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Foreword

Lean Education has a double meaning. The most familiar meaning would be the teaching of lean principles, concepts, tools, and techniques. Contributed chapters to this book provide a representative sample of undertakings currently underway in higher education. A less familiar meaning could be applying those same lean topics to improve the delivery of education. There are two distinct categories for this meaning, namely applying Lean Thinking to: (1) the development and delivery of curriculum and (2) the functions that support education such as admissions and facilities. Examples of (1) appear in several of the contributed chapters. There are numerous examples of (2) in primary, secondary, and higher education, but I will not be mentioning them further in this Foreword. However, I would like to remark that in a keynote talk at the first Lean Educator Conference in 2006, Womack suggested that an effective way to teach the principles and tools of Lean Thinking in an academic setting would be to apply them as class projects to operational processes of universities (Womack 2006). Tishler presents an interesting example of this using the admissions follow-up process as a class project (Tischler 2006).

A couple years ago, I presented at a workshop in Zagreb, Croatia, titled Universal Lean. Lean has been applied in many countries. *Lean Education* reflects this geographic reach with chapters from Portugal, Brazil, the Philippines, USA, France, and Poland. It is now well established that Lean is not peculiar to Japanese culture. Lean also applies to every enterprise: manufacturing and service, government, education, and nonprofits. However, lean lingo can obscure this fact to those not familiar with the material. Terms such as lean production or lean manufacturing might imply to the unknowing that lean is not universal. I prefer to use terminology introduced by Womack and Jones (1996)—Lean Thinking. Fundamentally, Lean is a way of thinking and that is why it is universal.

This book is about Universal Lean Education, spanning the dimensions mentioned above—not completely but at least representatively. Lean Thinking is about improving productivity and worker's satisfaction through continuous process improvement and respect for people. Its principles are as fundamental as mathematics and reading/writing to a developing a well-educated individual. Aspects of

Lean Thinking should be embedded in education starting in first grade. However, this is not the situation. Why?

My personal experience in Lean Education started in the early 1990s, but let me begin by recounting my first experience teaching the lean principles and tools. It was in June 2003 to twenty summer college interns at Rolls Royce in Indianapolis, Indiana. On short notice of six weeks, four instructors who had never taught together assembled a week's short course curriculum. It embodied many pedagogical techniques you will encounter in this book: simulations (also called serious games in some chapters), active learning exercises, gemba walks, a case study, a team project, and (of course) lectures. There were ragged spots in the quickly assembled course, e.g., slides for one whole module failed to present. Nevertheless, it was a huge success and eventually led to the development of the LAI Lean Academy (Murman et al. 2014) which has been taught over 60 times, accessed by over a half million times on MIT's Open Courseware portal, and translated into Spanish.

At the end of the Rolls Royce course, half of the students personally thanked the instructors and said they learned more in that course than *any* course they had taken in college. One student said he learned more during the week than *all* the courses he had taken in college. Why? Was it our teaching styles or personalities? Was it the captivating Lego® airplane production simulation? Was it the subject material? I think it was some combination of everything, but most of all it was because it was Lean Education in the double meaning introduced above. I will explain more fully at the end of this Foreword.

Fast forward to today. As I write the Foreword, I am co-teaching a course in my small community in western Washington State. The audience of nineteen adult learners are an interesting cross section of the community: church, cheese manufacturer, public health department, public library, a youth hangout, an adult co-working space, and a couple of individuals. For the past couple of years, I have offered a daylong Lego® airplane production simulation-based workshop to our high school robotics team. They were very receptive. Much of the material taught to these various groups is the same, and some of its traces back to the 2003 Rolls Royce course. In the thirteen years, I have been teaching the subject material, I have yet to encounter an age group, an occupational sector, or a nationality that did not find the subject both interesting and valuable.

If Lean Thinking is so universally applicable and as fundamental to a well-rounded education as I have suggested above, why is the penetration of the subject material into post secondary school curriculum so shallow? There are a number of possible reasons, including the following:

- Most educators and many others think it is narrowly a manufacturing paradigm. So they pigeon hole it as suitable for industrial engineering, or maybe a management curriculum.

- It lacks the stature of a traditional academic discipline with research funding and learned journals. So academics discredit it as legitimate academic material.
- Being a field based upon practice, many faculty members who have only academic experience may not have firsthand exposure to the body of knowledge. So they lack confidence in approaching the material, or lack understanding of its importance.
- Effective pedagogy (as presented in this book) relies on simulations, active learning, and other techniques different than traditional lectures and recitations. So faculty members may not be well equipped to teach the topic.
- Accreditation standards do not include the topic. So there is no "pull" to cover it.
- There is simply no room in an already crowded and constrained curriculum to add yet another course or module or unit. So it is put on the margin.

It is this last listed reason that leads me to remark about the second meaning of Lean Education, namely applying Lean Thinking to improving the delivery of education. As the authors of Chap. 2 articulate, our legacy education system is based upon a mass production way of thinking. It is based on a teacher-centric thinking, not a learner-centric mentality. We divide the curriculum into topics that individuals know how to teach, and many of them never teach anything else. For example, we have the mathematics faculty who teach "all the math the students will need to know," and expect they will inventory that knowledge until they need it. Many students have little understanding why they are learning the material in the first place, and then when they finally need to use it, the "shelf life" has expired and they need to relearn it. Without belaboring with other examples, let me just assert that the legacy educational system has a great deal of educational waste, which if eliminated could open up plenty of time for topics such as Lean Thinking.

Putting on a Lean Thinking hat, we need to map the student value stream starting with kindergarten and look at all activities—in the classroom and otherwise—to analyze where value is added and where waste is created. Of course, we need to identify the customer (hopefully the student) and what they value (hopefully a solid education with employable skills). Maybe we can envision an (too daunting) ideal state, but surely we can seek an achievable future state which is a step forward. And then we can apply PDCA improvement cycles. This would be a huge undertaking with many stakeholders to engage and monuments to challenge. But we might find, for example, that "extra curricular" activities such as sports and debate teams add more educational value than ancient history or esoteric math. It is too much to think of every community, state, or country taking on a challenge like this. But it can be applied to more bounded value streams such as a course, a major, or maybe an institution.

The authors of Chap. 10 present a Lean Education Example for a particular class. The Ziskovskys present a fictionalized version of a true experience using basic lean concepts and tools to improve a 4th grade World Geography course. Chapter 2 presents a strategy for deploying Lean Education across a system of vocational educational schools in Brazil. Emiliani has published numerous articles and books

(Emiliani 2015a, b) about Lean Education at the college level, including reporting some of his experiences.

I stumbled into this topic quite unknowingly in 1991 when, as Head of the MIT Department of Aeronautics and Astronautics, I led an effort to completely revamp our undergraduate curriculum. At that time, I did not know about Lean Thinking. But in hindsight, we used many of the principles. We started with the Voice of the Customer (primarily those who hired our students) to define value. We then mapped our curriculum, year by year to identify where that value was delivered to our graduates. We defined what was called the "implicit curriculum," which was all the topics students were expected to gain, but which were not in the descriptions of our subjects. These were topics such as teamwork, communication skills, ethics, and so on. These were allocated across the subjects in a way that would expose each student to a coherent introduction by the time they graduated. And then we implemented the new curriculum. We did not get it all right, but we made a start. Using PDSA thinking (which we did not know about), my successor led a second, and much better, design and implementation. The second pass really addressed the learner-centric pedagogy. It was branded as CDIO for Conceive, Develop, Implement, and Operate—the basic stages of the aerospace product lifecycle which we were trying to impart to our graduates (Crawley et al. 2011). It took a lot of leadership, faculty buy-in, and time to do this system-level analysis of our undergraduate curriculum. We eliminated educational waste, increased educational value, and found ways to teach much more material more effectively than we had done before—albeit eliminating much outdated content. Looking back, we applied the principles of Lean Thinking to improve our educational delivery.

Returning to the 2003 Rolls Royce experience, I feel the main reason the students found the course so valuable was a combination of the two meanings of Lean Education covered in this Foreword. The topic was introduced to them "just-in-time" as they started a summer internship at a company that was aggressively implementing lean through all its operations. They literally could see Lean in action as we taught the course and they comprehend that they would be using what they were learning during their internship. Their first exposure to the topic was a gemba walk, and it was followed up by instruction on what they had just seen and heard. If more experiences like this could be embedded in education, more value can be delivered. This is just one example of the effectiveness of the second meaning of Lean Education. I hope to hear many more as the years go by.

Let us return to the question of why the penetration of lean content in curriculum—from elementary grades through graduate study—has been shallow. I think it is fundamentally that educational leadership has not given it high priority. My Lean Education journey was driven by a mandate from a four star general of the US Air Force (Murman et al. 2014). If educational institutional leaders gave priority to Lean Education, greater progress could be realized. Meanwhile, let us be inspired by the results reported in Lean Education and other publications and conferences.

Earll M. Murman
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Preface

The purpose of this volume is to compile and recognize the many wonderful higher education lean programs from around the world. This compilation is not a fully comprehensive list, but it does indicate that there is a lot of exciting curricular work occurring in the study of the Lean Body of Knowledge (BoK).

What is particularly of interest is that these programs represent disciplines beyond engineering, where lean has been traditionally placed in higher education programming. This highlights that Lean is powerful BoK due to its broad applicability. Also, lean encumbers both critical content and competency learning. For example, if one is to be a good lean practitioner, theoretical and empirical knowledge of the continuous improvement cycle is needed. But, also, a series of competencies, such as the ability to communicate, think critically, and manage change are also required. It is the theory to practice and practice to theory dynamic in the Lean BoK that makes it so interesting.

In addition, there is a business case for higher education institutions to offer Lean programming. And that is because lean training and credentials are valued in the workplace. The potential for university-business partnerships is immense with lean program offerings.

The higher education institutions featured in this volume are to be commended for their lean program offerings. In some cases, developing lean curricula has been pioneering work for these faculty and instructional designers. It takes a tremendous commitment to bring forth new programming in the higher education world and designing new courses, learning experiences, and formal degree programs from scratch is not easy. We believe that faculties have engaged in this work because they understand the incredible value in the Lean BoK for students.

This volume is offered with an insightful Preface from Earll Murman. The first chapter sets the stage for the volume, providing an argument for the value in formal lean programming in higher education, including a summary of feedback from the authors on critical areas of curriculum: quality of the learning experience, method of delivery, and valued student outcomes. The remaining chapters highlight internationally programs offered at institutions with detailed descriptions of various stages of planning, development, and deployment of lean programs. It is our hope that this volume is both informative and inspirational to those practicing and emerging champions of the Lean BoK. Enjoy!

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Chapter 1
Introduction

Anabela Carvalho Alves, Shannon Flumerfelt and Franz-Josef Kahlen

This chapter introduces the contextual issues that motivated this book project. Perspectives from Lean Operations to Lean Education are presented by several authors. To begin the book, it is important to have a concept of the Lean Education concept. The preface by Murman delineates that Lean Education includes both the inclusion of Lean Thinking as curriculum content and as a method of improving educational delivery. The thought of a Lean School or undergraduate or graduate Lean degree, for example, seems imminent, based on this preface.

For this chapter, engineering education is the focus. This is done only to provide advocacy for why Lean Education is needed and what is possible when Lean Education is used. However, the application of Lean Education is possible at any level of education, primary, secondary and tertiary, and in any field of study, such as medicine, business, and the liberal arts.

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1.1 Contextual Issues

Globalization is a reality, presenting advantages and disadvantages to society. At hand is the need for society to adopt and to adapt to globalization in the best possible manner. There is the expectation that globalization updates will be made in organizational paradigms and processes causing shifts in behavior, in culture, in practices. The cascading of this workplace need for change lands in the wheelhouse of education. And this is where challenges are emerging.

For example, engineering education has clearly identified the need to prepare professional engineers to deal with globalization by promoting whole-systems thinking and eco-sustainable solutions. In turn, this thinking and these solutions must be designed around enriched paradigms and processes that enact the needs of many, attaining the balance among the three vertices of pyramid: People, Planet and Profit (3P) within the organization. So, the importance of symbiosis for both education and the workplace exists that encumbers different ways of educating and of working. Examples of this are evident in Career and College Readiness standards required for K-12 educational delivery. Educators and employers are starting to work together to formulate and to deploy ideas for partnerships to support career and college readiness. This is particularly evident in STEM and STEAM initiatives, but it also extends to the traditional classroom.

In terms of engineering education, the pressure is on for educators to prepare students for this globalized world. Early graduates need to be able function as professionals who are aware and able to enact positive impacts through solution design and decision-making. These young practitioners must have the ability to engage with organizational mission and objectives to the point that their work aligns with the common needs of critical stakeholders.

The engineering workplace, therefore, demands a student who possesses many competencies, such as being a strong ethical sense maker, a whole-system thinker and real world literacy. To achieve these learning outcomes, it is necessary that students go beyond the universities' walls and traditional engineering content in textbooks. It is necessary to move learning experiences both inward and outward, so that critical and reflective thinking as real problem solving is embedded in the degree experience.

To obtain these outcomes, engineering students must have the opportunity to learn from other environments besides the halls of academe, including project-based learning, service learning, and workplace experiences. While real-world learning along with the formal school experience is needed, today more than ever, real-world learning at organizational sites willing to co-participate with the Academy are are serving as true extensions of higher education for future engineers.

Universities benefit from graduates who are able to function effectively in the workplace. Employers are able to achieve a two-fold objective for relevance today: (1) to develop global competitiveness and (2) to add to a sustainable business case. Organizations engaging with the academy at this level are advanced in their human resource practices. And, interestingly, they also tend to use Lean Management.

