pedagogical project is the Integrated Master Degree on Industrial Engineering and Management (IEM) program, which is accredited by the Portuguese Agency for Assessment and Accreditation of Higher Education—A3ES. The authors have a prime role on defining contents, promoting and providing for Lean Education (LE) at the University of Minho (UM) as well as supervising Lean IEM dissertations (industrial projects) for more than 15 years, which led them to identified a growing need for

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specific competencies and know how on the field. A proposal of an MSc degree in Lean Manufacturing was, correspondingly, issued by 2009, which, remarkably, was not approved by the Scientific Council of the Engineering School. Likewise, Lean Education was formally included in the curriculum of IEM few years ago only, in a number of distinct formats: (1) specific course units on Lean; (2) modules on Lean techniques on existing course units; (3) 1-year duration specialized training program, focused on professional engineers, starting in 2013.

This chapter presents the motivation and business case for Lean academic instruction. The following issues are also addressed: (i) course units, modules, projects and specialized training programs; (ii) the learning methodology in place, including active learning, Project Based Learning (PBL), serious games, scenarios, among others; (iii) highlight the students' development stage, during which LE is taught; and, (iv) summarize the estimated impact of this type of learning on the learners, organizations and society. Additionally, the authors present and explore how lean principles could be applied to the teaching/learning methodology.

This chapter is organized in six sections. This first one has introduced the context and the study goals. The second section presents the background, the motivation, the business case and the workplace community input. Section three presents the operational setting for introducing the training program and courses, taught at the University of Minho. The feedback from the students, industry and academia is presented in section four. Section six presents new developments on Lean principles applied to the teaching/learning activities. Finally, some concluding remarks are presented in section seven.

10.2 Background

A number of Lean concepts and tools are being taught by the DPS since the nineties; these include Just-In-Time (JIT) production, Quality Control Circles (QCC), Total Quality Management (TQM) among others. They are recognized as useful Japanese practices to improve production efficiency, flexibility and quality. At that time, the main program of DPS was the Graduation in Production Engineering, later labelled Industrial Engineering and Management, and, after the Bologna Process renamed into its current form, i.e. Integrated Master Degree on Industrial Engineering and Management (IEM). The IEM is a five year program with 300 ECTS (European Credit Transfer System) where 1 ECTS corresponds to 28 h of working hours/semester. As soon as the above referred concepts were becoming known in the west, they were introduced in different courses on a loose way. By the early 2000s, some projects devoted to lean were developed in the industry by IEM final year students, under the supervision of the IM group of lecturers. Since then, i.e. in the past 15 years, the IM group has continuously supervised a growing number of those projects (Master Thesis). In the 2001–2010 decade, 41 projects were developed (Alves et al. 2011). These projects were mainly developed according to the action-research methodology, which resembles the

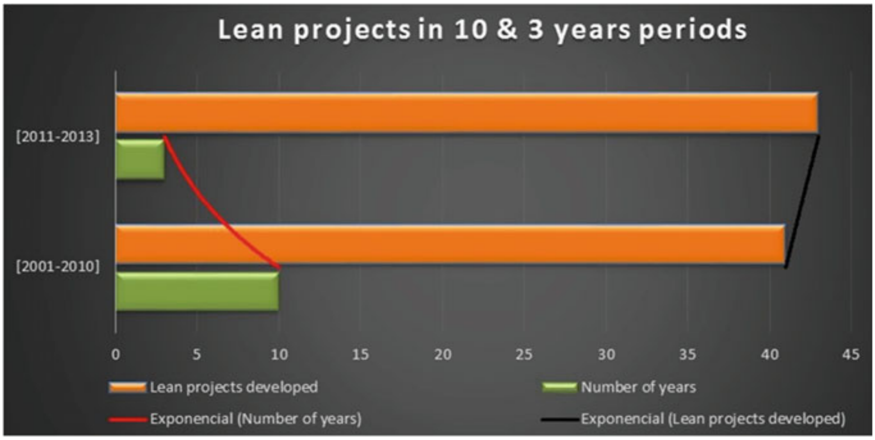

Fig. 10.1 Increase of Lean projects in IEM final year (Alves et al. 2014)

process of a PDCA (Plan-Do-Check-Act) cycle (Alves et al. 2009). The study showed a clear upward trend in the number of lean projects. This trend was reconfirmed in a new study developed in 2014 (Alves et al. 2014), which revealed that in a shorter time frame, of only three years, 43 Lean projects were developed, on the IEM program only (Fig. 10.1).

Besides the supervision of IEM students, the authors have also been supervising Lean projects of other distinct programs, namely the Master Degree in Industrial Engineering, the Master Degree in Engineering and Quality Management, and occasionally, the Integrated Master Degree in Mechanical Engineering and the Integrated Master Degree in Biological Engineering. The authors are also involved in the teaching of several course units with lean contents in several programs (Sect. 10.3).

10.3 Operational Setting

The Lean Education offer, that is synthesized in Table 10.1, respects the following structure:

- The target audience of the program and what does that offering looks like? (Program/course, what level, educational level or professional level, academic year, etc.);
- The duration of the program and what are the students' options for program participation?
- How often is the program offered in a year? (Frequency, duration, etc.);
- How long has the program been offered or what is the launch date?
- How many students are enrolled or enrolled per year or per cohort?

It is important to note that only in the specialized training program in lean manufacturing the industrial community was consulted in order to give their opinion and suggestions about the curricular structure of the program.

Table 10.1 Lean education offer at DPS-UM

To whom	What	Why	How	When	How many
Program/courses:	Contents:	Motivation:	Learning methodologies:	Started at:	
Integrated Master Degree in Industrial engineering and management: Topics of Industrial engineering and management (1st year); Production systems organization (4th year); Option: Lean enterprise (5th year); Option: Lean tools (5th year); Option: Lean healthcare (5th year); Master thesis (5th year)	Introduction to Lean history; Lean principles and tools; Lean production system design; flow management; Lean project management; Lean office; Lean startup; advanced Lean tools; cells design and reconfiguration	Viewed as a demand for better preparation of future engineers	Lectures; classes preparation by the students using videos; simulation; presentations; serious games; hands-on activities; PBL involving companies; final year projects	2008/09	+60/year
Integrated Master Degree in Polymers engineering: Production management and planning (4th year)	Introduction to Lean history; Lean principles and tools		Lectures; individual/teamwork assignments; hands-on activities	2007/08	30/year
Integrated Master Degree in Materials engineering: production systems organization (5th year)	Introduction to Lean history; Lean principles and basic tools		Lectures; individual/teamwork assignments; hands-on activities	2008/09	20/year
Graduation in Systems information and technology: Logistics and production organization (3rd year)	Introduction to Lean history; Lean principles and basic tools		Lectures; teamwork assignments—projects	2010–11 (1 year)	84/year

(continued)

Table 10.1 (continued)

To whom	What	Why	How	When	How many
Graduation in Fashion design and marketing: Production and project management (3rd year)	Introduction to Lean history; Lean principles and basic tools	Better preparation of future designers	Lectures; teamwork assignments; projects	2012/13	25/year
Master Degree in Industrial engineering: Lean production systems (1st year); Master thesis (2nd year)	Introduction to Lean history; Lean principles and basic tools; production systems design and reconfiguration	Viewed as a demand of professional engineers and graduated students	Lectures; visits to companies; seminars by professionals; consulting services; hands-on activities about cells design; individual/teamwork project in their own companies	2008/09	40/year
Master Degree in Engineering and quality management: Lean six-sigma (1st year); Master thesis (2nd year)	Introduction to Lean history; Lean principles and basic tools			2013/14	37/year
Specialized training program in Lean manufacturing	All courses are related with Lean (6 courses by semester, 1 year)			2013/14	18/year
Master Degree in Engineering project management: Option 1: Lean production systems (1st year)	Introduction to Lean history; Lean principles and basic tools		Lectures, visits to companies; teamwork assignments—research; hands-on activities about cells design	2015/16	24/year

10.3.1 Lean Content: Key Elements

The key elements of most programs are contents related with introduction to Lean:

- Lean Production basic concepts and definitions;
- Toyota Production System house and pillars as roots of the Lean Production;
- Models of work organization and respective comparison;
- Model 4P of the Toyota way (philosophy, process, people and partners and problem solving);
- Main phases of evolution of Lean;

- The importance of flow time reduction;
- Lean Thinking principles;
- Concept of waste, 3M (*muda*, *mura* and *muri*), seven wastes and others;
- Tools identification and presentation;
- Methodologies to implement TPS and Lean;
- Activities by small groups (quality control circles—QCC);
- Strengths favoring and resisting Lean.