Some of these organizations include: Toyota Motor Company, Bosch Company, General Electric Company, Jabil, various hospitals, non-profit and public sector systems, along with many, many others. In fact, it is difficult to find a Fortune 500 company that does not use or try to use Lean Production or Lean Management and Lean Thinking.

Lean Production or Management (Womack et al. 1990) has its roots in the Toyota Production System (Ohno 1988; Monden 1998). All over the world, organizations, from corporate operations to manufacturing to educational institutions, are adapting Lean Thinking principles (Womack and Jones 1996) to their own contexts and cultures (Alves et al. 2014b).

Additionally, a recent report of National Academy of Engineering by the committee for Foundational Best Practices for Making Value for America (Donofrio and Whitefoot 2015), recommended that "*Manufacturers should implement principles and practices such as Lean Manufacturing that enable employees to improve productivity and achieve continuous improvement*." They point out that organizations and communities must take action to upgrade America's ability to "make value" in this manner in order to prosper in the 21st century.

On a global scale, it is clear that Lean is internationally well accepted and recommended as a means to attain success in a healthy manner. For these reasons, it is believed that Lean Education provides the ideal platform to educate engineers and all others for the workplace by providing them with the content and competency mastery that globalization requires.

1.1.1 Engineering Education Challenges

Specifically, the objective of engineering education is to prepare students with the knowledge, dispositions and abilities to design solutions that allow society to evolve without damaging the planet. To achieve this, engineering education must be aware of the challenges that future engineers need to address. Fifteen years ago, Rugarcia et al. (2000) saw this need driven by seven features: (1) the proliferation of information; (2) the evolution of multidisciplinary approaches as a result of technological development; (3) globalized markets; (4) the endangered environment; (5) emerging social responsibility; (6) participatory corporate structures and (7) rapid change.

Some organizations and professional associations such as, National Academy of Engineering (NAE) (2005, 2012), National Science Foundation (NSF) (Ulsoy 2007), the Millennium Project (Duderstadt 2008), American Society of Civil Engineers (ASCE) (2009), American Society of Mechanical Engineers (ASME) (2010), and UNESCO (2010) also addressed these and other challenges in a discussion about how engineering educators must better prepare better engineers.

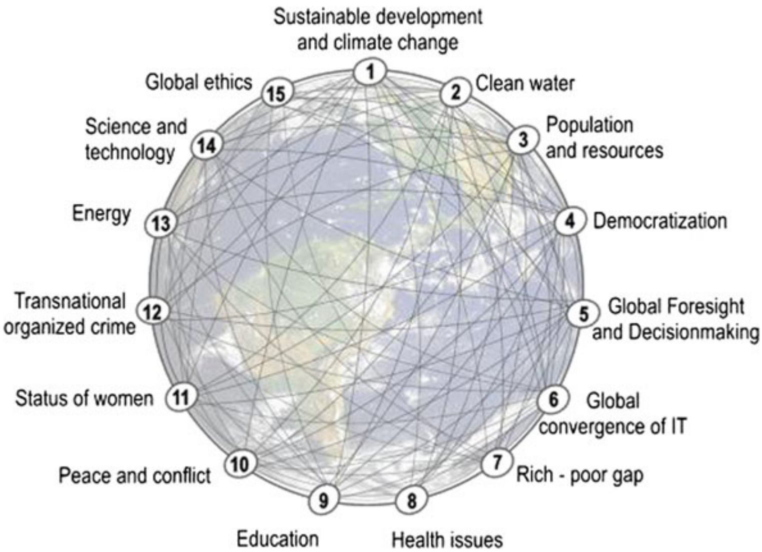

Fig. 1.1 Fifteen global challenges facing humanity [retrieved from The Millennium Project (2009)]

Their concern is the urgent need to address Grand Challenges of Engineering (2010) but, to also grasp the 15 Global challenges facing humanity (2009), Fig. 1.1. These challenges inform all educators in any discipline or specialization what is relevant for the 21st workplace. Further, it is inferential as to what the 21st century classroom should be. As these issues are examined, it is also evident that from any lense, each of the problems can be considered through disciplinary literacy informed by the tenets of Lean Management and Lean Thinking.

Fifteen years ago, the eight Millennium Development Goals project were promoted by United Nations Development Program (UNEP) where 189 nations signed a declaration to free people from extreme poverty and multiple deprivations (UNDP 2010) with a 2015 deadline. Engineering education and all other fields of study also have an important role to help to address and overcome these problems. Education for Sustainable Development (ESD) (Colombo et al. 2015), incited that engineers with excellent content and competency mastery are needed more than ever based on this initiative.

However, various fields of study, such as engineering, are facing the problem of being a profession not chosen by young people, especially females. For engineering, this is due to the decline of student interest in scientific and engineering careers. It is feared that engineering programs are perceived as unattractive and too hard (Pickard 2014). Reversing this situation is another challenge that engineering education must address. And this is where the use of Lean Education as a method of educational improvements is needed.

1.1.2 Gaps of Traditional Engineering Education Systems

Despite the challenges in engineering education, it is amazing that these gaps are perpetuating by long-recognized shortfalls that exist between engineering education systems and the needs of engineering graduates and employers. Fifteen years ago, Bucciarelli et al. (2000) discussed this at a workshop at MIT sponsored by the National Science Foundation about the need to reform. He shared a concern of one of the speakers in the workshop: "What kind of a student are we sending out to the world? …a graduate harboring technical arrogance with no understanding of the manufacturing process, who lacks design capability and creativity, lacks appreciation of alternatives, who all want to be analysts, with no understanding of the quality (improvement) process, weak communication skills, and little skill in working in teams." (Bucciarelli et al. 2000).

Not much has changed. For example, eight years later, findings from a 2008 survey of Aalborg University (Ingenioren 2008), Denmark, showed the deficiencies in engineering graduates (Fig. 1.2), as a lack of understanding of business models, project management and communication.

Another study taken two years later from North America was a survey driven by the ASME Vision 2030 (2010) (Fig. 1.3).

The red arrows of the graph in Fig. 1.3 show five competencies that need more strength: (1) problem-solving and critical thinking; (2) communication (oral and written); (3) practical experience; (4) overall system perspective and (5) engineering codes and standards. Immediately followed are other competencies such as project management. This graph also shows that in general, technical content mastery, outside of codes and standards, are in good shape.

So, it seems that a solid and longstanding accomplishment has been in the mastery of content. However, the same cannot be stated about mastery of workplace

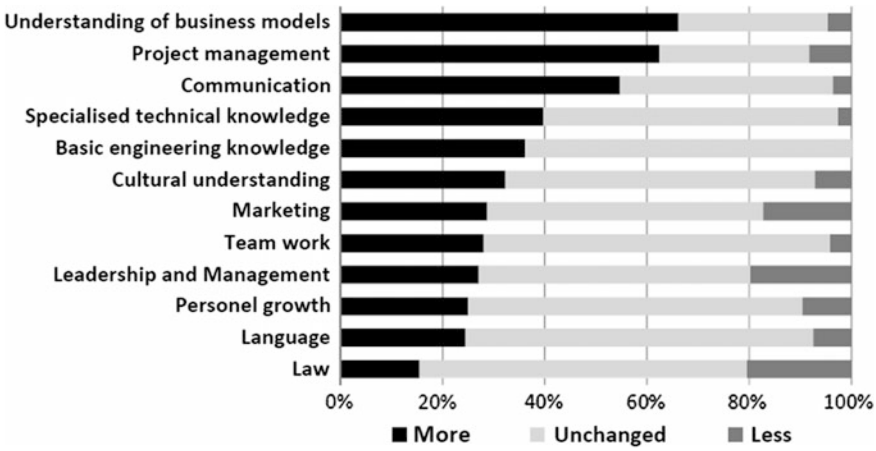

Fig. 1.2 Deficiencies of engineering students, from Aalborg University (Ingenioren 2008)

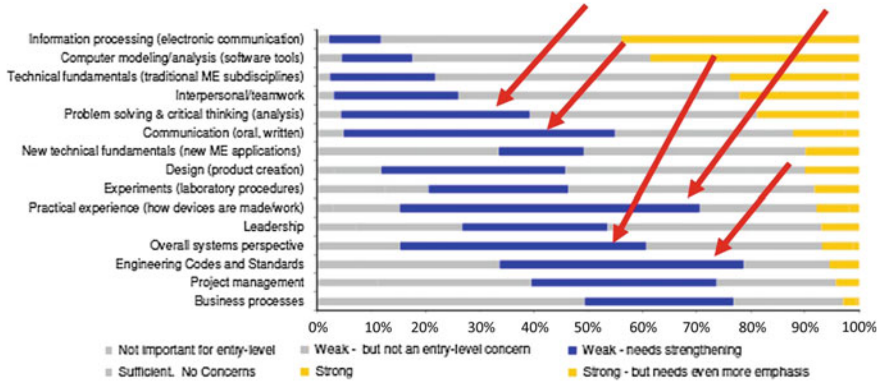

Fig. 1.3 Deficiencies of engineering students, findings from ASME Vision 2030 (2010)

competencies. According to OCDE (2005) "a competency is more than just knowledge and skills. It involves the ability to meet complex demands, by drawing on and mobilizing psychosocial resources (including skills and attitudes) in a particular context. For example, the ability to communicate effectively is a competency that may draw on an individual's knowledge of language, practical IT skills and attitudes towards those with whom he or she is communicating." For varied reasons, competencies such as problem-solving and critical thinking, project management, communication, and team work amongst others are missing in engineering graduates' acumen.

There is a gap in engineering professional practice (EPP) demands and graduate readiness. It is a competency gap. Curricula and programs designed and provided by the Academy are not addressing competency development that is needed in the workplace. Therefore, there is a need to establish a positive interaction between engineering education systems and engineering professional practice. This is demanded to create a meaningful work environment for engineering professional practice, a challenge which is considered inconceivable in any other way (Davey et al. 2011).

A lot of causes could be the roots of this gap in engineering education development of competency mastery for professional practice. This problem was explored in at least two conferences devoted to the Engineering Education theme by the authors of this book. During these sessions, participants (that included students), were asked to fill in the cause-effect (or fishbone) diagram (Alves et al. 2013a, b) (Fig. 1.4) on what they believed were the sub-causes for the lack of connectedness of engineering education to practice. Six main causes were identified as contributors to this gap:

(1) faculty, (2) culture/governance (administration), (3) industry, (4) learning methodologies, (5) student and (6) contextual issues.

The largest number of sub-causes were pointed out in the faculty (or academy) branch of this diagram. This is aligned with what Graham (2012) from Royal

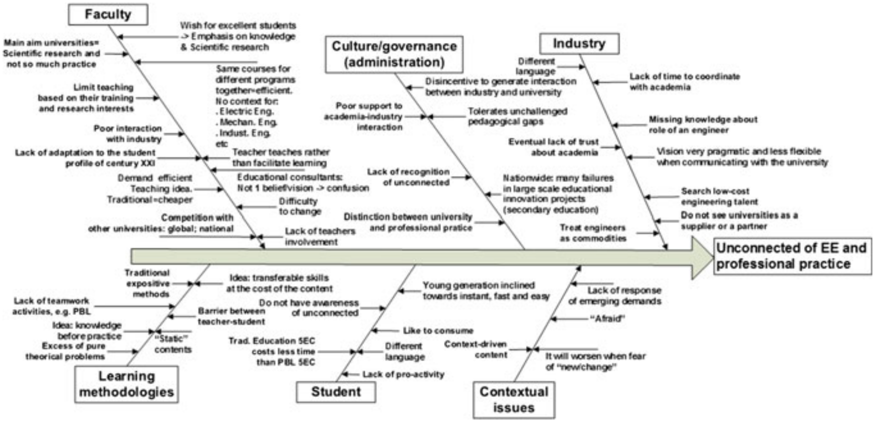

Fig. 1.4 Cause-effect diagram with the causes for the unconnected of Engineering Education and professional practice filled by conferences participants

Academy of Engineering reported as the resistance to change, isolated instances of success in individual programs and on individual campuses, the gap between what universities teach and what industry needs versus shared faculty intelligence on what change is needed and how to do it.

Additionally, Mills and Treagust (2003) emphasized similar critical issues about engineering education systems: (1) engineering curricula is too focused on engineering science and technical courses without providing sufficient integration of these topics or relating them to industrial practice; programs are content driven; (2) current programs do not provide sufficient design experiences to students; (3) graduates still lack communication skills, teamwork experience and programs need to incorporate more opportunities for students to develop these and other competencies; (4) programs need to develop more awareness amongst students of the social, environmental, economic and legal issues that are part of the reality of modern engineering practice; (5) academic staff lack practical experience, hence are not able to adequately relate theory to practice or provide design experiences; and (6) the existing teaching and learning strategies or culture in engineering programs is outdated and needs to become more student-centered.

As pointed out earlier, the academy has the essential role to play in these matters. Unfortunately, very few teachers are aware of these challenges. This may be because they are not engaged in the process or they were not prepared to face changes in the ways that they teach. As a response to the need to better prepare faculty for teaching students for real world applications, the European Commission asked for a report from the High Level Group on the Modernization of Higher Education (European Commission 2013) on how to improve the quality of teaching and learning in the European Higher Education Institution.

This report presented sixteen recommendations, some related to teachers' pedagogical training (Recommendation 4). In addition, the need to recognize and reward the teaching activity at the same level as research activity was made (Recommendations 2 and 6). The importance of assessment of teaching performance (Recommendation 5) and the need for new methods of teaching and learning (Recommendation 7) were also made. In addition, commentary was presented on the heavy and bureaucratic structures that have been characterizing universities that must be transformed into flatter organizations allowing them to meet society's demands in a timely manner.