Production systems design and reconfiguration topic is mainly instructed on Production Systems Organization and on Lean Production Systems course units, which are more focused in cells design. Its main contents are:

- Comparison of production systems;
- Operational problems that lead to cells adoption;
- Main benefits of cells;
- Disadvantage of cells;
- Cells design:
  - Parts/products families formation;
  - Cells instantiation (machines grouping, takt time, etc.);
  - Workstations instantiation (people grouping, competences, balancing, etc.);
  - Organization and intracellular layout (layout types, types of movements and transport systems, operating modes, standard work sheets, etc.);
  - Organization and intercellular layout (layout types, types of movements and transport systems, systems of control activity production, etc.);
- Cells application;
- Office cells.

The contents related to lean tools are transversal to almost all program/courses and include:

- VSM—Value Stream Mapping (Rother and Shook 1999)—includes team assignment involving a real scenario;
- Ishikawa Diagram (Ishikawa 1989)—includes individual assignment;
- OEE—Overall Equipment Effectiveness (Nakajima 1988)—includes individual assignments;
- SMED—Single Minute Exchange of Die (Shingo 1985)—includes serious games and hands-on activities;
- 5S (Shingo 1989; Hiroyuki 1990)—includes serious games and team assignments;
- Standard Work (TPPDT 2002)—includes hands-on activities and team assignments;
- Visual Control (Shimbun 1995).

Particularly, the Specialized Training Program in Lean Manufacturing (STPLM) is focused in the development of professional competences in Lean. The *numerus clausus* is 25 students, but during the three years of existence only about 10

Table 10.2 Curricular plan of 2013/14 STPLM (first edition)

Sem.	Course	ECTS	Working hours	Contact hours
1	Lean production systems	5	140	15 T + 15 TP = 30
1	Lean project management	5	140	15 T + 15 TP = 30
1	Production flow management	5	140	15 T + 15 TP = 30
1	Information systems for production	5	140	15 T + 22.5 TP = 37.5
1	Human factors in production	5	140	15 T + 15 TP = 30
1	Lean flow project	5	140	37.5 TP
2	Lean advanced tools	5	140	15 T + 15 TP = 30
2	Distribution management	5	140	15 T + 15 TP + 7.5 PL = 37.5
2	Lean enterprise	5	140	15 T + 15 TP = 30
2	Total quality management	5	140	15 T + 15 TP = 30
2	Lean advanced project	10	280	82.5 TP
		60	1680	405

students enrolled on each year. This program was launched in a partnership with the Kaizen Institute and, due to the inherent costs, a high registration fee had to be established. The partnership implies the involvement of the Kaizen Institute in two sessions on every course unit. In the first edition of the STPLM (2013/14) the curricular plan shown in Table 10.2 was implemented (Type of classes: T—Theoretical; TP—Theoretical/Practical; PL—Lab. Practice; Contact hours—represents the expected time spent on classes with lecturers). The schedule was set for four hours per day three days a week, evening lectures (18 h 30–22 h 30 from Tuesday to Thursday), targeting a professional audience.

After the second edition (2014/15), a meeting with managers/administrators of important companies (usually involved in students' projects) was scheduled at DPS-UM in order to get feedback about the STPLM curricular structure. Besides three elements of the IM group (also authors of this chapter), seven companies were represented by a total of nine managers/administrators. The results of that meeting led to some changes in the STPLM curricular plan: (i) The Lean Flow Project was removed (first semester) because it was considered that a single project in the second semester (after the main core contents have been taught) would better serve the STPLM purpose; (ii) the Information Systems for Production course was removed (first semester) because its contents was not considered as being completely suitable to STPLM; (iii) the Distribution Management course was removed (second semester) and its most relevant contents were included in the Production Flow Management course (first semester); (iv) the Lean Advanced Tools course shifted to the first semester (and the designation was shortened to Lean Tools) because it was recognized the importance of teaching such contents in the early stages of STPLM; (v) the Lean Project Management course (first semester) was

Table 10.3 Curricular plan of 2015/16 STPLM edition

Sem.	Course	ECTS	Working hours	Contact hours
1	Lean production systems design	5	140	30
1	Lean project management and Lean teams	5	140	30
1	Production flow management	5	140	30
1	Lean tools	5	140	30
2	Human factors in production	5	140	30
2	Lean enterprise	5	140	30
2	Total quality management	5	140	30
2	Lean integrated project	5	140	30
		40	1120	240

modified in order to include contents related to lean teams; and, (vi) the Human Factors in Production course was moved to the second semester. With these changes, the STPLM workload was reduced from 60 to 40 ECTS, corresponding to a cut of 560 working hours (working hours include the contact hours) becoming thus aligned with one of the concerns mentioned in the meeting with the companies: the excessive workload demanded to the STPLM attendees. Table 10.3 presents the new curricular plan implemented in the 2015/16 edition.

The schedule was reduced from 12 to 8 h per week and the classes shifted to Thursdays and Saturdays. After the conclusion of the 2015/16 edition a new assessment will be conducted in order to get feedback from both attendees and companies, according to a trial and error process so that the continuous improvement policy is accrued.

10.3.2 Learning Methodology and Delivery

The authors started by introducing modules in existent courses of Production System Organization, Management and Planning of Production and other similar courses in Engineering and Fashion Marketing and Design programs. Meanwhile, aware of the companies' continuous need for people knowledgeable in Lean, the authors decided to expand the Lean offer, mainly on the IEM program. In 2014/15 two courses were offered to final year students as options: Lean Enterprise and Lean Tools. In 2015/16 one more was offered: Lean Healthcare. The two first options were chosen by the students in both years (Lean Enterprise with 17 students in 2014/15 and 31 in 2015/16; Lean Tools with 41 students in 2014/15 and 39 in 2015/16). Although being chosen by some students, the Lean Healthcare course did not reach the minimum figure imposed by the DPS (10 students) to run on the 2015/16 academic year.

Knowing the importance of active learning in teaching lean principles and tools, the authors have been implementing teamwork assignments, hands-on activities and serious games. Teamwork assignments are related with the research of case studies on lean implementation when the course is introductory on lean. This type of research work has two main benefits: First, the students get to know different companies that implement lean and start recognizing some concepts and tools associated with its implementation—this captivates and stimulates their curiosity about the lean tools that later, in more advanced courses, are explained in more detail. The second benefit is the database that is being formed grounded on these case studies (more than 40).

Hands-on activities are particularly interesting as the students are invited to simulate in a class a production system, starting with a job-shop solution and then improving the solution by adopting production cells. This kind of hands-on activity is mainly used in Production System Design (Alves and van Hattum 2011). For example, Fig. 10.2 shows the simulation of operating modes in a cell, using an electric torch product in the Design of Production Systems course.