1.1.3 Demands for New Educational Methods and Strategies

Attending to the challenges faced by engineering education and the gaps of education systems, it is evident that there are urgent needs for new educational methods and strategies to emerge. UNESCO (2010) enlightened four main needs regarding engineering education as: (1) to develop public and policy awareness and understanding of engineering, affirming the role of engineering as the driver of innovation, social and economic development; (2) to develop information on engineering, highlighting the urgent need for better statistics and indicators on engineering (such as how many and what types of engineers a country has and needs); (3) to transform engineering education, curricula and teaching methods to emphasize relevance and a problem-solving approach to engineering; and (4) to more effectively innovate and apply engineering and technology to global issues and challenges such as poverty reduction, sustainable development and climate change—and urgently develop greener engineering and lower carbon technology.

This same report highlighted the increased risk for both engineering practice and society due to budget constraints and funding reductions due to the current economic crisis. Also, it recommended some changes for universities: "*University courses can be made more interesting through the transformation of curricula and pedagogy using such information and experience in more activity-, project- and problem-based learning, just-in-time approaches and hands-on application, and less formulaic approaches that turn students off. In short, relevance works! Science and engineering have changed the world, but are professionally conservative and slow to change. We need innovative examples of schools, colleges and universities around the world that have pioneered activity in such areas as problem based learning. The future of the world is in the hands of young engineers and we need to give them as much help as we can in facing the challenges of the future.*" (UNESCO 2010 p. 32).

According to King (2012), flexibility should be added to the curriculum by incorporating: (1) more understanding of the human condition, cultures, and society; (2) an ability to work effectively with public policy, business, and government; (3) an understanding of the process of innovation and factors contributing toward it; (4) an ability to work in synergy with persons from other disciplines, including both

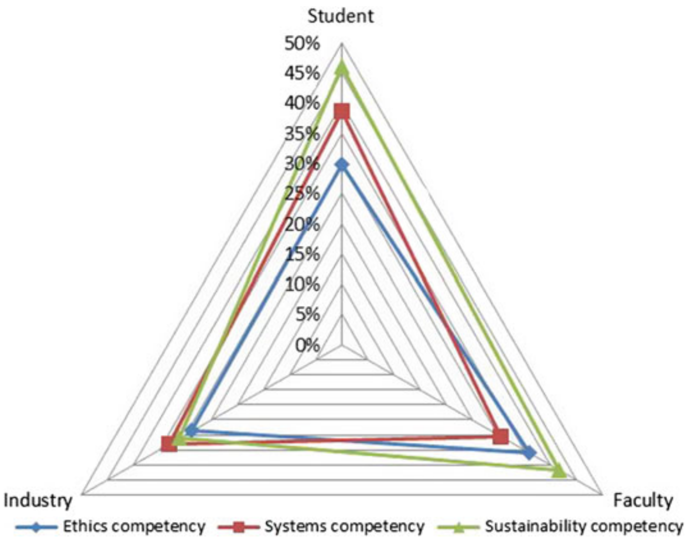

Fig. 1.5 Radar chart of competences needed for ME graduates

other science and engineering fields and non-science/engineering fields, such as business, law, economics, public policy, political science, and sociology; (5) an ability to communicate and to express technical issues in simple, understandable terms; and (6) promotion of a general liberal education, integrated with EE.

According to the ASME Vision 2030 (2010), three competencies are fundamental to the engineering graduate: ethics, system-thinking and sustainability, as viewed through the lens of students, industry and faculty (Fig. 1.5).

Beyond this, it is necessary for scaled collaborations with organizations to help define the profile of the graduating student and in identifying the skills and competencies that students must possess to be successful on the job. As an example of the collaborations needed, organizations can provide students with real life projects with mentors, offering both students and faculty internship opportunities in engineering settings as stated by Morell (2008).

Such initiatives are happening in different regions (NAE 2012; Rokkjæ et al. 2011; Alves 2013a, b). Active and student-centered learning methodologies that provide better educational methods, have been adopted (Mills and Treagust 2003; Felder et al. 2000; Powell and Weenk 2003; Kolmos and de Graaff 2007). These learning methodologies also provide appropriate methods, e.g., through projects that link to the workplace. There are many examples of successful education programs that use projects or Project-Based Learning (Lima et al. 2007, 2009; Alves et al. 2012a, b, 2014c; Oliveira 2007; Aggarwal 2011).

1.2 From Lean Operations to Lean Education

This section briefly introduced Lean Production and the need to change education to meet the needs of the workplace through competency development. To provide more detail, Lean Management origins, principles and tools in manufacturing are succintly presented next, followed by applications of Lean Management to other areas. Finally, the case for Lean Education is presented.

1.2.1 Lean Production: Origins, Principles and Tools

The National Institute of Standards and Technology (NIST) (2015) defined Lean Production as "*… a series of tools and techniques for managing your organization's processes. Specifically, Lean focuses on eliminating all non-value-added activities and waste from processes. Although Lean tools differ from application to application, the goal is always incremental and breakthrough improvement. Lean projects might focus on eliminating or reducing anything a final customer would not want to pay for: scrap, rework, inspection, inventory, queuing or wait time, transportation of materials or products, redundant motion and other non-value-added process steps.*"

In this definition, wastes are also presented, which were first defined by Ohno (1988). Additionally, others authors, namely Liker (2004) have defined additional waste categories, such as social capital waste as untapped human potential. Social capital waste is considered the most serious form of waste as inhibits evolution and innovation. Human potential, supported by process improvement and technology, is a hierarchial combination. The ability of people to learn and continuously improve is the organization's way to achieve perfection.

The pursuit of perfection is the fifth Lean Thinking principle from Womack and Jones (1996). The other four are: (1) Value—identify what is the value for the client; (2) Value Stream—identify the activities that add value to the products; (3) Continuous flow—means a smooth and levelled workload without waste and (4) A pull system—this means that it is the client that triggers the product/services delivery, content and metrics. Systematically applying these principles, organizations continuously improve in order to aspire perfection.

To comprehend these principles, organizations must also have the ability to apply the correct tools to achieve each principle. There are many tools available such as standard work, visual management, 5S, kaizen, quick changeover (QCO), single minute exchange of die (SMED), poka-yoke mechanisms, and levelling, among others (Feld 2000). It is necessary to know when and how to apply these tools (Wilson 2010; Maia et al. 2012) for a successful Lean implementation.

1.2.2 Lean Production Extended

This section presents disciplinary areas that had been applying LP. Moreover, it presents its application in Educational curricula in some universities.

It is now evident that Lean Management is cross-sectional and global (Alves et al. 2014b). Furthermore, Lean Thinking (LT) has been adopted in many disciplines/areas (Fig. 1.6):

- Lean Services—applied to services delivery (offices, hospitals, education, restaurants, …)
- Lean Office—applied to administrative processes in office; is normally included in the first category
- Lean Higher Education—applied to universities processes; is normally included in the first category
- Lean Construction—applied to construction of houses, roads, bridges, ships and others products of large dimension in a fixed site (or project) type layout
- Lean Green—applied to achieve the sustainable development (toolkits of U.S.—EPA)
- Lean Coaching—applied to human resources, training and people development

Fig. 1.6 Disciplines/areas that apply/combined Lean Thinking

- Lean Six Sigma—applied to process improvement
- Lean Supply Chain Management/Lean Logistics—applied to supply chain and warehouse management
- Lean Accounting—applied to accounting
- Factory of One/Personal Kanban/Personal Management—applied to individual performance
- Lean Startup—applied to software development and entrepreneurship
- Lean Project Management—applied to project management
- Lean Leadership—applied to leadership
- Lean Product Development—applied to product development
- Lean—TRIZ—combined the methodology Theory of Inventive Problem Solving with Lean
- Lean Education—applied to Education program, curriculum design and delivery.

The success of Lean Management is related with its inherent philosophy, Lean Thinking, as this implies a culture change and a new mind-set. Any company that embraces Lean Thinking will be in a continuous improvement effort where everything is questioned by valued stakeholders. People are transformed in truly active thinkers and learners (Alves et al. 2012a, b) who will continuously search for problems to solve, being unsatisfied with status-quo. Lean Management prompted by Lean Thinking is carried out in a systematic and continuous way. Organizations are better prepared to face the global challenges which technological progress is not capable to solve. In fact, technology sometimes, provokes more damage than good if it is not a solution for an identified problem. Therefore, it is not a surprise than Lean Thinking principles and tools have been adopted and combined in so many disciplines.

1.2.3 Lean Education

Authors in this book show both why and how they have been integrating Lean Management into courses within programs. For example, this section is dedicated to examples of training the workforce and educating students in Lean as an imperative for the new industrial challenge. This coursework prepares students to work in Lean environments, saving organizational investment in employee training.

For these reasons, Lean Education has been a concern of some important initiatives and networks. The Lean Aerospace Initiative (LAI) Educational Network (EdNet) is one of these networks. This was established in 2002 and comprised 32 universities (from US and UK) who share a common interest to collaborate on developing and deploying curriculum for teaching lean six sigma fundamentals (Murman et al. 2007). In a faculty collaboration effort, supported by a small staff centered at MIT, a LAI Lean Academy® a week-long course was developed. This course is delivered to multiple audiences on-campus, in industry and government.

The course is based on the CDIO approach (Comprehend/Conceive, Design, Implement and Operate) (Crawley et al. 2011).

Murman et al. (2007) discussed the Body of Knowledge (BoK) for Lean Thinking arguing that this BoK is not based upon laws of physics and chemistry and is not represented by sophisticated mathematics. This is due to its roots that are based on processes and people/organizational dynamics for which there are no laws. According to Murman, the Lean BoK relies on understanding “best practices” which are observed through field research of actual enterprises. These best practices are variable with time, which means that the Lean BoK is subject to change. Just like many engineering science disciplines are, information technology is a big factor in the current evolution of the Lean BoK.

Murman et al. (2014) presented the LAI Lean Academy’s experience as a decade-long undertaking to develop and widely deploy an introductory Lean curriculum. The origins, objectives, and history of the effort are summarized, as is the content of the core three-day short course. Versions of the curriculum have been offered to over 1600 participants in 60 short course and semester-long subjects taught by 45 different instructors in the United States and Latin America. Over 270,000 visits have been made to the curriculum posted on MIT’s Open Courseware. Findings on the learning outcomes are presented in the paper mentioned based upon the extensive database complied from student feedback and self-assessment.

Another network is Lean Education Academic Network (LEAN) (Fliedner 2007). LEAN is a group of university educators seeking to promote Lean education in United States higher academia. LEAN also helps improve Lean education through sharing of knowledge and teaching materials, collaboration, and networking among colleagues.

These networks, together with Lean Enterprise Institute (LEI) that has been also concerned with Lean Education (Womack 2006), are sponsoring a conference—Lean Educator Conference (LEC) with the objective of sharing best practices in Lean curriculum and pedagogy (http://www.leaneducatorconference.org/news/99-2014-lean-educator-conference-call-for-papers.html).

Moreover, a project joined Dutch, Swedish, Polish, Portuguese and Romanian universities and companies in a project in the framework of an Erasmus–Lifelong Learning Program (LLP). Martens (2009) presents the report of this project considering this an innovative training program on Lean Manufacturing. The objectives of Lean Learning Academy (Martens et al. 2010; Carvalho et al. 2013) with this project are to satisfy the need for training lean manufacturing principles in companies and to improve engineering students’ employability in professional life.

Another important school in Lean Education is Buckingham University which has been providing a Masters in Lean for 15 years (Bicheno 2014). Another author, Emiliani (2015) provides information on Lean Teaching and how to use Lean principles and practices to improve college and university teaching (2015). This author has been actively involved in Lean Leadership and Lean Management. Lean Leadership Education has also been a concern of Flumerfelt, presented in Chap. 6.

It is important to notice that teaching Lean Management content demands active learning methodologies (Prince 2004) to engage students in their own thinking, learning and in collaborative learning. Moreover, it is also evident that project work in organizations or as job-embedded learning is a frequent methodology. This is not a surprise because the Toyota Education Model is a “learning by doing” system. According to some authors, namely Huntzinger (2002), this system was adopted from the model, Training With Industry (TWI), for equipping people in industry to support U.S. industry during World War II. TWI has Lean roots, using a lean tool, kaizen. Lean is the foundation for TWI.

These publications evidence that incorporating Lean Thinking into Lean Education is truly a valuable proposition for students to develop competences needed by the workplace and society now and in the future. This issue is discussed in detail in the next section.

1.2.4 Lean Engineering Education

Lean Education derives from the Toyota Education Model that was taught in all factories of Toyota in Japan and abroad (Liker 2004). Under this model, Lean is promoted using Socratic methods versus didactic methods, allowing for learner-centered methods and project-based learning. The Toyota Education Model therefore, is regarded as the mechanism which helps to build the fundamental mind-set for continuous improvement. It was also recognized by others who rapidly adopted the Toyota Education Model (Sugimori et al. 1977; Suzaki 1993; Spear and Bowen 1999; Minoura 2003; Spear 2004; Stewart and Raman 2007; Takeuchi et al. 2008; Yamamoto and Bellgran 2010).

As an instructional improvement method, higher education faculty are beginning to adopt the concepts in the Toyota Education Model to prompt continuous improvement in different ways. For example, this is being done through a focus on instructional improvement at the classroom level; concentration on system-wide improvement; and addressing the collective impact of educational programming through data versus expertise (Park et al. 2013).

1.2.4.1 Definition

Lean Education is promoted as the most aligned way to obtain two benefits: (1) to provide content-competency mastery via the Toyota Education Model and (2) to engage in education continuous improvement. Specifically, Lean Engineering Education is defined by Flumerfelt et al. (2015) as:

> A systematic, student-centered and value-enhanced approach to educational service delivery that enables students to holistically meet, lead and shape industrial, individual and societal needs by integrating comprehension, appreciation and application of tools and concepts of engineering fundamentals and professional practice through principles based on respect for people and the environment and continuous improvement.

This definition is the basis for designing the curriculum, for teaching and learning, and for assessing student progress in the engineering classroom. From an incremental and analytic building process of continuous improvement through the Toyota Education Model, the authors see Lean Education as a body of knowledge that provides a framework for lean competencies to emerge. For example, Lean Engineering Education provides a holistic engineering education (DeGrasso and Martinelli 2007) through the development of a competency-based model of Head-Heart-Hands (3H) taxonomy (Flumerfelt et al. 2014).

1.2.4.2 Lean Thinking Principles to Educational Services

Lean Thinking principles are translated to the educational services as described:

- Value—identify what is the value for the client. At first place, it is necessary to define the client. In this case, clients are engineering student, the engineering employer or, in a more global view, the society and faculty. The engineering students pay tuition to receive a value in the form of an education. The employer hires the engineering student to benefit from the value added to the products designed, created and built to a consumer society. Faculty must provide engineering education services of quality and supply the right needs of society and employers at a reduced cost and time. At the same time, they must feel they are doing something with meaning.
- Value Stream—identify the activities that add value to the products. This means to organize the programs in a way that only valued activities are processed. Clients did not pay waste activities, so engineering student want an education that serves perfectly the employer and society needs, with faculty collaboration and engagement that care for them.
- Continuous flow—continuous flow means a smooth and levelled workload without waste pushing back the students, faculty and society.
- Pull system—this means that the client triggers the services, delivery and content. So, needs from student engineering, faculty and society must be addressed. It was possible to see above the three competences are systematically referred: systems, sustainability and ethics competencies. Seeing the whole, and not only a part, using problem-solving tools and system thinking are skills needed in systems engineering (Kahlen et al. 2013). Sustainability competency demands knowledge of sustainability characteristics, principles and to some tools like product life-cycle analysis among others (Moreira et al. 2010). Sustainable development is achieved when students are taught Lean principles of reducing waste in all of their forms (Alves et al. 2014a). Ethics competency is an expected behavior of the engineering profession and is normally supported by a body of knowledge (standards, fundamental canons and behavior descriptions). But, more than knowing, competencies must be believed in as valuable and practiced as such (Flumerfelt et al. 2012). So, Lean Engineering Education, as taught with respect for people from the Toyota Education Model

is a platform to achieve this (Flumerfelt et al. 2013). These three competencies, among others, are the dorsal spine of the value stream that adds value to the delivery of the Lean Education—incorporating competency mastery as a student learning outcome.

- Pursuit of perfection—means to continuously be unsatisfied with the status-quo and search continuous improvement, i.e., eliminating wastes of all types. This only happens when people are engaged and continuously think about the improvement to the process, making this a way of life (Alves et al. 2012a, b).

The proposal for Lean Engineering Education offers a model for Lean Education. Lean Education posts benefits for the Academy that include the improvement of course design/delivery based on Problem/Project-Based Learning and the improvement of the overall quality of the learning experience based on student-centeredness. In addition, it is possible to obtain student outcomes that encompass the double helix DNA mental model of content and competency mastery simultaneously. It is believed that Lean Education is a venue to bridge the gap between academy and the workplace (Kahlen et al. 2011).

The authors of this book consider Lean Education as a suitable platform to prepare students for the workplace. The poster in the format of A3 report of Fig. 1.7 depicts how Lean Engineering Education would accomplish this.

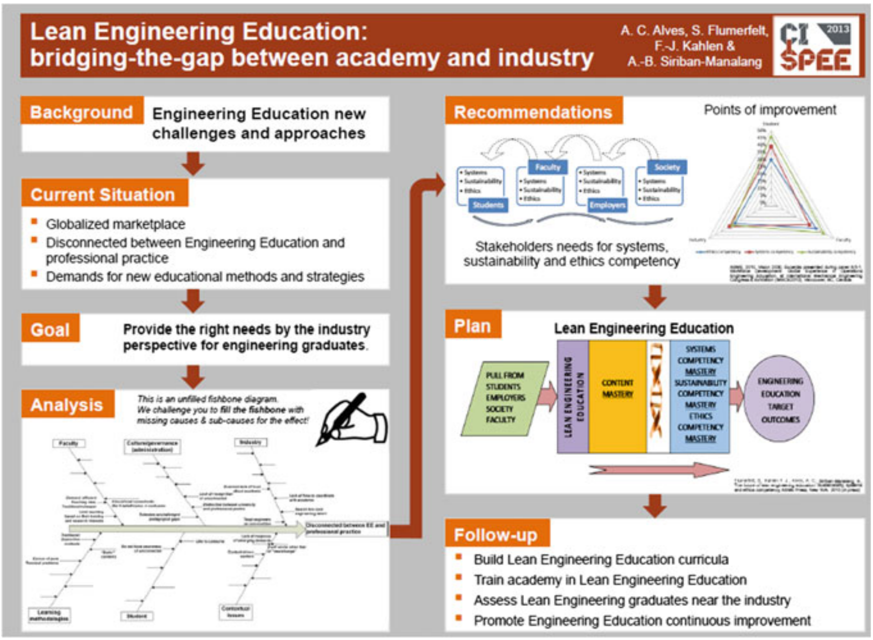

Fig. 1.7 Poster presented in First Conference of Portuguese Society of Engineering Education advocating Lean Engineering Education (Alves et al. 2013a, b)

It is proposed for Lean Engineering Education, that sustainability, ethics and system-thinking, along with content mastery, should be spiraled and integrated in the engineering program. Notice that by adopting Lean Education as a strategic methodology for curricular programs, the workplace, students and faculty will need to be aligned in the same purposes. The workplace benefits come with provisions of Lean Education through real work applications for students, such as in reducing cost and increasing productivity/profits, by reducing/eliminating waste and having more potential employees prepared and motivated. This work requires technical content knowledge, lean knowledge and competencies, such as system-level thinking, ethical, and sustainability competency.

Through Lean Education, the Academy benefits from the improvement of course design/delivery, overall quality of the learning experience delivered to students and more relevant student learning outcomes. Because of its global recognition, Lean Education could provide leading edge approaches to content and competency mastery for workplace preparation. Lean Education is a venue that translates well culturally, corporately and educationally.

1.2.4.3 Lean Engineer Profile

Lean Engineering Education is developing a different profile of engineers and is recognized as a must in this education (Alves et al. 2016). For example, in the case of the Industrial Engineer, a new type of worker is defined. According to Black and Phillips (2013) this new type of Engineer is a Lean Engineer defined as "*The Lean Engineer (LE), has an Industrial Engineering foundation, enhanced with lean tools, six sigma capability and a lean to green outlook to take the plant to zero waste going to the landfill*."

Further, students who could benefit from learning about Lean or engaging in an institution using Lean Education is endless as Fig. 1.8 shows. Anyone can learn Lean principles because they are universal. People taught to think using lean, benefit from critical thinking and data-driven analyses.

1.3 Lean Education: Some Cases

This chapter presents the authors that were invited to write about their Lean Education experience. Before this invitation, they were invited to fill a survey about Lean Education experience in their university/organization. The list of contacts come, mainly, from LEAN (Lean Education Academic Network) and personal contacts. The link for the electronic questionnaire of the survey was sent to more than 130 emails in March, 2015, from these almost 40 gave an error of delivery. To this call, 22 valid questionnaires (24 %) were received.

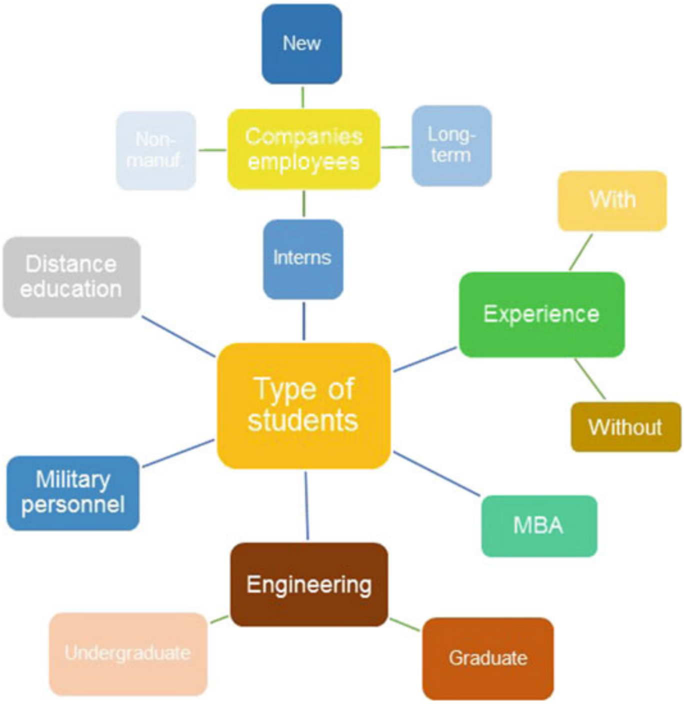

Fig. 1.8 Lean Student profile

To the call for writing the book, nine authors answered and one of the chapters came in after a posterior contact. Next, this chapter introduces nine sections related to the authors chapters.

The following sections present these chapters that are examples of Lean Education just by the order of reception. The first case comes from a Federal Institute of Applied Sciences, Brazil which is still preparing the Lean Education implementation. The second case is from De La Salle University, Philippines. The third case occurred at Kettering University, USA, which emphasizes the student-active simulations to teach Lean. From the Faculty of Science and Technology, Universidade NOVA de Lisboa, emerges the fourth case of Lean education that joins the TRIZ methodology to lean teaching. The fifth case is about Lean education in Oakland University, focused on Lean Leadership, rather than management or engineering, typicall programs in Lean Education. The next case describes the application of Lean Education in France, ECAM Lyon. The seventh case is described in Chapter Eight and presents an educational model from the University of Tennessee by Sawhney. Case nine comes from Poland, the Faculty of Mechanical Engineering and Aeronautics of Rzeszow University of Technology which was integrated into a Lean Learning Academy. The tenth case comes from Portugal, the University of Minho and describes the faculty innovation in lean engineering education.

1.4 Responding to the "What, Who, When, Where, How and Why"

From the cases presented in the following chapters, it will be possible to respond to the what, who, when, where, how and why of Lean Education that drove this book project. In the previous sections, the attentions were on Engineering Education and Lean Engineering Education maybe because of the alignment of Lean origins in manufacturing as this is the most natural fit. Nevertheless, some chapters show the importance of using Lean Education to train students at early grades and also to training our future leaders as lean leaders. In summary, this book presents a solid case for new important and useful Lean Education is worldwide as widely embraced content. And further, it builds a case that Lean Education assists in answering the demands of globalization and the workforce needs of this era.

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Chapter 2
Lean Education for Applied Science Universities: A Proposal by Federal Institutes of Applied Sciences in Brazil

Andre Fernando Uébe Mansur, Fernando Carvalho Leite and Helvia Pereira Pinto Bastos

2.1 Introduction

"Lean" is the Womack et al. (1990) designation for the industrial process revolution proposed by Kiichiro Toyoda for his father's company—Toyota, after the Second World War. More than a collection of tools and methods, Lean is a philosophic approach that changes both the individual and the organizational culture taken by principles "continuous improvement" and "respect for people" to increase the value and performance of processes by elimination of waste tasks and improvement of its remaining.

Lean principles can be applied in many different areas like construction, coaching etc. Lean Education is an appliance of the philosophic approach (also Lean Thinking) in educational contexts intending to increase student performance and save costs by increasing the value and performance of school organizational processes.

Despite Brazilian government investments in Education, a lot needs to be done. From infrastructure to review of pedagogical methods. It is not an easy challenge: in a territorial comparison between Brazil and Finland, for instance, you can see that Brazil is 25 times larger. The exceptional territorial and population magnitude increases, significantly, the challenges of managing this young country (only 515 years old) of European colonization.

From the first industrial revolution processes, Brazilian education adopted the organization model and practices. Although not a Brazilian privilege, since public

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schools, on a global level, traditionally ground their practices and ways of thinking on the "factory model", these disseminated models are not suited to the new demands of contemporary society.

As explained above, Brazil has a large territory and population—202,768,562 inhabitants in 2015 (IBGE 2015). In this context, the role of the network of Brazilian Institutes of Applied Science plays an important role in Brazilian education.

As detailed in Sects. 2.3.1 and 2.3.2, the roots of Brazilian Federal Institutes of Applied Science date back to 1909, consisting now of quite a large institutional network comprising of 341 campuses spread throughout the Brazilian territory.

Despite few exceptions, and considering the magnitude of the network of Institutes of Technology, empirical observation shows that the "factory model" is widely applied in management and pedagogical thinking. From this problem, it is possible to identify some driving questions such as: Is it possible to increase performance outcomes from an educational process as a whole? Is it possible to increase effectiveness and quality of the learning process of students? Is it possible to improve cost saving? Is it possible to increase customers and stakeholders satisfaction?

Lean appliance in Brazilian industries is very late. Until the 90s, it was not a reality in the industrial production context (Ferro 1992). In the educational area, it is not a reality as the "factory model" is still common sense. It is not possible, at this point, to address all the aspects involving such relevant issues, which justifies, therefore, the need for improvement.

Thus, the main goal of this study is to present a model to trigger the discussion about Lean Education under a pedagogical and managerial point of view, not only within the Brazilian network of Institutes of Applied Science, but also in other similar public educational systems. The study also presents a review of Lean and Lean Education concepts, as well as an overview of pedagogical models used at the Brazilian Institutes of Applied Science.