As another example, the Fig. 10.3 represents a preparation for a simulation of a cell to produce electric plug-ins.

Serious games are mainly related with the teaching of lean tools such as SMED, Standard work and 5S (Sousa et al. 2013, 2014). Figure 10.4 shows a physical device (machine) used to demonstrate the implementation of the SMED methodology. Despite its apparent simplicity, this game is able to clearly demonstrate the most important tools/techniques inherent to SMED implementation (e.g. use of check lists, auxiliary jigs, functional clamps and elimination of final adjustments). The game session is conducted with three competing teams.

In the IEM context, this game is applied in the 4th or 5th year because the issue of reduction of setup time is a common task that occurs in a substantial number of master theses developed in industrial environments.

Fig. 10.2 Cell operating modes simulation

Fig. 10.3 Preparation for a cell simulation in the STPLM

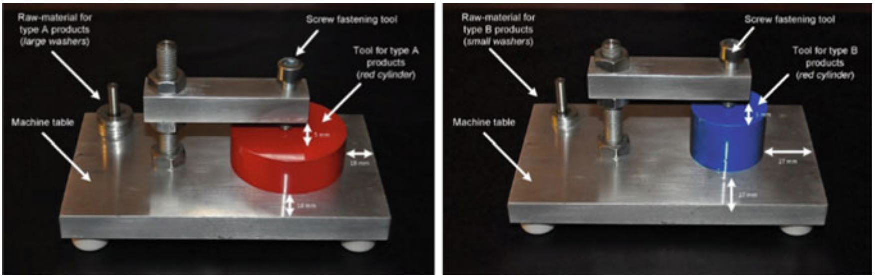

Fig. 10.4 The SMED game (Sousa et al. 2013)

10.4 Students, Industry and Academic Feedback

As Table 10.1 showed, Industrial Engineering and Management is the program that has more courses related with Lean, which is normal, attending to the students' profile. Particularly, in the fourth year they have Lean classes, whose contents can be applied in a project developed in a company in a Project-Based Learning (PBL) context (Lima et al. 2014). Lean contents are specifically applied on the "Diagnosis and improvement proposals of a production system". Tools like Value Stream Mapping (VSM) or cells production concepts are used in the diagnosis and as improvement proposals, respectively. The feedback from companies has been very positive as some of the proposals suggested by the students were implemented (mostly related with Lean tools).

Another important result of Lean Education come from the final-year projects developed during the fifth year of the Integrated Master on Industrial Engineering and Management and during the second year of the Master on Industrial Engineering, that have reached about 120 master dissertations (from 2001 onwards). These can be consulted in the repository of University of Minho (https://repositorium.sdum.uminho.pt/) bringing some recognition to the university. The authors of this chapter supervise most of these projects. Results of some of the projects have been published in conferences and journals in Industrial Engineering in a total of 22 papers, developed since 2008. Table 10.4 presents a list of such papers and the main benefits companies achieved with the projects. The table presents only the results that were published, therefore providing a small sample of the overall benefits. Alves et al. (2014) specifically presented the main benefits of 43 projects supervised in the 2011–2013 period. One main benefit that could not be measured is the critical thinking that is promoted in companies by introducing Lean Thinking in their practices (Alves et al. 2012).

An additional benefit is that some of the companies never heard previously about Lean Production, and for all purposes, the Industrial Engineering student was the enabler of a cultural change (Alves et al. 2015a). At the same time, these companies are assessed on their openness to such a change (Eira et al. 2015a, b, c; Maia et al. 2015).

Table 10.4 Publications of final-year master students with their supervisors

References	Lean tools implemented	Main benefits for companies	
Cardoso et al. (2008a, b)	Comparing ergonomic conditions in lines and cells production	Better environment for teamwork and consequent motivation and responsibilities Workstations rotation	
Cardoso et al. (2008a, b)	Redesign of production system: lines to cells production	Reduce/Eliminate: • No. of operators: from 33 to 26 • Disturbances and deficiencies • Occupied space: from 40 of length to 12 m • WIP level; Throughput time	Increase: • Flexibility to accommodate market demand changes • Transparency in the process • Materials supply efficiency
Costa et al. (2008)	Quick changeover and SMED	Reduce the changeover time from 5 to 3 min; Reduce the WIP level from 110 to 70 units	Adoption of standard work that reduced the time lost searching for what to do next
Afonso and Alves (2009)	Pull levelling	• Reduced stock of finished products of 9.95 days to 8 days => less 2 days of stock means savings in tied up capital around 18000 € • Every Part Every Interval (EPEI) decreased significantly from 1.6 to 1.1 approaching the ideal value for “A” references (EPEI = 1) • Weekly levelling fulfillment increased to 90 %, close to the ideal value (100 %) • LIWAKS (accomplishment of the due date negotiate with the client) increased from 88 to 97 %	
Oliveira and Alves (2009)	Operating modes in cells	• Selection system plan through the elaboration of a skills matrix; • Better internal organization of the cells and the	• Reduction of misadjusted ergonomic conditions • Productivity increased
Rocha et al. (2011)	Pull system	• Reduced stock of 17.62 %, from 42813 € to 35267 € (a reduction of 7546 €) • The lead time had a reduction of 30.56 % • The level of rework reduced from 5808 to 3761 units, a reduction of 35.24 % that implies a gain of 25915.02 € • People trained and motivated for Lean journey	
Carvalho et al. (2011)	Redesign of job-shop into 3 cutting cells and 3 assembly cells	Reduce/eliminate: • Lead time: from 11 to 2 days (80 %) WIP level • Transp. and travelled dist. by 25 % • Delivery delays; Occupied area • Defects and errors	Increase: • Simplification of the flow • Standardized operating procedures • Balancing efficiency • Lean culture awareness

(continued)

Table 10.4 (continued)

References	Lean tools implemented	Main benefits for companies	
Araújo and Alves (2012)	Pull system and FIFO lane	• Standard deviation (in relation to planned CT) from 24.07 to 14.38 s (40 %), a gain of 6840 €; • Space (m2) from 9.86 to 3.82 (61 %) a gain of 731 €; • OEE (%) form 80 to 90 (10 %) a gain of 5320 €; • Change over time (min): from 10 to 2 (80 %) a gain of 1920 €; • Change over time not planned: from 21 to 1 % (20 %);	• WIP max (containers): from 216 to 72 (67 %) Fulfilment: from 16 to 8 % (50 %) a gain of 1960 €; • Lead Time (days): from 4.03 to 3.92 [3 (2 h)] a gain of 4800 €; • Distance (m): from 40 to 25 (37.5 %); • Transp. time(s): from 80 to 50 (37.5 %) • Total gain: 21 771 €
Ribeiro et al. (2013)	Standard work	• Reduction of defects by about 27 %; • Rework rate dropped 33 % and the scrap rate dropped 31 %; • Improvements to the production efficiency by 14 %; along with reduction on the need for extra work hours; • Increased versatility of the operators	
Bragança et al. (2013)	5S, Visual management and standard work	• Increase the shop floor area; • Distances travelled: 90–0 m; • Reduce errors and non-conform; • Reduce the required operators; • Improvement on the organization	• Reduce energy and material consumption, mainly due to the decrease of defects and reduction of rework • Total gains: 18,905 €/ year
Costa et al. (2013a, b)	SMED	• Reduce setup times; • Reduce WIP and distances travelled by operators;	• Standardized process, becoming faster and intuitive for the operators; • Total gains of 1629 € per year
Costa et al. (2013a, b)	SMED	• Reduction of 64 % in setup time (from 15.1 to 5.4 min); • Reduction of 50 % in WIP amount (from 12.8 to 6.4 days);	• Reduction of 99 % in the distance traveled by the operator (from 136.7 to 1.7 m); • Gains of about 7315 € per year