This chapter is structured in six sections. Section 2.2 gives a brief description of the historical evolution of Lean concepts. This is followed by a section on Lean in Education. Section 2.3 brings an overview of the development of Brazilian vocational education, specially the creation of the Federal Institutes of Applied Science, and their pedagogical and administrative infrastructure. Section 2.4 presents the model of Lean Education proposed for implementation at the Federal Institutes of Applied Science, which may be a starting model to similar cases in Brazil, or in other countries. Section 2.5 brings some outcomes from the presented model, and references are given in the last section.

2.2 About Lean

After World War II, Japan was a war-torn country with economic, financial and social development needs. For this reason, the Japanese government promoted a series of visits to American companies trying to apprehend their industrial models, and apply them in Japan to boost their economic and industrial development.

In this context, a young engineer and entrepreneur named Kiichiro Toyoda had contacted the famous American industrialist Henry Ford who showed him his enormous and complex automotive industrial process. From this experience Toyoda noticed that the American industrial process could not be applied in the Japanese context, since Japan did not have the same amount of resources as the United States.

The social and economic context in Japan was different from the United States: while the industrialization process and urban life were a reality in the United States, Japan was a rural country. The United States had plenty of resources and avid urban consumers with general needs. On the other hand, Japan was a country with very limited production resources and rural consumers with specific needs. Therefore, the challenge for the Japanese development was to create a model adapted to the existing reality of scarcity in which do more with less, have continuous improvement and respect for individuals, would be a kind of mantra. In this context, "less" means not only few resources (human, material etc.) but little effort, compared with the American industrial model (Womack et al. 1990).

With such challenges, Toyoda developed a production process model based on four premises: (1) Long-term thinking philosophy; (2) Waste elimination by continuous process improvement; (3) People and partners respect and grow; (4) Continuous improvement and learning by a problem-solving approach (Liker 2003). These basic premises has driven the production style proposed by Toyoda, allowing Japan to change the global industrial production model after the 70s. According to Alves et al. (2014, p. 1), "This learning system inside company doors has been the Toyota success and inspiration for many manufacturing industries and services providers to follow".

Because of the petrol crisis, the United States was under a restrictive economic situation in the late 70s. The high prices of oil made American automobiles and their industrial production model unsuited for the new reality. The huge and guzzling cars produced on assembly lines based on the outdated concepts of Henry Ford, in which the waste production was constant and the employee was a mere operating machine, no longer accounted for the current reality. Thus, the American government focused on the Japanese production model developed by Toyoda, hoping it could solve their problems.

In this scenario, Womack and colleagues, MIT researchers, made a series of studies that adapted the Toyota model to the western management philosophy which they named Lean (Alves et al. 2014). According The National Institute of Standards and Technology (NIST, s.d.), Lean is "… a series of tools and techniques for managing (…) organization's processes. Specifically, (…) focuses on eliminating all non-value-added activities and waste from processes."

To apply the principles of Lean, Womack et al. (1990) developed a methodological process to improve the productive process of manufacturing, eliminating seven different wastes by following five steps along the industrial production process.

- **Over processing**—is any demand of tasks, activities existing at the production process that are not really useful to aggregate value perceived by the customer in the final product. For this reason, this idle process is considered as waste, since all effort and resources applied will not be useful to the final result and perceived as quality by the customer.
- **Overproduction**—is caused by a production faster or larger than necessary (demanded by customers), resulting in problems like large batch sizes, unreliable process, production and market/customer demand mismatch. Contributing to increasing inventories of final products and processing products, is a kind of waste since these waiting products mean investment of production resources (material, people etc.) that do not aggregate value to customers and the organization.
- **Inventory**—Promoting huge product stock of manufactured or in process products. It is a consequence of Ford's way of thinking. Focused on a homogeneous market, this concept is a trap to contemporary production needs since it hides many bad contingencies that exemplify waste of resources like unidentified defective machines manufacturing defective products; unnecessary human workload and unnecessary use of production resources.
- **Transport**—Within the Lean context, this kind of waste refers to any kind of unnecessary and useless movement of raw materials, products, production equipment etc., resulting from inadequate layout of the workstation, bad work flow, poor layout with extended gaps between operational steps, multiple and redundant stocks. All these are examples of waste cause.
- **Motion**—Refers to all the unnecessary motion of human parts or machines within a process. It can result from an inadequate step-by-step workload plan or an inadequate building layout or equipment arrangement.
- **Waiting**—is any idle time produced when interdependent processes are not synchronized, generating human or machine waiting, or slowing the process in its whole.
- **Defects**—is a quality error that increases final costs more than expected, because of the need of defective items to be reworked or replaced is a waste of resource and materials.

Waste elimination is a priority in lean application, and five steps can be followed to achieve it (Womack et al. 1990):

- **Specifying value**—Value can be understood as what is perceived as really important by the customer. It is not the organization but the customer who defines what is valuable. A usual mistake at this point happens when the organization is sure it knows what is really important for customers without previous enquiry.
- **Mapping value stream**—Once the customer's concept of value is defined, it is important at this step to analyse the value chain in its whole, and categorize the process in three categories: (1) the ones that really aggregate value; (2) the ones that do not aggregate value but cannot be eliminated at first since they contribute

to the maintenance of process and of quality and; (3) the ones that do not aggregate value and need to be eliminated immediately. In its chain value analysis, the organization usually focuses only on short-term indicators, i.e., being more concerned about costs than value.

- **Flowing the processes**—This is the most difficult and stimulating stage, since it presupposes changing the mind of those involved in the process. From a philosophical perspective, it is like shifting from the Cartesian (Descartes 1637) way of thinking to the Complex (Morin 2001) way of thinking. The adoption of a Systemic approach (Bertalanffy 1968; Uébe Mansur et al. 2013) helps this change of mind process since it extrapolates the initial idea of process segmented in departments and sections as recommended by Ford and Taylor.
- **Pulling the processes**—Once the processes are flowing, it is necessary to reverse them, making the customer call for the production. This concept production originally occurring at push conception will happen under a pull conception. This process is important in the way to eliminate a lot of wastes like inventory, transport and others since the production will start and be produced after customers ask for it.
- **Promoting perfection**—The main goal of this step came from the idea that Lean application needs to be a continuous improvement, as there is no end in the process of reducing wastes and since customers' need and behavior change all the time in regards to what is valuable for them.

Until the 90s, Lean was not a reality in Brazilian industrial production. This was mostly due to two main aspects: working models and human resource policies.

Several issues contributed to effective adoption of Lean Effective in the 90s, including: previous success of mass production model since the 50s; adoption of Lean techniques not regarded as a behavior philosophy; lack of dialogue among employers, workers and unions; centralisation of management authority; lack of pay-for-performance (Ferro 1992).

As a methodology for improving production processes in industries, Lean has been very successful worldwide and, as a result, its premises have been applied in different fields such as services, offices, higher education, construction, education, coaching and so forth (Colombo et al. 2014). For this study, the authors focus on an application of Lean—Lean Education (LE).

2.2.1 Lean in Education

Education is a term used to refer to the process of providing the development of knowledge, skills and reasoning in a student or student community (Ziskovsky and Ziskovsky 2007).

Lean Education (LE) is the Lean principle applied to Education with the intention of boosting student performance and saving costs. According to Ziskovsky and Ziskovsky (2007, p. 12), the goal of LE is to "…allow educators to perform the work they went into education to do" by "…a common vision and clear goals that everyone both owns and understands". Some questions can guide this path: What things keep you from doing your work? What should you not continue doing? What makes your work easier, satisfying, and successful? What would improve the skills and capabilities of your collaborators? What would improve your work environment?

LE does not mean shortage of resources. The most adequate idea for LE would be "Doing more with enough", i.e., eliminating steps not valued by customers, since the focus for each step is the aggregation of value by respecting people and recognizing the importance of each process to the mission of the organization.

Taylor and Ford's "factory model" has traditionally been adopted in public schools grounded on Cartesian routines and ways of thinking. Adoption of this scientific management model results in process wastes that reduce efficiency (Flumerfelt 2008). Schools structured around quantitative variables such as amount of time spent on learning tasks, length of the school year, and amount of time teachers spend on instruction are examples of this ineffective way of thinking (Sizer 1984).

LE shows a useful way to change this disadvantage context, because Lean is not only an application tool, method, strategy or a set of improvement process steps, but a kind of map to a journey of learning by an organizations (Flumerfelt 2008).

Flumerfelt (2008) highlights some issues concerning bad results from LE application that come from an intent to use LE not as a philosophy but as a tool without promoting an organizational Lean culture. In this case, problems like inadequate budget prediction, ineffective remediation, and lack of developmental learning opportunities for students can result in Lean failure results.

2.3 Evolution of Brazilian Vocational Education

This section provides a brief overview of how education evolved in Brazil. Following a summary of how instruction was delivered during the colonial and monarchy periods, we present the sequence of reforms that paved the way to the current institutes of technology.

In colonial Brazil, education was mostly provided by the Jesuits who, following their goal of evangelizing non-catholic populations worldwide, opened missions and schools throughout the country. To facilitate the understanding of religious texts and participation in rituals, the Jesuits focused on the teaching of writing, reading and basic calculus (Xavier et al. 1994).

The moving of the Portuguese Court to Brazil in 1808 shifted the political status of the colony, bringing along an increase in various economic areas. This required the opening of the first vocational courses oriented to prepare technicians to work in Agriculture and in the incipient industry of the period. Several institutions, including military academies, were opened to boost studies in Arts, Science, Law and Medicine. Nevertheless, the disregard of the State to implement general instruction nationwide contributed to increase exclusive opportunities for the more privileged classes.

The last decade of the First Republic (also Old Republic 1880–1930) was the period in which the traditional economic model based on the production and export of crops was gradually confronted by the need to increase and improve industrialization to supply missing products not available from European markets during or shortly after World War I. Along with the growth of the middle class, other factors such as the strengthening of leftist political groups (inspired by similar activities in Europe), and various modern literary and art movements, led to more demands for educational reforms.

One initiative was, indeed, successful in the long run, as explained next.

2.3.1 From Schools of Apprentice Crafters to Institutes of Applied Sciences

President Nilo Peçanha created, in 1909, the first public vocational schools—the so-called "Escolas de Aprendizes e Artífices" (EAAs)—one unit in each state capital, and the origin of the future federal network of vocational schools. The motivation for such action was the growth of the urban population in Brazil which, in turn, resulted in larger working classes who required better professional qualification.

Two proposals for educational reforms emerged in the following decades, especially in the early years of the Vargas administration (1930–1954): (1) the Brazilian Association of Educators considered education an essential instrument for social reforms and construction of a national identity; (2) the New School movement (also Progressive School), inspired by the principles of John Dewey and Adolphe Ferrière, claimed that schools should follow the rationale of factories to meet the demands of the increasingly industrial and urban society. The New School ideas also matched the principles of Taylorism (also Scientific Management). This meant adapting industrial means of production to schools; instead of one workshop in which the apprentice learned all the manufacturing steps of a certain component, the learning compound was organized in "sections" made up of various workshops. Gomes (2003) explains that the student would attend the various workshops, but become an expert in only one.

Significant changes in the Brazilian society of the period, added to the development model based on industrialization, strongly affected educational programs. The main concern of the Vargas administration was to train labour forces quickly and objectively to work in the new industrial compounds. Thus, the former EAAs became "Industrial Lyceums" in 1937, and later renamed "Industrial and Technical Schools" in 1937. This reform allowed students who finished vocational schools to apply to Higher Education institutions. According to Machado (2011), the Vargas' educational policy "legitimized separation between manual and intellectual work" by offering more structured secondary instruction programs to meet the aspirations of the leading social elites, while leaving vocational studies for the less privileged.

Following President Kubistchek's plan of economic growth (1956–1961), the "Industrial and Technical Schools" became "Technical Federal Schools" (Escolas Técnicas Federais/ETFs). A significant landmark in the 1960s was the implementation of Law 4.024 in 1961, which established the national educational guidelines (LNDBE[1]). Machado's understanding (2011) is that this document met the demands of the national modernization goals, but encouraged, on the other hand, the increase of vocational evening courses of questionable quality.

Another proposal made after the military coup in 1964 aimed at "fast and constant recycling of the working forces" in the light of changes in various areas worldwide, and based, as well, on the principles of the Human Capital Theory.[2] This led to financial and technical assistance from foreign agencies, known as the MEC/USAID agreements. Despite the intentions of improving education within the government plan to boost economic development in Brazil, Machado (2011, p. 230) emphasizes the increase of: (1) private institutions to supply for the lack of public schools; (2) concern with preparing technocrat-bureaucrats; (3) ideological control of educational programs by associating education with the productive and capitalist demands of multinational companies; (4) decentralization of educational programs by transferring management of basic instruction to the municipalities.

This scenario remained quite the same for the next several decades including the civil democratic administrations as of 1991. However, several important factors contributed to economic and social changes: globalization and the emergence of digital technologies. In 1994, Law 8.984 integrated all federal educational institutions into the National System of Technological Education, reshaping the former ETFs into Federal Centres of Technological Education (CEFETs). Even though this reform was opposite to the previous neo-liberal educational policies, as it sought to expand public vocational schools, it failed to prevent the growth of private institutions who offered more qualified instruction to those wishing to enter a university. (Brasil/MEC/INEP 2010).

By federal decree in 2008, this pool of federal schools gained new status as Federal Institutes of Education, Science and Technology (IFs). Currently, there are 38 IFs with 341 campuses spread throughout the Brazilian territory, offering courses at various levels, including post-graduation. This educational network also comprises 02 CEFETs, Colégio Pedro II,[3] and a technological university.

The underlying learning design of the IFs is that vocational studies become increasingly closer to more holistic educational curricula, i.e., that they provide both specific and general knowledge. Another goal is the offer of programs designed in accordance with regional productive arrangements in order to avoid migration of

[1]Lei das Diretrizes e Bases da Educação Nacional.

[2]For further understanding, see: "Human Capital Theory and Education. Fitzsimons (1999)".

[3]Located in the city of Rio de Janeiro, this school is the third oldest educational institution in the country.

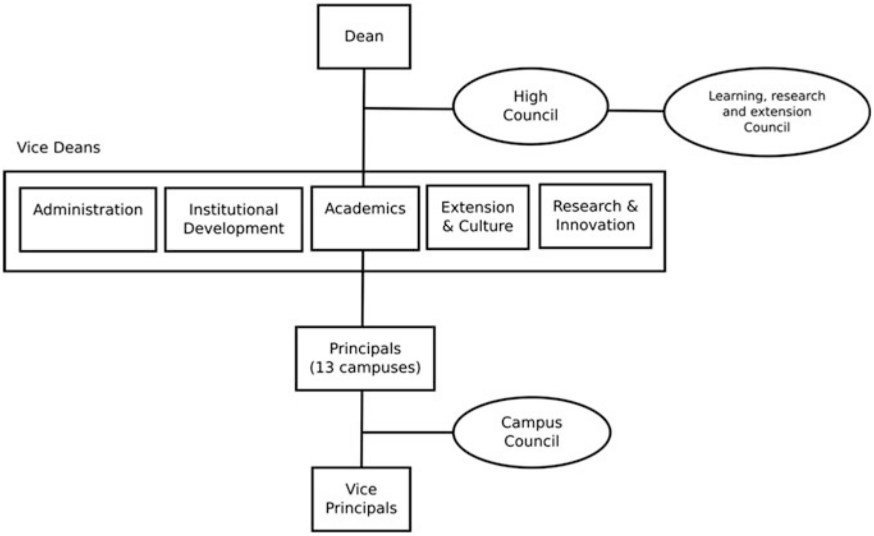

Fig. 2.1 Organizational chart of IFFluminense (IFFluminense 2016a)

local students. Tavares (2012) explains that while Brazilian education was largely influenced by the neo-liberal policies of the late 20th century, the current stage shows a more "democratic-popular" nature. One of the major features of the IFs is the offer of a vertical pedagogical structure in order to include historically marginalized individuals, and the development of critically-thinking citizens instead of the mere training of workforces.

2.3.2 *Instituto Federal Fluminense: Structure and Mission*

To illustrate the range of operation and the organizational complexity of the IFs, this part of the study presents the Instituto Federal Fluminense (IFFluminense).[4] IFFluminense is a large institution located in the northern part of the State of Rio de Janeiro. The main sectors of its structure are presented in the followed chart (Fig. 2.1).

The following data in Tab. 2.1 provide an overview of Instituto Federal Fluminense·

The Institutional and Pedagogic Project drawn by IFFluminense in 2009 defines the philosophical and theoretical principles that guide its mission and academic actions. Some of the objectives listed in this document are:

[4]URL: www.iff.edu.br.

Table 2.1 Instituto Federal Fluminense in numbers (IFFluminense 2016a)

Campuses	13
Students	19,494
Teachers	913
Administrative Staff	744
Levels	High School; College; Post-Graduation; Adult Education

- Offer courses at various levels (High School, Higher Education, Post Graduation, Adult Education);
- integrate instruction, research and extension programs;
- acknowledge the student's contributions and experiences in the construction of knowledge;
- implement policies that foster social inclusion, access and permanence in the institution;
- enable dissemination and use of information and communication technologies as a tool for building citizenship;
- develop applied technological research to contribute to local and regional development;
- qualify and give due value to academic and administrative staff.

Academic and Administrative Structures at IFFluminense campus Campos-Centro

To best demonstrate how a campus is structured, we describe the administrative and academic organization of campus Campos-Centro (the oldest and largest unit of IFFluminense). The school principal is assisted by 12 directors (one for each school level, and/or specific support services) who, in turn, are supported by 47 coordinators (responsible for the various courses, areas of knowledge, and/or specific services such as the library, telecommunications, and various student support services).

Following the guidelines given by the Institutional and Pedagogical Project, Campos-Centro offers a wide range of academic programs as shown in Table 2.2.

As an institution devoted mostly to vocational programs, Campos-Centro provides the necessary facilities for empirical learning (workshops and computer labs, for example) which, in turn, require that teachers have good command of digital technologies. The 2014 Report issued by the New Media Consortium ratify the growing demand for pedagogical strategies such as personalized learning and/or other learner-centered approaches. This includes the use, for instance, of social media, virtual learning environments, and other information and communication technologies (ICTs).

A survey conducted in 2010 at IFFluminense campus Campos Centro shows that 90 % of teachers used some form of digital technology for elaborating class materials, but only 40 % actually used them in class activities. The survey also detected that one reason for this was the lack of adequate technological infrastructure in the classrooms. To increase and facilitate the use of ICTs in teaching and

Table 2.2 Courses offered at Campos-Centro (IFFluminense 2016b)

Level	Degree	Courses
High School (vocational)	Technician	Electro-Technology; Mechanics, Chemistry; Telecommunications; Labour Safety; Building Construction; Computer Science
College	Technologist	Industrial Maintenance and Electric Systems; Telecommunications; Systems Analysis; Graphic Design
	Bachelor	Automation and Control Engineering; Architecture and Urban Development; Information Systems; Science (Biology, Physics, Chemistry), Geography; Portuguese Language and Literature; Mathematics; Drama
Post-Graduation	Lato sensu	Environmental Education; Teaching in the 21st Century; Management, Design and Marketing; Management Information Systems
	Stricto sensu (Master's)	Environmental Engineering
Adult Education	Elementary to High School	PROEJA[a]

[a]Program that integrates basic and vocational instruction for students over 18 years of age

learning activities, the school implemented a special program—PTCE (Technology-Communication-Education Program) which led to several actions, including equipping classrooms with internet connection and various technological devices. Another significant move to foster the use of ICTs is the continuous incentive and support given to teachers to obtain qualification in the use of technologies. Despite these incentives, empirical observation by the authors show that most pedagogical activities are still carried out in more traditional formats.

2.4 Lean for Vocational Education in Applied Science Universities

The Lean Education model proposed in this study intends to bring Lean industrial concepts of wastes and improvement to vocational education in Applied Science Universities. Following this objective, we propose a model that takes into consideration the concept of wastes and its ensuing elimination steps adapted to the aforementioned educational reality.

- **Over Processing**—In education, it means any demand to students such as tasks, assessments, activities that are not really useful to the learning process. This situation usually occurs in teacher-centred learning approaches. Another situation that illustrates this issue happens when administration and academics promote overflow procedures for students as a result of the lack of rules and regulations.

- **Overproduction**—represents any knowledge acquired and assessed more than what is needed to the learning process. Traditional learning models overwhelm the student's mind with a lot of knowledge presuming it will be useful at some point of his/her professional life. Lesson preparation, application of assessments, application and correction of exercises can mean loss of energy useless for the needed knowledge. This learning approach usually generates unpleasant feelings in students who cannot understand the utility and applicability of a certain knowledge in their professional or personal life.
- **Inventory**—This waste is a consequence of Over processing since excess knowledge brought by over processed learning means a stocked knowledge in the student's mind, as student learning efficiency is proportional to absorption, maintenance and assessment capability. For this reason, it is necessary to identify what is actually waste and what is really meaningful to be maintained at the risk of maintaining obsolete knowledge.
- **Transport**—It refers to any kind of waste related to the process of knowledge exchange between students and teachers. Some examples of this waste are: bad teaching classroom methodologies, non-adoption of *multimedianess*[5] (in an excessive adoption of "brick and mortar" approach in comparison to insufficient adoption of multimedia resources), lack of accessibility to knowledge for students with special learning needs, non-flexible course structure and schedules can result in waste since it does not represent value for students or for the job market (waste from Over processing).
- **Motion**—In the Lean education context, represents all activities carried out by students, teachers and staff of an institution', from class resources to classroom schedules, for instance. Waste examples are difficult in transit among university facilities (e.g.: distant campuses without adequate transport), bad accessibility for students with special locomotion needs. The synchronous-centred learning (face to face classes) approach without means to record and/or promote asynchronous class meetings. The adoption of a synchronous-centred approach promotes a linear, Cartesian and non-indexable knowledge motion framework. Student questions during class are usually lost, considering linear and non interruptible transport flow.
- **Waiting**—This waste occurs within the academic context, as some learning processes involve some sort of waiting by individuals. Lack of coordination among people and processes from inaccurate, inefficient or non-existent rules and regulations can bring bad results such as those. Some example are long-waiting lines students have to stand in the library, school registrars office, and even teachers late for class. Other examples are related to the lack of indexed knowledge like non-synchronised disciplines co-requirements.
- **Defects**—Knowledge is the most important product of a learning process. Wrong, inappropriate and obsolete knowledge acquired in learning process

[5]State of digital multimedia resources adoption.

means a waste by defective knowledge. Small batches of knowledge and its due assessments can avoid accumulation of knowledge defects by a just-in-time detecting problems approach.

Application of Lean Education (LE) is based on the five steps used in the implementation of Lean Thinking. It is interesting to highlight that, before any step, it is necessary to have a commitment vote from the managing staff for empowerment of leadership and team. Only after this, will it be possible to follow the Lean steps.

In the case of the Federal Institutes network, for each institute under the same Dean (since its structure provides a multi campus organization) it will be mandatory to define in which campuses the LE implementation will start. Each campus will have to establish a team to lead the first steps, and strong ties among team members are highly recommended. After these careful actions, it will be possible to follow the adapted implementation steps originally proposed by Womack et al. (1990):

- **Specifying value**—It does not make sense to think about quality in education if the institution does not know what is value in learning from the students' point of view. Since needs promotes value, the right thing to do is to identify the students' needs. Thus, it is very important that the student body trust institution managers. Students must perceive that the institution does not operate for its own benefit only, and meeting their demands is its sole reason for existence. For this reason, it is strongly recommended to include student participation in pedagogical planning meetings as a way to promote student-institution confidence.
- **Value stream mapping**—After identification of values in the learning process from the student's point of view, it is necessary to analyse each part of the learning process from a pedagogical and management perspective, and classify the process into the three categories: the ones that really aggregate value, the ones that do not aggregate value but are not possible to be eliminated at first as they contribute to the maintenance of the process and quality, and the ones that do not aggregate value and need to be immediately eliminated. From a pedagogical point of view, these actions illustrate the notion of value stream mapping: flexibilization of course curricula in order to eliminate, as much as possible, requirement disciplines; efforts to promote learning based on knowledge demand pulled by students, in which a learner-centred approach would be a significant contribution. From a management point of view, it is important to promote organizational streams and systems that facilitate the apprehension of what is really valuable by stakeholders as customers (students) and market companies (employers).
- **Flowing the processes**—In an educational context, the change of mind occurs in the pedagogical and management approaches. In the pedagogical approach, it is important to identify how to promote the values highlighted by students. Teacher-centred and "factory model" approaches are not recommended for this kind of change. For this reason, we need to think about how to promote interdisciplinarity, and more deeply, about how to eliminate knowledge stocked

in disciplines, promoting a just-in-time transit of knowledge in a student-centred approach. This means to reflect about how to promote ways to synchronise access to knowledge by students (not limiting knowledge access to the classroom, as it is usual in traditional teaching models), and how to promote knowledge at small batches (including assessments) in order to promote a more accurate student feedback of their learning feelings and confidence (decreasing the risk of idle knowledge inventory, for instance). A practical illustration of how it can be done is Khan Academy, a learning project proposed by Salman Khan (SRI 2014), where small knowledge batches, just-in-time and non-synchronicity are key elements of this approach. At this stage, the team responsible to manage changes will experience more difficulties due to the need of dealing with issues related to organizational policies, such as decentralization and loss of hierarchical power by teachers and staff to promote student empowerment in and out of the classroom.
- **Pulling the processes**—It is necessary to motivate students to pursue knowledge by adopting learning methodologies like Project-Based-Learning and Problem-Solved-Learning that usually promote a pull learning approach. At management level, the challenge is trying to think under organizational systems in comparison to the original point of view of a departmental "factory model".
- **Promoting perfection**—In educational contexts, perfection means developing confidence compromise to be an increasingly precious partner to students (customers) and the job market (as company employees or entrepreneurs), in addition to running processes with mastery by eliminating waste. The team responsible for implementing LE needs to be synchronized with the Federal Institutions academic and managerial commissions, in addition to the students and companies by continuous and endless upgrading meetings. The plans, tasks and conclusions need to be in convergence, since there is no sense in disconnected improvements. Satisfactory results such as good performance self-assessment of their learning confidence do not indicate the process should be interrupted.

2.5 Outcomes

As reported by Ferro (1992), the factory model approach in education is almost a common sense in public education. Despite some isolated cases, this scenario is no different in Brazil.

Lean Education (LE) seems to be an interesting way to promote a student-centered learning since this approach fits the student as a customer in the learning process, disrupting traditional learning approaches.

The present model is proposed as a philosophical basis to be implemented in the next years in pedagogical and management contexts. For this implementation, we suggest a pilot project for a Federal Institute campus as of 2016, with the following initial outcomes expected with the application of the this methodological actions:

- Focus on the concerns of students and institutional partners (companies) during the definition of educational contents;
- Strong connection among students from different campuses;
- Student-centered learning approach as learning philosophy;
- Learning centered in knowledge via cross-disciplines; not via centered-disciplines;
- Learning centered in the development of student skills and capabilities;
- Assessments focused on skills and abilities; not on acquired content;
- Focus on process learning; not merely on final assessments;
- Elimination of eventual lack of teachers for specific disciplines;
- Closer relationships among students, faculty, companies and society.

This is a redesign that may generate effective results over time and deepening of methodology. Therefore, the purpose of this study is to give a kick start and not exhaust the issue, something that meets the philosophy of Lean continuous improvement.