(continued)

Table 10.4 (continued)

References	Lean tools implemented	Main benefits for companies	
Costa et al. (2014)	SMED, 5S, Visual management and standard work	SMED intervention • Reduction on setup (53–67 %); • Reduction of travelled distances (45–78 %); • Reduction WIP (50 %); • Standardized processes and workspace reorganized; • More enjoyable work environment; • Annual saving of 3,143.39 €	• Increase of 50 % in the capacity of the sector's supermarket; • Reduction of 8.5 min in the duration of the operations of 3 workstations; • Reduction of 90 min in the distances travelled by the operators; • Specific workstation savings of about 2,475.66 € per year; • Annual production increase 484 units
Queta et al. (2014)	Kaizen, standard work, levelling, project of supermarkets	• Reduction of idle time (45 %); • Increase of productivity (57 %); • Reduction of travelled distances (3038 m per day);	• Reduction of transport time (3.5 h per day); • Gains of 24 500 € per year
Resende et al. (2014)	5S, PDCA cycle, Kanban, SMED and Kaizen	Tangible and financial results: • Increase of productivity of the assembly lines by 12 %; • Operating income by 6 %; • Reduction of the cycle time of six dies to 10 %;	• Reduction by 15 % of tool changeover time; • Increase of total incomes estimated in €360,000.00 Intangible results: operators' engagement and involvement with the continuous improvement and Lean implementation
Simões et al. (2015)	Redesign of production system: from fixed to mixed-lines layout	• Reduction of a guillotine assembly time from 87 h to only 47 h (46 %); • Reduction of press brakes assembly time from 71 h to only 42 h (41 %);	• Decrease of a number of operators from 10 to 8 (20 %); Annual production of guillotines would increase from 72 to 112 (55.6 %); • Annual production of press brakes each year will be 186 (63 %)
Correia et al. (2015)	Design for Lean and TRIZ	• Reduction of product develop time • Improved product (sensor) • Improve the assembly sequence	• Reduction of the no. of sensor components; • Eliminate no-value added activities • Cost reduction
Eira et al. (2015a, b, c)	Rearrangement of layout and ergonomics assessment and improvement	• Dist. travelled (m) with transport activities 136–34 (75 %);	• Minimize the risk of musculoskeletal injuries; • Improve the ergonomic working conditions; • Lean culture awareness

(continued)

Table 10.4 (continued)

References	Lean tools implemented	Main benefits for companies	
		• Time spent (secs) with transport Activities: from 102 to 47 (54 %); • Annual Costs (€) with Transport Activities: from 522 to 378 (28 %); • WIP: from 329 to 283units (14 %);	
Vicente et al. (2015a, b)	5S; Ship-to-Line (STL) supply strategy Continuous improvement; Employees Involvement;	• Distance of the STL material (67 %) • Walking distance (32 %) • Transport time (24 %) • Waiting (21 %) • Handling of STL material (40 %) • Reduction of direct costs e.g.: (1) renting costs (≈5000 €/year) and; (2) energy costs (≈3000 €/year);	• Elimination of the MR transp. system; • Reduction of 2 co-workers (gains of ≈15,000 €/year); • Improved communication and coordination by defining standards; • New ideas and contributions (59 problems identified) given by coworkers promoting the company's financial and social sustainability

Table 10.4 presented the main tools used only, other tools were additionally useful to achieve the reported results, such as: 5S, Visual Management, SMED, Kanban, Kaizen, among others.

Additionally, the supervisors retained some important results on the redesign of the production systems in the context of Lean implementations. These were published in Alves et al. (2015a, b). Supervisors also benefited from the supervision by enabling the creation of a database of practical examples to support the classes on the terminal years. To conclude, it is important to notice that the link academy/industry and theory/practice is bridged with Lean Education (Alves et al. 2013).

10.5 Lean Principles Applied to Teaching/Learning Methodology

This section presents a discussion about how Lean principles could be applied to a learning/teaching methodology to improve the students learning, showing some important active learning methodologies that are aligned with these principles. Additionally, a more systematic approach of the application of these principles in the classes is presented.

10.5.1 Learning and Research Methodologies Aligned with Lean Thinking Principles

This section aims to discuss how the five principles of the lean thinking philosophy can be applied to teaching/learning methodologies. These principles are: (i) identification of value, (ii) mapping of the value stream, (iii) creation of flow, (iv) implementation of pull production and (v) pursuit of perfection.

Regarding the first principle, the concept of value must be identified according to the customer viewpoint. The direct customers of a teaching/learning process are the students and, indirectly, the companies. Thus, from those viewpoints, value should be the development of competences, not only technical but also transversal (e.g. teamwork, leadership, time management and communication). The lean education approach adopted in the DPS-UM, which, as previously described, uses different instruments (e.g. lectures, PBL, teamwork assignments, hands-on sessions and serious games) aims to provide an environment where the students can effectively develop those competences.

The identification of the value stream in a teaching/learning process is certainly an interesting exercise. The lectures are supposed to provide value-added activities, but it is widely recognized that in traditional expositive lectures students quickly lose focus. That's why the inclusion of active learning elements (e.g. inclusion of short duration individual/team assignments) are important in predominantly expositive lectures. Additionally, instruments like lean games, PBL and hands-on sessions, among others, clearly contribute to the increase of the percentage of value-added time during the semester. So, such practices and learning methodologies are aligned with Lean Thinking principles. Another methodology is the action research methodology that the students use in final year projects. This is a "learning by doing" methodology that resembles the PDCA cycle. Diagnosis, actions planning, implementation, evaluation of the results and learning specifying are the five phases of this methodology that are developed in the iterative process.

The third principle can be regarded as the creation of a continuous flow of competences development. In that sense, the implementation of a continuous assessment policy (e.g. PBL has a set of milestones and deliverables along the semester) contributes to the achievement of that goal, by keeping the students engaged in the learning process, contrarily to the traditional approaches in which the students only study for the final exams at the end of the semester. Traditional learning systems, mainly the ones based in expositive classes, have an assessment in "large batches", i.e., final written tests of two or more hours. This is totally contrary to Lean principles and a more similar approach is to have more assessment moments and diverse methods (more different products and in less quantities, preferably, "one piece flow", i.e., levelling the production). For example, having small quizzes in all, or almost, all classes is an approach to "one-piece-flow". Section 10.5.2 will discuss in detail this concept.

In the learning/teaching context, the implementation of pull production means that the students, and the companies, should pull the need for specific knowledge. That's exactly what happens with the projects developed in the industry (not only Master Thesis, but also PBL team projects developed, for example, in the fourth year of IEM). Typically, these projects involve the development of specific solutions for specific problems requiring thus specific knowledge. Project-Based Learning, is according the authors, a learning methodology totally aligned with Lean Education as are the "clients" (students) that pulls the "production", i.e., the knowledge they want to learn or that they need to learn in order to apply in the project development. They also pull this knowledge from teachers, forcing them to select the right contents and the best learning methodologies. Also, in the case of the specialized training program in lean manufacturing (STPLM), the referred meeting with companies' managers/administrators (Sect. 10.3.1) can be considered as being aligned with the pull production principle and also with the principle of value identification.

The last principle of the lean thinking philosophy is consistently adopted by the group of teachers involved in Lean Education at DPS-UM, which are always seeking for improvement opportunities in the teaching/learning process. Some of the concepts referred and others will be discussed in the following section through a specific systematic approach for applying Lean principles to classes.

10.5.2 Lean Principles in the Classes—An Experience

As the Toyota Production System, the Lean philosophy may be seen as being based on two basic concepts (Sugimori et al. 1977): the first concept is the cost savings achieved by reducing production waste (activities with no value adding) and the second concept is treating workers as human beings and with consideration. In Lean context, waste is any activity that does not add value to products or services, assuming that value is assigned by the customer. There are 7 types of classic waste already defined in TPS (Ohno 1988): Overproduction; Materials waiting (inventories); People waiting; Defects; Excessive or inappropriate processing; Transport; and Motion. Although the second concept (treating workers as human beings and with consideration) is central in any lean implementation and success very little attention will be given here in this document since in learning/teaching environments the concept of worker does not fit easily.

Lean approach to production is being applied with enormous success in many different areas of activity. Starting in industry in the decade of 1950 as the Toyota Production System (Ohno 1988) became known worldwide as Lean approach to production in the decade of 1990 through a famous book by Womack et al. (1990). This approach to production is focused in the elimination of activities that do not add value to products as well as in using the full potential of people. The lean principles expressed by Womack and Jones (1996) are:

- Value—the value must be defined by the customer since the customer is the one that will pay for the product.
- Value Stream—Identification of all the steps needed to build a product from raw material to the customer.
- Flow—the products should flow through the various process steps without interruptions or delays at the rate that the customers need.
- Pull Flow—nothing is performed without being required by the next process or by the customer.
- Pursuing Perfection—the organization need to always find ways to improve, to do better and better all the time.

These principles are largely applied not only in industry but also in hospitals (Graban 2011), in offices (Keyte 2004), in construction (Alarcón 1997) as well as in other sectors of activity. Applying lean principles and concepts to the teaching/learning process is far from being easy. Lean thinking was developed in industrial environments with some particularities that do not exist in the class room. The intangibility and complexity of learning processes make them difficult to be defined precisely and very difficult to measure their performance. For all these reasons the application of lean thinking in these processes becomes a very difficult task. Nevertheless, since lean thinking has being applied in more and more non-industrial environments, it also may bring improvements in teaching/learning environments. Emiliani (2015) has already proposed a model for lean teaching where some lean principles are applied with success.

A key lean concept applied in the experience documented here, is the continuous improvement. The continuous improvement model, often used in Lean environment to materialize the 5th principle of Lean (Pursue Perfection), is frequently based on PDCA cycles and the concept of Standard Work (Fig. 10.1). The concept of standard procedures or Standard Work (TPPDT 2002) is based on the assumption that if an operation or set of operations are carried out always in the same way then the result is always the same both in terms of quality and in terms of time spent (important for planning).

Taking as its starting point an opportunity for improvement or a problem to solve a particular case, the PDCA cycles can be summarized as follows: (Plan) the current situation is clearly defined and a plan is developed in order to make the desired change; (Do) the plan is executed to reach the desired state; (Check) verifying if the results is what was expected or not; and (Act) a decision taken about what to do in the next PDCA cycle. A new cycle will then be initiated. The PDCA methodology only work effectively if there is a default rule or procedure (Standard Work) assumed for the case in which the PDCA cycles are applied. Whenever the PDCA cycles result in an improvement then the standard procedure should be updated to ensure that the gains are maintained (see Fig. 10.5).

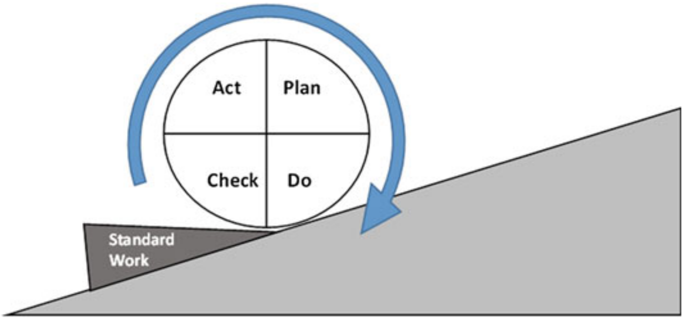

Fig. 10.5 PDCA cycle and standard work

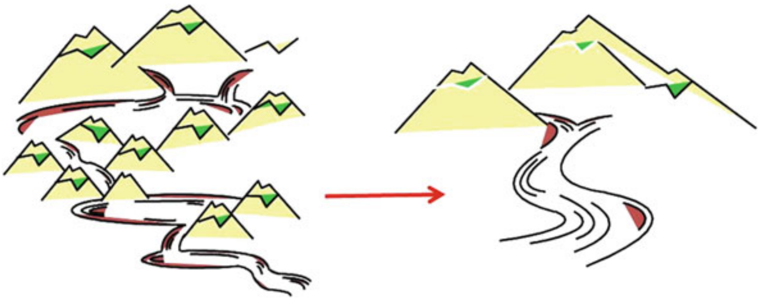

Fig. 10.6 Flow concept (Cousineau 2012)

Another relevant concept is the creating of flow (third lean principle). Flow is based on a likely unintuitive aspect of Lean thinking. The act of processing products in batches is naturally seen as a way of reaching high performance but that is not exactly true. Batch processing is the opposite of flow and in lean approaches flow is required as much as possible. Flow is achieved when products flow continuously along the system processes.

The desirable limit of flow is called "One Piece Flow" which in fact reflects perfect flow since the items (products, parts or components) never wait to be processed, advancing from process to process in a perfect rhythm. Figure 10.6 shows the lack of flow (left side of diagram) where there is water stagnation at some points along the process while the right side in the same figure shows flow, where the water flows continuously along the river bed.

10.5.2.1 Methodology

This lean teaching experience was carried out in a course named "Lean Enterprise" of the 5th year of the Integrated Master in Industrial Engineering and Management at the University of Minho. This is an optional course that involved 31 students between September and October 2015. During the 6 weeks of the course duration there was room for a total of 12 sessions of 2 h each. The aim of this course is to help students develop skills in the context of creating continuous improvement systems in companies and the application of concepts and Lean thinking in non-industrial processes such as lean office, lean accounting and in Lean leadership aspects.

Applying concepts of lean thinking in the course makes a lot of sense since the course itself is about that. The methodology applied in the case presented here is inspired in concepts and principles of lean thinking as well as in some tools that have been developed to help the materialization of lean concepts and principles.

In the first class the methodology was presented to students as well as the evaluation system. The classes followed a pattern established of 100 min per class with a defined instant to start and a defined instant to finish. The main structure of the methodology is that in each class a PDCA cycle of continuous improvement is performed. A set of standards were created at the start to make the continuous improving effective. One of the created standards is the standard structure for the class (see Table 10.5). The PDCA is carried out as follows:

- Plan—The class is planned to comply with the standard structure. Presentations are prepared as well as active learning activities and online tests. This planning phase is important to ensure that there will be space for the active participation of students in a significant part of the class.
- Do—The class is performed following the plan. It is important to keep the relatively strict control of time.