The network of Federal Institutions of Applied Science in Brazil is enormous. Therefore, proposals for dealing with pedagogical approaches as management actions need to be planned and patiently developed. Starting with a pilot experiment might be an interesting way to implement LE in the Brazilian network of Institutes of Applied Science.

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Chapter 3
Lean Education in a University in the Philippines

Anna Bella Siriban-Manalang

3.1 Introduction

Lean education is paramount in the practice and pursuit of high productivity, efficiency, economic gain and sustainability, not only among engineering graduates but even among professionals. There is a vital need to educate engineering graduates because they are at the forefront of product, service and systems design. “Lean” is a mindset that needs to be inculcated in the students’ thinking processes so that when they join any organization thereafter sustainability practices become second nature.

Engineering educators are faced with seemingly impossible challenges in the 21st century (Flumerfelt et al. 2015). They are expected to prepare today’s millennial generation (Strauss and Howe 2000) for work in companies that make up our global society using an educational system that should continuously evolve to meet the changing needs of industries and societies.

Lean Engineering Education (LEE) is one of the service courses of Industrial Engineering (IE) at the De La Salle University. As the gatekeeper of continuous improvement and robust standard processes, IE offers LEE to all engineering degrees. In the undergraduate levels, Total Quality Management (TQM), the basic principles of Lean Manufacturing, is a required course content in IE, as mandated by the Commission on Higher Education (CHED) in the Philippines, embedded under the CHED Memorandum Order Number 15 issued in 2008. TQM is also incorporated in all engineering degrees at the University. LEE is introduced at the undergraduate levels in courses such as production management and human

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behavior in organizations. At the graduate level, LEE courses such as Lean Manufacturing and Design of Experiments are offered to all engineering degrees and are required in the MS Industrial Engineering degree.

The De La Salle University's engineering program consults a board of advisers from industry about their current needs which are incorporated in the design of program objectives, expected graduate attributes (EGAs), program outcomes and learning outcomes. The Industrial Engineering (IE) Program's educational objectives (PEO) are three-fold: (1) leadership, (2) life-long learning and (3) social responsibility. DLSU-IE graduates will assume leadership roles in the practice of Industrial Engineering and its allied disciplines of manufacturing, service, business enterprise, and government (PEO (1)-Leadership). They will continue to be engaged in life-long learning, understanding and applying knowledge and ideas in industrial engineering and allied fields (PEO (2)-Life-long Learning) and will become informed and involved members not only of IE professional society/ies or other professional organizations but also in community-based organizations (PEO (3)-Social Responsibility) (Li and Siy 2014).

Developing a mindset of lean manufacturing amongst practitioners is one of the goals of the industrial engineering program. One of the student outcomes (I: Life-long Learning and Keeping Current) is the ability to engage in life-long learning and an understanding of the need to keep current of the developments in the field of discipline (see Fig. 3.1). Coupled with Student Outcome H which is Systems Thinking (an understanding of the effects of engineering solutions in a comprehensive context), the industrial engineer is expected to be well-informed of the current evolving needs of industry and society and to create solutions that address these needs.

Philippine companies put a high premium on engineering graduates who have a working knowledge of lean manufacturing. Later, when these graduates earn more advanced accreditations in Lean Six Sigma proficiency (e.g. green, black, and master black belt degrees), they get more chances at being promoted to higher positions in the company.

At the outset, Lean has been identified as a jump-off point for green initiatives and sustainability. The practitioners and experts on lean manufacturing have seen the potential of lean practices in the whole chain of anthropogenic activities [e.g. lean consumption (Womack and Jones 2005)]. The specific values that the student is expected to learn include an appreciation of the complexity of Lean manufacturing production lines and efficiency differences in terms of the various factors of production—man, machine, materials and methods among traditional and lean manufacturing systems.

By virtue of the nature of the systems discipline of IE, environmental sustainability, sustainable production and consumption are allied disciplines. The current state of the art in the analysis of systems is highly utilized in understanding sustainability in its various levels and dimensions of agglomeration.

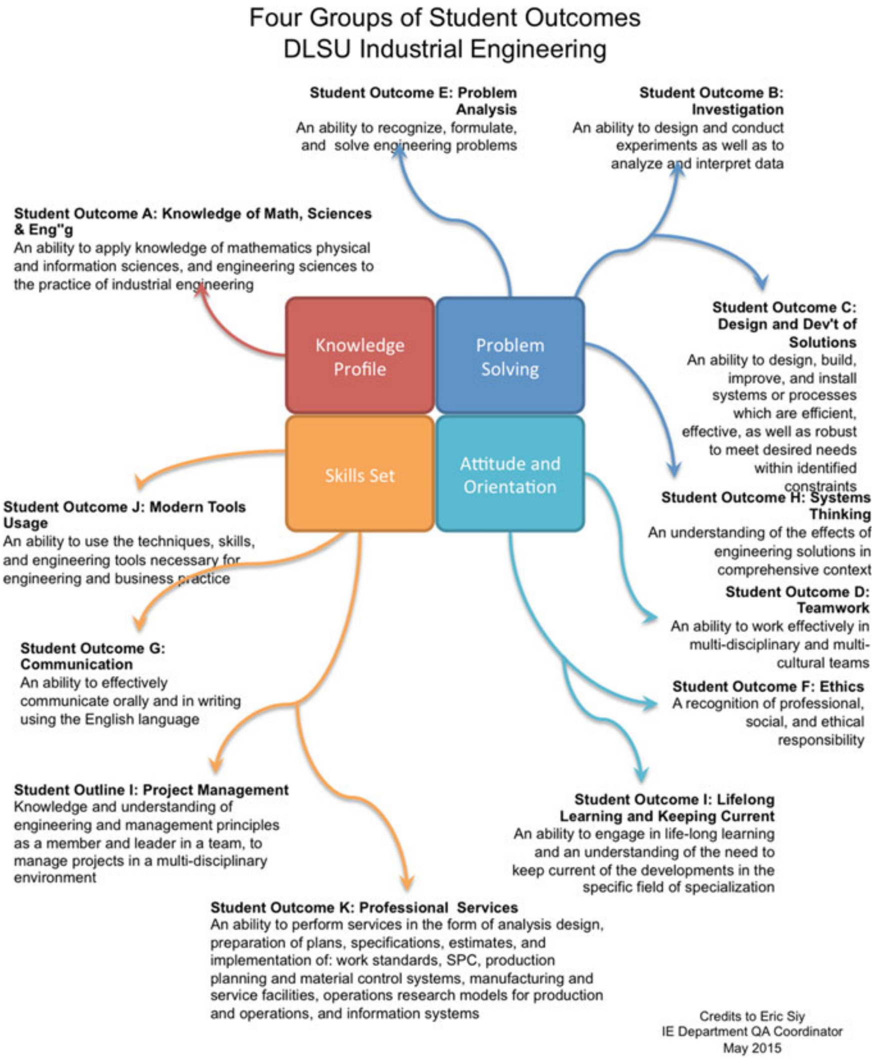

Fig. 3.1 Four groups of student outcomes in DLSU Industrial Engineering

De Rosnay (1979) in The Macroscope masterfully designed a conceptual framework of the whole economic machine highlighting the various linkages amongst cells, organisms, individuals, resources, and societies, that contextualizes extraction, production, consumption and disposal activities that make up global sustainability systems.

3.2 Pedagogical Framework

The Experiential Learning Theory (Kolb 1984) underpins the theoretical support to the pedagogical methodology. Experiential learning comes from actual practical experience which leads to a reflection on what has been seen, experimented, felt, experienced and recorded. This reflection leads to learning, understanding, and the desire to try again, experiment further and understand deeper.

The Lean courses in the undergraduate and graduate levels are based on iterative rounds of the Lean production structured learning exercises that alternate with short lectures, cases and video presentation on Lean topics. The experience and application of each tool individually help to increase the knowledge and skills levels regarding its main technical implementation aspects and scope. As designed, due to its modular structure, this course relies on Lean tools configured to address different learning needs of the students. More specifically, the structured learning exercises (SLE) are implemented as follows:

1. The Lean course starts with a first round of the Lean production structured learning exercises after students form learning groups or teams, acting like corporations engaged in manufacturing representative products, usually a simple and easy to assemble product.
2. After that round, team members compute and measure Lean Key Performance Indicators (LKPI's) for the corporation (corporate level KPIs) and the individual (individual KPIs).
3. Teams formulate problems and/or make suggestions for improvement.
4. To assist the team in fully understanding the problem and providing the team with an appropriate improvement tool, the teacher lectures on the related course module.
5. Using a problem solving methodology learned in previous courses, the team members use this knowledge to find the most appropriate improvement actions.
6. As soon as the whole team agrees on the actions to be taken, they implement them in the Lean production structured learning exercise by changing the structured learning exercise setup. Then, the team is ready to play a next round and a next learning cycle begins.

In the undergraduate junior program, students become familiar with the fundamentals of production management. Students who enroll in an elective course on production management (PROLEC1) learn more about factory physics and lean manufacturing. This is further reinforced by enjoining students to join groups in a project study to be completed in one term as required by the course.

The topics of PROLEC1 are designed to address the needs of the industry to enable the students to apply Lean Principles in their project study, at least at the introductory levels. Upon completion of the term project study, students are required to make presentations to owners and managers of the host companies.

At the graduate level, the scope, depth, breath and intensity of the topic discussions are further reinforced by more advanced case problems.

3.3 Lean Projects

The student groups scouted for companies to work with for their term project study.

But more than simply teaching Lean principles and tools, the course also aims at developing a Lean mindset. This means there is a lot of attention to and feedback on the Lean behavior of the students. In order to enhance the output quality, the authenticity of incorporated cases and the relevance of all material included, other external experts from the industry are involved in the project, especially those faculty members who have been serving as consultants to various companies.

3.3.1 Design of the Course

The Lean Manufacturing course covers how the Lean Manufacturing philosophy and techniques can be applied to an organization to maximize customer value, minimize waste and reduce costs. By adopting a Lean Manufacturing approach, a company will become faster and more responsive to customer requirements while using fewer resources. As a general course objective, the student by the end of the term, should be able to achieve multiple goals such as:

1. Learn how a company can transform a traditional manufacturing firm into a Lean manufacturing system by focusing on material flow and lead-time reductions;
2. Learn how to take advantage of the benefits of Lean techniques through the demonstration and application of Workplace organization and visual controls, Standard Work, Cellular manufacturing, one-piece flow, Systematic Layout Planning, Quality Management Systems, Pull systems, Kanban, Point of use storage, Continuous Improvement; and
3. Illustrate the applicability of these concepts in the Philippine setting.

This is an overview course for the Lean Manufacturing discipline. It focuses on the tools, techniques, concepts and principles of Lean. While most of the emphasis is on the manufacturing environment, examples from administrative functions in the service sector are also used to explain key concepts.

3.3.2 Syllabus of Lean Manufacturing, Graduate Level

The plan of teaching content is contained in the syllabus, such as in Table 3.1.

Table 3.1 Syllabus

Week	Topic/details
1–2	**Laying the foundation** This is an introduction to the basic principles and concepts of Lean Manufacturing. The teacher gives short lectures and will lead students through a basic factory simulation (hands-on) that will demonstrate how Lean can be used to dramatically improve productivity
	Overview and Introduction of Lean principles/concepts/tools Context of Lean (green/sustainability) Principles of Lean Manufacturing Stockless production (video) Kinds of wastes Factory simulation (hands on, short demonstration) Building a practical lean strategy that works *Readings*: Lean Thinking, Part I by James Womack and Daniel Jones (Womack and Jones 2003)
	Upon completion of laying the foundation, **students will be able to**: • Know the origin, history and emerging trends of lean manufacturing • Learn its basic philosophy • Identify the critical factors for a successful implementation
3–4	**Lean leadership and the tools of lean manufacturing**
	Lean Production at a Company (video) Process centered organization and change management Getting started with lean 5 S: 5 step approach to developing safe, clean and organized working environment Kaizen/continuous improvement The visual factory Mistake proofing/defect prevention
	Readings: Lean Thinking, Part II by James Womack & Daniel Jones (Womack and Jones 2003)
	Upon completion of 5S/visual factory, **students will be able to**: • Define the five S's • Describe how 5S activities are linked to bottom line measurements • Use visual signals to speed the decision making process • Understand the importance of developing standards for visual systems
5–7	**Value stream mapping (VSM) and analyses**

	Mapping the Entire Value Stream for the Enterprise
	    Current state
	    Ideal state
	  Analyzing the value chain
	  Transformation methodologies overview
	    Pull systems
	    Standardized work
	    Continuous flow
	    Error proofing
	    Setup reduction
	    Total Productive Maintenance (TPM)

	Readings: Learning To See by Mike Rother and John Y. Shook (Rother and Shook 2009) Design and Analysis of Lean Production Systems by Ronald G. Askin and Jeffrey B. Goldberg (Askin and Goldberg 2002)

(continued)

Table 3.1 (continued)

Week	Topic/details
	Film Showing: Value Stream Mapping *Case 3*: Value Stream Maps (current and ideal states), Spaghetti maps
	Upon completion of value stream mapping, **students will be able to**: • Learn how to map out current and ideal states of companies and value chains • Analyze value-adding and non-value-adding activities and relate these to takt time • Determine sources of waste • Identify optimal transformation strategies
8–9	**Lean tool-box**
	Set-up time reduction Fundamental principles of waste reduction Barriers to reducing set-up time Shingeo Shingo's Single Minute Exchange of Dies (SMED) Rapid changeover Process flow improvement techniques Pull systems (pull versus push product) Standard Work Line Balancing
	Upon completion of Lean Tool Box, **students will be able to**: • Define the setup reduction process • Identify opportunity areas for setup reduction • Learn how 5S/visual factory positively impacts setup reduction • Determine which tools are more appropriate to use when designing leaner systems
10–12	**Creating continuous flow manufacturing** Students will learn how manual and machine operations can be linked to increase efficiency while minimizing transport and delay. These concepts will then be used to explore a step-by-step approach to design and implement a flow line (cell). A video on the visual factory is used in this module.
	Linking and balancing manufacturing operations Design and implementation of continuous flow cells Creating the flow Seeing the whole (extended value stream mapping) for the Supply chain
	Readings: Seeing the Whole and Creating the Flow, Dan Jones and Jim Womack (Jones and Womack 2011) Video: visual factory
	Upon completion of Creating continuous flow, **students will be able to**: • Determine product families that qualify for manufacturing cell layout • Determine production capacity by process • Analyze cell loading based on customer requirements • Design an effective manufacturing cell • Calculate new takt time and balance work based on customer requirements • Complete a standard work sequence sheet
13–14	**Integration**

3.4 Hurdles Encountered

A number of hurdles are normally encountered, the most difficult of which is getting started. Matching the groups with a willing company embarking on Lean initiatives proves to be the hardest. This usually takes a week or two from the start of the term. The teacher ensures that the specifications are discussed thoroughly at the very start of the term and a company profile is submitted at the immediate succeeding meeting to ensure the students aggressively convince the host companies to divulge data and consider Lean Exercises and be a part of the program. There is no requirement for the company to implement the results of the term project. As soon as this is done, the next difficulty is how to encourage the companies to fully divulge their data and systems to the study groups. This is easily addressed by issuing non-disclosure agreements with the host companies and giving them an assurance that only the faculty members will have access to their data and findings. In cases where they wish to be hidden behind a pseudonym, the groups comply.