Table 10.5 Standard structure for 100 min class

Introduction (5 min)	Presenting performance results from previous class
	Remembering key points of previous class (using visual information)
	Presenting class plan
	Presenting learning outcomes expected to the present class
Execution	Activity 1 (30 min) Presentation of material or group work (active learning). *Note that even presentation of material also must incorporate active participation of students*
	Activity 2 (30 min) Group work if activity 1 was presentation or the other way around
Evaluation (15 min)	Product evaluation—Groups of 3 students perform a test to evaluate the learning outcomes. During the test the students in each group will discuss and learn with each other Process evaluation—Students will respond to a questionnaire (see Table 10.6)
Project presentations (15 min)	Each team presents the work performed since last project presentation. Feedback is provided by the teacher and by other students. This project work is assessed
Conclusion (5 min)	Open discussion on lessons learned, improving opportunities and next steps

Table 10.6 Questionnaire to evaluate the process

Question	1	2	3	4	5
The learning objectives for the class were clear					
The duration of each activity was suitable					
The strategy used by the teacher was adequate for learning the content					
The test was effective in evaluating the knowledge					
Solving the test in group contributed to consolidate the knowledge					
The class activities promoted my involvement					
The teacher was kind and understanding					

- Check—This phase is used to evaluate the product (the results) as well as evaluate the process. Regarding the product evaluation, an online test is submitted to teams of 3 students whose composition changes every class. This test has two functions. The first one is for students to discuss the issues in order to share lessons learned and consolidate knowledge. The second one is to evaluate the product (whether the learning objectives were achieved). Regarding the evaluation of the process the students are asked to answer an online small survey to assess the process (please see Table 10.6).
- Act—Based on the results obtained through the evaluation of the product (test in teams of students), the evaluation of the process (the survey results at the end of the class), the students inputs from the open discussion at the end of the class, and from the teacher´s own perception of learning activities, decisions are taken in order to adjust the standards or other practices in order to improve the next class.

10.5.2.2 Assessment System

The applied mechanisms to assess the students were created to be aligned as much as possible with the learning objectives, learning effectiveness and also to follow Lean principles and concepts. The classes are the most important learning moments but extra class activities are also expected to be part of the process. Each class is self-contained in a way that the learning outcomes are taught, experienced, discussed and tested. In lean thinking this is aligned to the flow principle since the students do not have to be tested on these learning outcomes later in the semester. The extra class learning activities are assigned to a project where the knowledge is applied. In the project the team of students must present every week on how the project is developing. The teams receive feedback and tips to keep going with the project. This is also a way of materializing the lean principle designated as “Flow”. The wastes such as overproduction and inventory are also reduced with the creation of flow.

The final grades are obtained by adding 40 % of the project grade with 45 % from the written tests and with 15 % of the punctuality grade. The punctuality grading works as two important lean concepts: the elimination of one type of waste which is "people waiting" and the respect for people.

10.5.2.3 Results

Table 10.7 presents in summary the most relevant lean concepts and tools applied. The fifth principle of Lean (Pursue Perfection) was the most important lean concept applied which is associated to PDCA cycles and Standard Work. It played the main role because the teaching/learning process itself was based on it. There was an attempt to identify Value (first principle of lean) by the mechanism of enquiries at the end of every class and at the end of the course. The results are not very clear since the concept of value in learning/teaching processes is not easy to specify.

Flow was achieved because as soon as new knowledge was added in the class the students had to experience it, discuss it and then being tested about it. Flow was also promoted in the project that students had to do out of the class room. Every week teams had to present the status of the project eliminating the accumulation of project tasks waiting to be performed during long periods. Another lean concept known as "Mura" (meaning imbalance) was also achieved because students had to do some work every week instead nor doing anything in some weeks and then a lot of work at the end of the course.

People waiting waste at the beginning of the class was completely eliminated through the punctuality grading (15 % of the final grading) but other cases of people waiting during the class were not addressed.

Table 10.7 Lean concepts and tools applied

Lean concepts	Tools	Level of application
Pursue perfection or continuous improving	PDCA cycles and standard work	High—applied as the main structure of the learning/teaching process
Identification of value	Feedback from students	Low—the definition of value was not very effective
Flow	Assessing in every class and project presentations every week	Medium—the project part of the course had some accumulation at the end of the course
"Mura" (imbalance) and "Muri" (overload)	Assessing in every class and project presentations every week	Medium—Since most work was performed in teams some students may had more work than others
People waiting waste	Punctuality grading	Medium—applied only in one case of waiting waste
Low cost automation	Online testing and online inquires	Low—many other low cost automations may be applied

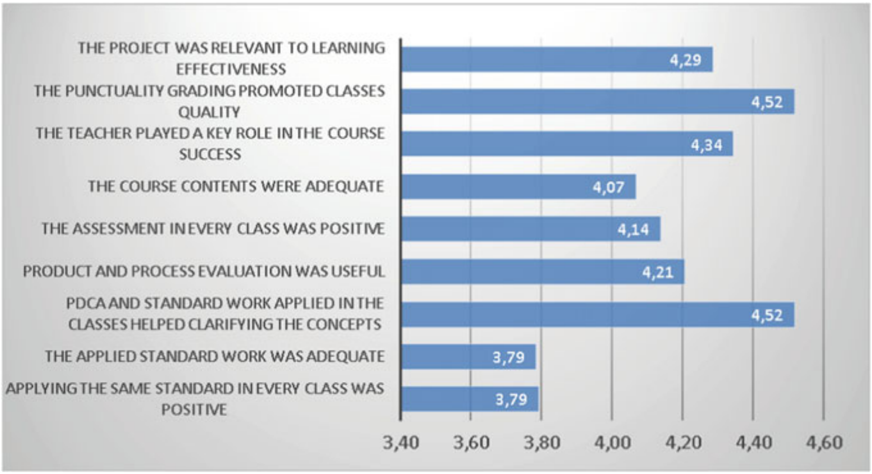

Fig. 10.7 Results from the final enquiry

Low cost automation is another concept associated to lean thinking that was also applied. The online testing and inquiries as well as some automatic processing of data were introduce in this course with same gains in teacher's time. Nevertheless, many other low cost automation possibilities are still to be developed and used.

At the end of the course all 31 students answered an inquiry whose results (averages) are presented in Fig. 10.7. A likert scale was adopted to collect the answers that could go from 1 (strongly disagree) to 5 (strongly agree). One of the questions with the highest scores (4.52 out of 5) was "The punctuality grading promoted classes quality". The students appreciate the fact that all students were at the class room before the starting time and therefore the class time was effectively used. The reason was that 15 % of the final grading were taking from punctuality. Interestingly the students appreciated it. The other question with the same high score was "PDCA and Standard Work applied in the classes helped clarifying the concepts". In fact the main structure applied in the classes is based on PDCA cycles and Standard Work concept.

On the other end the answers with poorest score were "Applying the same standard in every class was positive" and "The applied standard work was adequate", both with 3.79 out to 5. The class structure standard must be redesigned to be more effective and recognized by the students in a better way.

In this enquiry students had the opportunity to include written comments. Interesting comments regarding question "The assessment in every class was positive" and question "Product and process evaluation was useful". One frequent type of comment was related to the discussion created during the test performed in every class. Many students stressed the value of those discussion as an effective learning tool. Comments such as "allowed exchange of points of view", "developing capacity of working with different people", "helped consolidating knowledge”. Other comments were: “worked as a class conclusion and clarification of key points” and “a good way of keeping students alert during the class”. Regarding the recognition of flow created by the assessment system one student stated “the tests in every class avoided accumulation of work”.

Student assessment is always a critical issue and hardly the system appeals to everyone. Students that normal achieve high grades in written testes do not feel very happy with the system applied in this course.

10.6 Concluding Remarks

This chapter addressed Lean instruction at the University of Minho, Portugal. The chapter describes a number of diverse approaches taken by a group of lecturers of the Industrial Engineering field, in order to promote the development of competences in Lean Manufacturing. A growing need for such specific competences was observed in the northern region of Portugal, which resulted in a rise of Lean MSc dissertations conducted in the local industrial companies.

The approaches taken to Lean instruction at University of Minho were analyzed regarding the level of adhesion to the Lean principles, and some findings deserve some emphasis: (1) the ultimate customers of the lecturing activities are the students, and additionally also the companies who absorb that workforce, therefore we could identify competences development (technical and transversal) as the value that we ought to add; (2) a number of strategies can be used to complement traditional lectures and assessment processes, so that more active learning elements are introduced to make the process of competence development better levelled and pulled by the students instead of pushed by the lecturers; (3) Feedback on contents and instruction formats can be used to promote a continuous improvement approach. The Lean education has brought a number of rewards to the students, academics and the industry, the latter observing the development of a workforce that is more clearly aligned with their needs.

In spite of many master, projects, doctorates in the area, traditional academics continue denying the evidence of the new paradigm. Even with a Lean office project in progress in the department of the authors, this do not convince the more traditional faculty that continues seeing Lean as Industrial Engineering classical, or a “sense-common” methodology, not giving credit to Lean Thinking principles and the new paradigm imbedded. Like in the companies, Lean implementation demands a “shift” in the mind-set, an open minded difficult to find in the, supposedly, most prepared and intelligent people. Nevertheless this do not discourages the authors to give one more try to prepare and propose a Master for the next year.

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References

Afonso, C., & Alves, A. C. (2009). Implementation of the pull levelling project in a car radio assembly firm. In J. F. Silva Gomes & S. A. Meguid (Eds.), *Proceedings of the 3rd International Conference on Integrity, Reliability and Failure (IRF2009)*, Porto, 20–24 July, 11 p. (Paper Ref: S0233_P0552) (CD-ROM). ISBN: 978-972-8826-21-5. http://hdl.handle.net/1822/19119

Alarcón, L. (1997). *Lean construction*. Rotherdam, Holand: A. A Balkema.

Alves, A. C., Carvalho, D., Sousa, R., Moreira, F., & Lima, R. (2011) Benefits of Lean management: Results from some industrial cases in Portugal. In *Proceedings of Sixth Portuguese-Mozambican Congress of Engineering (CLME2011)*, Maputo, Mozambican, 29 August–2 of September. http://hdl.handle.net/1822/18873

Alves, A. C., Dinis-Carvalho, J., & Sousa, R. (2012). Lean production as promoter of thinkers to achieve companies' agility. *The Learning Organization*, *19*(3), 219–237. ISSN: 0969647. http://dx.doi.org/10.1108/09696471211219930

Alves, A. C., Kahlen, F.-J., Flumerfelt, S., & Siriban-Manalang, A.-B. (2013). Lean engineering education: Bridging-the-gap between academy and industry. In *First International Conference of Portuguese Society of Engineering Education (CISPEE)*, cispee13_Submission40. http://hdl.handle.net/1822/30297

Alves, A. C., Moreira, F., Sousa, R., & Lima, R. M. (2009). Projectos para a Aprendizagem na Engenharia e Gestão Industrial. in Livro de Actas do X Congresso Internacional Galego-Português de Psicopedagogia., (Eds.) Cied-Universidade do Minho, Braga-Portugal, 9–11 Setembro 2009, Universidade do Minho, pp. 3360–3375 (CD-ROM), ISBN 978-972-8746-71-1. http://hdl.handle.net/1822/19132

Alves, A. C., Sousa, R. M., & Dinis-Carvalho, J. (2015a). Redesign of the production system: A hard decision-making process. In *2015 IEEE International Conference on Industrial Engineering and Engineering Management*, Singapore, 6–9 December. doi:10.1109/IEEM.2015.7385824

Alves, A. C., Sousa, R. M., Dinis-Carvalho, J., Lima, R. M., Moreira, F., Leão, C. P. et al. (2014). Final year Lean projects: Advantages for companies, students and academia. In *Proceedings of the Sixth International Symposium on Project Approaches (PAEE2014)*, Medellin, Colombia, 28–29 July, ID56.1–56.10. http://hdl.handle.net/1822/30172

Alves, A. C., Sousa, R. M., Dinis-Carvalho, J., & Moreira, F. (2015b). Production systems redesign in a Lean context: A matter of sustainability. *Faculty of Mechanical Engineering Transactions,*. doi:10.5937/fmet1504344A

Alves, A. C., & van-Hattum, N. (2011). Hands-on simulation in the classroom to teach new concepts and to prepare future industrial engineers as operator's instructors. In *Proceedings of International Symposium in Project Approaches in Engineering Education (PAEE2011)*, Lisbon, 1–2 October. http://hdl.handle.net/1822/14940

Araújo, A., & Alves, A. C. (2012). Pull System implementation through FIFO lane to achieve synchronism between lines and assembly cells. In R. M. Lima, D. Carvalho, V. Cavenaghi, M. V. Junior, G. L. R. Vaccaro, R. F. M. Marçal, F. S. Másculo, & L. F. R. R. S. Carmo (Eds.), *Proceedings of International Conference on Industrial Engineering and Operations Management (ICIEOM2012)*, ISBN: 978-85-88478-43-5. http://www.abepro.org.br/biblioteca/icieom2012_submission_332.pdf

Bragança, S., Alves, A. C., Costa, E. & Sousa, R., (2013). The use of Lean tools to improve the performance of an Elevators company. In *Proceedings of Integrity, Reliability and Failure (IRF2013)*, Edições INEGI, Funchal/Portugal, 23–27 June 2013. http://hdl.handle.net/1822/25316

Cardoso, A., Arezes, P., Alves, A. C. & Carmo-Silva, S. (2008a) Análise Ergonómica de Sistemas de Produção Orientados ao Produto: estudo de um caso industrial. In *Proceedings do 5º Congresso Luso-Moçambicano de Engenharia (CLME2008)*, Maputo, Moçambique, 2–4 de Setembro. http://hdl.handle.net/1822/19134

Cardoso, A., Arezes, P., Alves, A. C. & Carmo-Silva, S. (2008b). Reconfiguração de Sistemas de Produção Orientados ao Produto: estudo de um caso industrial. In *Proceedings do 5º Congresso Luso-Moçambicano de Engenharia (CLME2008)*, Maputo, Moçambique, 2–4 de Setembro. http://hdl.handle.net/1822/19138

Carvalho, R., Alves, A. C., & Lopes, I. (2011). Principles and practices of Lean production applied in a metal structures production system. In *Proceedings of The World Congress on Engineering 2011, WCE 2011*, London, U.K., 6–8 July 2011, pp. 744–749.

CCDRN. (2015). Norte Portugal: A unique region. Comissão de Coordenação e Desenvolvimento Regional do Norte (English edition).

Correia, M., Barbosa, J., Alves, A. C., Seabra, E., & Silva, L. (2015). Design for Lean production on the improvement of a car component. In *ICEUBI2015—International Conference on Engineering—Engineering for Society* (Submitted August 27, 2015).

Costa, P., Alves, A. & Sousa, R. (2008) Implementação da metodologia Quick ChangeOver numa linha de montagem final de auto-rádios: para além da técnica SMED. In *Proceedings do 5º Congresso Luso-Moçambicano de Engenharia (CLME2008)*, Maputo, Moçambique, 2–4 de Setembro. http://hdl.handle.net/1822/11879

Costa, E., Bragança, S., Alves, A. C., & Sousa, R. (2014). Action-research methodology to improve performance using Lean production tools. *Technics, Technologies, Education, Management (TTEM)*, *9*(2), 253–264.

Costa, E., Bragança, S., Sousa, R., & Alves, A. C. (2013a). Benefits from a SMED application in a punching machine. *International Journal of Industrial Engineering*, *7*(5), 869–876. http://www.waset.org/publications/17166 (World Academy of Science, Engineering and Technology, International Science Index 77)

Costa, E., Sousa, R., Bragança, S. & Alves, A. C. (2013b). An industrial application of the SMED methodology and other Lean production tools. In *Proceedings of Integrity, Reliability and Failure (IRF2013)*, Edições INEGI, Funchal/Portugal, 23–27 June 2013. http://hdl.handle.net/1822/25314

Cousineau, K. (2012). Why business leaders apply Lean before six sigma. http://www.opticompinc.com/why-business-leaders-apply-lean-before-six-sigma/

Eira, R., Maia, L. C., Alves, A. C., & Leão, C. P. (2015a). An initiation of a Lean journey in a clothing company. Recent advances in mechanics and materials. In J. Silva Gomes et al. (Eds.), *Proceedings of the 6th Conference on Mechanics and Materials in Design (M2D)*, Ponta Delgada, Portugal, 26–30 july 2015, pp 1349–1358. ISBN: 978-989-98832-2-2. http://hdl.handle.net/1822/36860

Eira, R., Maia, L. C., Alves, A. C. & Leão, C. P. (2015b). Perceptions and understandings on the need of change: Viewpoints across management levels. In *3rd World Conference on Information Systems and Technologies (WorldCIST'15)*, Ponta Delgada, Açores, Portugal, 1–3 de abril.

Eira, R., Maia, L. C., Alves, A. C. & Leão, C. P. (2015c). Ergonomic intervention in a Portuguese textile company to achieve Lean principles. In P. Arezes, J. S. Baptista, M. P. Barroso, P. Carneiro, N. Costa, R. Melo, A. S. Miguel, G. P. Perestrelo (Eds.), *International Symposium on Occupational Safety and Hygiene (SHO2015)*, Guimarães, Portugal, 12–13 de fevereiro, pp. 100–102. ISBN: 978-989-98203-3-3. WOS:000350559600035

Emiliani, B. (2015). *Lean teaching: A guide to becoming a better teacher*. Connecticut, USA: CLBM, LLC.

Graban, M. (2011) *Lean hospitals: Improving quality, patient safety, and employee engagement*. CRC Press.

Hiroyuki, H. (1990). *5 pillars of the visual workplace—The sourcebook for 5S implementation*. Portland, Oregon, USA: Productivity Press.

Ishikawa, K. (1989). *Guide to quality control*. Tokyo: Asian Productivity Organization, imp. ISBN 92-833-1035-7.

Keyte, B. (2004) *The complete Lean enterprise: Value stream mapping for administrative and office processes*. CRC Press.

Lima, R. M., Dinis-Carvalho, J., Campos, L., Mesquita, D., Sousa, R., & Alves, A. C. (2014). Projects with the industry for the development of professional competences in industrial engineering and management. In *Proceedings of the Sixth International Symposium on Project Approaches (PAEE2014)*, Medellin, Colombia, 27–28 July, ID13.1–13.11. http://hdl.handle.net/1822/30134

Maia, L. C., Eira. R., Alves, A. C., & Leão, C. P. (2015). O valor das condições de trabalho para a melhoria organizacional. In A. P. Costa et al. (Eds.), *Atas do 4º Congresso Ibero-Americano em Investigação Qualitativa (CIAIQ2015) e do 6º Simpósio Internacional de Educação e Comunicação (SIMEDUC2015)*, Aracaju, Brasil, 5–7 de agosto, pp. 43–48. ISBN: 978-972-8914-54-7. http://hdl.handle.net/1822/36862

Nakajima, S. (1988). *Introduction to TPM: Total productive maintenance*. Cambridge, Mass: Productivity Press, cop. ISBN 0-915299-23-2.

Ohno, T. (1988). *Toyota production system: Beyond large-scale production*. Portland, Oregon: Productivity Press.

Oliveira, A. R. & Alves, A. C. (2009). Operating modes in manufacturing cells—An action research study. In M. Gen, G. A. Suer, H. Hwang, K. H. Kim, K. Ohno, S. Fujimara (Eds.), *Proceedings of the 5th International Conference on Intelligent Manufacturing and Logistics Systems and Symposium on Group Technology and Cellular Manufacturing (GT/CM 2009)*, Kitakyushu, Japan, February 16–18, pp. 107–115. http://hdl.handle.net/1822/19121

Queta, V., Alves, A. C., & Costa, N. (2014). Project of ergonomic shelves for supermarkets in a Lean work environment. In *Proceedings of the International Symposium on Occupational Safety and Hygiene—SHO 2014*, Guimarães, SPOSHO 2014, ISBN 978-989-98203-2-6.

Resende, V., Alves, A. C., Baptista, A., & Silva, A. (2014). Financial and human benefits of Lean production in the plastic injection industry: An action research study. *International Journal of Industrial Engineering and Management*, *5*(2), 61–75. http://www.iim.ftn.uns.ac.rs/casopis/volume5/ijiem_vol5_no2_2.pdf

Ribeiro, L., Alves, A. C., Moreira, F., & Ferreira, M. (2013). Applying standard work in a paint shop of wood furniture plant: A case study. In *Proceedings of 22nd International Conference on Production Research (ICPR 22)*, Iguassu Falls, Brazil, 28th July–1st August. http://www.scopus.com/inward/record.url?eid=2-s2.0-84929380306&partnerID=MN8TOARS

Rocha, G., Alves, A. C., & Braga, F. (2011) Implementação de um Sistema Pull numa Linha de Montagem de Componentes Electrónicos. In *Proceedings do 6º Congresso Luso-Moçambicano de Engenharia (CLME2011)*, Maputo, Moçambique, 29–2 de Setembro. http://hdl.handle.net/1822/18864

Rother, M., & Shook, J. (1999). *Learning to see—Value stream mapping to create value and eliminating muda*. (1.2 ed.). Brookline: The Lean Enterprise Institute.

Shimbun, K. N. (1995). *Visual control systems*. Productivity Press. ISBN 978-1-56327-143-4.

Shingo, S. (1985). *A revolution in manufacturing: The SMED system*. Productivity Press.

Shingo, S. (1989). *A study of the toyota production system*. Portland, Oregon, USA: Productivity Press.

Simões, T., Alves, A. C., & Carneiro, P. (2015, March). From fixed to mixed: Rethinking production systems design for increased efficiency. *Industrial Engineer—Engineering and Management Solutions at Work*, *47*(3), 43–48. ISSN: 2168-9210. http://www.iienet2.org/industrialengineer/Details.aspx?id=38776

Sousa, R. M., Alves, A. C., Moreira, F., & Dinis-Carvalho, J. (2014). Lean games and hands-on approaches as learning tools for students and professionals. In *Proceedings of International Conference of Production Research Americas (ICPRAmericas)*, Lima, Peru, 31 July–1 August.

Sousa, R., Moreira, F., & Alves, A. C. (2013). Active learning using physical prototypes and serious games. In *Proceedings of the Fifth International Symposium on Project Approaches (PAEE2013)*, Eindhoven, Netherlands, 8–9 July, pp. ID27.1–ID27.9. http://hdl.handle.net/1822/30296

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

TPPDT, Productivity Press Development Team. (2002). *Standard work for the Shop-floor*. Portland, Oregon, USA: Productivity Press.

Vicente, S., Alves, A. C., Carvalho, S., & Costa, N. (2015a). Business sustainability through employees' involvement: A case study. *Faculty of Mechanical Engineering Transactions*, *43*, 362–269. doi:10.5937/fmet1504362

Vicente, S., Carvalho, S., Alves, A. C., & Araújo, R. (2015b). Lean logistic to improve ship-to-line strategy in an electronic components automotive company. In *Encontro Nacional de Engenharia e Gestão Industrial (ENEGI)*, Lisboa, 11 September.

Womack, J., Jones, D., & Roos, D. (1990). *The machine that changed the world*. Rawson Associates.

Womack, J. P., & Jones, D. T. (1996). *Lean thinking: Banish waste and create wealth in your corporation*. New York: Free Press.