3.5 Student Outcomes

As part of the experiential learning method applied in the course administration, we receive feedback and evaluation from the students at the end of video presentations, structured learning exercises, cases, problem sets and the course.

Box 1 shows an excerpt from a student's reaction paper after the structured learning exercise.

Box 1. Reaction to a Structured Learning Exercise (SLE) Academic Term 3, School year 2007–2008

"It was also said that there's a "discipline required to implement Lean and the disciplines it seems to require is so often counter-cultural, that makes successful implementation of Lean a major challenge". Individual examples of success and failure exist in almost all fields of business and activity and therefore cannot be taken as indications of whether Lean is particularly applicable to a specific part of activity. It seems clear from the "successes" that no part is immune from possible benefits.

They also directed us to perform a game to simulate a production system and made us think on how we can apply Lean concepts to improve the system. I think this is a good way to give us a first hand experience on implementing it. You can visualize more where the value and non-value adding activities, where the bottlenecks usually occurred, the importance of different tools and techniques such as Kanban.

***The most important point I have learned with the lecture is that the most common mistaken approach in using Lean is to focus on maximizing activities that are value adding in the whole process**, **then most non-value adding activities are being overlooked**. They emphasized that although it is important to maximize value adding activities, it is more important to properly identify and eliminate non-value adding activities in the processes to make Lean more successful."*

Box 2 is another student's reaction to the entire course implemented over one term.

Box 2. Reaction to the Lean Manufacturing Course (IEN532M) Academic Term 2, School year 2008–2009)

"This is a reaction paper for the just concluded course, Lean Manufacturing (IEN532M), under the programme Masters of Science in Industrial Engineering of the College of Engineering at De La Salle University. The course was taken on the 2nd term of school year 2008–2009 under our professor Dr. Anna Bella S. Manalang. The aim of this paper is to state the most value adding element of Lean (in terms of benefit) together with its areas for improvement in terms of the different approaches.

Lean Manufacturing

The course started with the lecture on Lean concept. I think the idea of lean manufacturing is not totally new. Lean manufacturing seeks to look for waste and inefficiencies and eliminate them. Anything that does not add value to the functionality or quality of the product should be removed from the production process. The goal is to continuously improve and shorten the processes.

There were two major approaches to Lean that were retained in my mind. First is the identification and elimination of waste through the use of different tools. This approach can help improve the quality and can reduce production time cost. These tools were Value Stream Mapping, Five S, Kanban, and poka-yoke. The second approach focuses on improving the flow of work. This is where production leveling, pull production by the use of kanban, and the Heijunka box takes part. The implementation of smooth flow exposes quality problems which already existed and thus waste reduction comes next.

Benefits of Lean Manufacturing

The major benefit of Lean, most of the time, is the shortening of lead time from order taking to shipping. The work-in-process (WIP) inventories outside the cell is also much reduced and in effect, space is also saved. There's also a tendency to have a higher quality output because defects are discovered much sooner in the line. In terms of employee's culture, Lean promotes better team communications and "ownership" through cell set-up. The cultures are standardized, thus, unfavorable practices and behaviors of both the *employees and the management are reduced, if not eliminated. It also supports a demand "pull" operation that yields much better material control and schedule control compared to "push" scheduling systems.*

Areas for Improvement

Some of the disadvantages that can possibly serve as the areas for improvement in implementing Lean would be lower equipment utilization for non-bottleneck cell operations, unless multi-functional equipment is employed, and if there is no equipment redundancy within the cell, the whole cell may shut down when one piece of equipment goes down. An operator must also operate several different pieces of equipment that decentralized their expertise. Another observation was, if demand falls and production output is below the planned cell capacity, per unit manufacturing costs tend to be higher with some cells. This occurs when a good labor balance cannot be achieved at the lower output level. Any small subsequent changes in the production process or sequence could also have major changes on the cell layout and cell efficiency, sometimes there is more flexibility when using traditional departmentalized layouts. Finally, some multi-product cells are not suitable for higher volume orders where they may become a bottleneck to scheduling other parts.

Conclusion

For lean manufacturing to work best, everyone in the system needs to be more informed because the end result usually involves several manufacturers. If there is a communication breakdown, things will be less efficient.

At the end of the term, the most important point I have learned with Lean Manufacturing is that if a process in the manufacturing is being unnecessarily duplicated in supply chain members, it can be eliminated if it does not contribute to the value, function, or quality. A smooth work flow is the only way to get the best results at the lowest cost. This is all the more reason for cooperation within a supply chain. The value of lean can be realized only to the extent that the method is methodically implemented, it should be with depth and breadth throughout the organization, otherwise it will only be superficial."

3.6 Organizational Feedback About the Competencies of Our Engineering Graduates

The University through its Institutional Testing and Evaluation Office (ITEO) conducts a tracer study every two years of our engineering graduates. General responses from the industry, as validated by comments from employers, indicate that our engineering graduates are more preferred by many companies because they are more persevering, can work overtime, and can apply skills learned from the University very quickly on the shop floor.

The short-term successes are that they are able to conduct a full systems study on the lean host companies and design a full transformation strategy from the company's current to the future value stream map.

Some groups, under the tutelage of their professors, publish their findings with the consent of the host companies in conference proceedings and journals.

A handful of our graduates both in undergraduate and graduate levels pursue researches in the field of Lean Manufacturing in their undergraduate, masteral and doctorate theses.

3.7 Conclusion: Lessons Learned

A structured learning exercise simulation-based approach, coupled with lecturettes and videos with workshop, can be a powerful means of motivating students and improving experiential learning.

The students are able to reflect on their learnings and apply these real-life situations and actual companies, thereby creating an opportunity to get feedback from experts and company owners regarding the validity and feasibility of their lean transformation strategies.

More significantly, graduates of the course come out of the University with a Lean mindset. As such, they would have developed the potential to become change agents in increasing the productivity, efficiency, economic gain and sustainability of companies that will help these companies become more competitive. Overall, they have the strong potential to help in advancing the whole nation into higher levels of productivity, efficiency, economic gain and sustainability. Ultimately, they can champion global sustainability. It all starts with the Lean Mindset.

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Chapter 4
Using Student-Active Simulations in Lean Education

Lawrence J. Navarre

4.1 Introduction

Teaching Lean is a challenge. Lean is different enough that simply talking about it in a lecture is not convincing. The challenge of teaching undergraduate students at Kettering University has resulted in coursework improvements that have encouraged hands-on, student-active simulations. Four principles for applying simulations to coursework are presented with examples, as well as suggestions for implementing simulations into crowded courses.

The author teaches Lean Operations, Supply Chain, and Product Development as well as other related topics. Kettering University is unusual in that all students are required to complete co-operative work experience during their baccalaureate curriculum. A typical student will study for one quarter, work as a co-op at a partner employer for the next quarter, and cycle through this process for four and one half years. Students typically graduate with about two years of work experience and are often hired into the firm where they completed their co-op work. This deep experiential learning generates a demand by students to acquire skills that can be applied in the workplace—in the next three months!

Given the legacy of Kettering as the former General Motors Institute, Kettering continues to have a strong automotive engineering and management emphasis. Kettering is located in southeast Michigan where the auto industry is concentrated. With the relatively large adoption rate of Lean in the auto industry, one can see why Lean Education is in demand Kettering University students and their employers.

Teaching Lean is a challenge. Lean is different enough that simply talking about it in a lecture is not convincing. The challenge of teaching undergraduate students at Kettering University has resulted in coursework improvements that have encour-

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aged hands-on, student-active simulations. Four principles of applying simulations to coursework have resulted including:

- Practice Lean Principles
- Eliminate Waste
- Quick Cadence Learning Cycles
- Success After Challenge

4.2 Practice Lean Principles

Theory: Important… but insufficient. We academics feel an obligation to deliver the principles of any topic in a compelling way. After 20 years in industry, the author began teaching the way he was taught: by carefully crafting engaging lectures with examples intended to deliver the material in a way that transfers learning. For the first few terms, after completing instruction in class and inviting questions he heard… crickets.

He needed to make a change. There was a lot of teaching going on, but not a lot of learning. So he reflected on the best instructors of his industrial career. The most powerful lessons, the ones he remembered, were the ones where he experienced the learning principle through an activity. Things improved after applying hands-on, student-active simulations in coursework to reinforce the principles of Lean.

Simulations are particularly helpful in learning because Lean is such a different way of thinking that explaining it as a lecture is not convincing. Few learners get it. Compound this with the contradiction of Lean compared to traditional management methods and it is difficult for students to accept one versus the other. Explain Kanban, for example, and people just don't believe it's better than computer scheduling backed by a warehouse of inventory. To really understand Kanban, you need to do it. Students who complete a simulation have a visceral feel for the principle. So much so that we might expect that students will quickly forget the information delivered in the course, but they will remember the simulation forever. The power of a simulation is to create a memorable experience that will give students enough confidence to apply the principle in their workplace.

4.3 Theory as Presented in Textbooks

Lean is seldom recognized for what it is—the evolution in operational excellence succeeding Mass Production and, before that, Craft Production. Studying the principles of Lean one can see the legacy of what can be referred to as traditional management methods of Mass Production. Many of these methods remain the foundation of Lean principles and remain a valid theory. What is defined as theory as presented in popular textbooks of operational excellence is dominated by traditional methods.

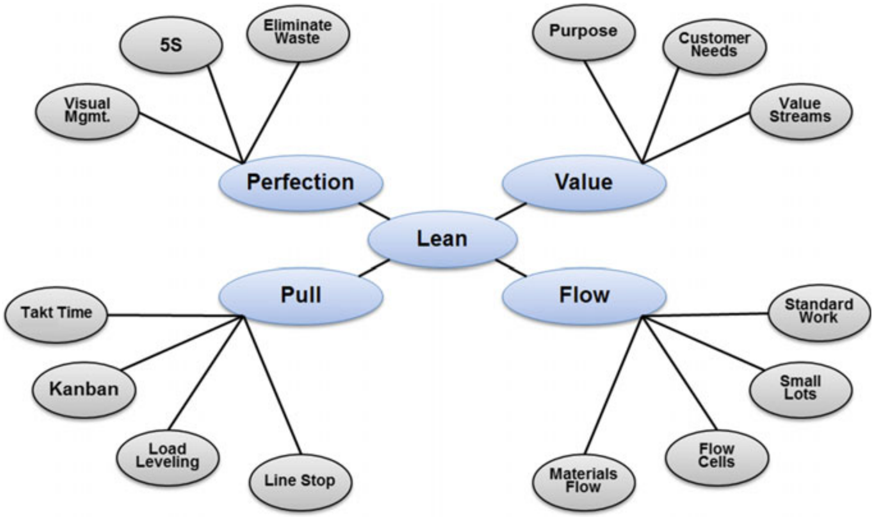

Fig. 4.1 A taxonomy of Lean concepts supporting core principles of Lean

An important reason for teaching Lean using simulations is that the theory supporting Lean is often strongly contradictory to traditional management. Theory presented by textbooks available from traditional higher education publishers are dominated by traditional methods, with Lean typically presented as one chapter. Typical textbook coverage of Lean is very broad and somewhat shallow, meaning there are many principles of Lean that are covered in a very brief way. A taxonomy of Lean principles built around the core concepts presented by Womack and Jones in *Lean Thinking* (Womack and Jones 1996) is suggested in Fig. 4.1.

Consider all of the concepts of Lean and summarize that into a single chapter of a textbook and it is easy to see how diluted the treatment can become. There is simply so much to absorb that it needs not only more depth, but also some spacing throughout a course.

An approach applied in courses on Lean Operations Management and Lean Supply Chain Management (SCM) at Kettering University is to contrast the traditional methods of operational excellence with Lean principles throughout the course. An advantage of this approach is that students are presented with the conceptual differences between the two approaches throughout the course. A challenge of this approach is that typical textbooks and other course materials do not have the depth required to promote a strong understanding. Often the Lean Educator is faced with adapting materials intended for practitioners to the college classroom, which can actually be quite good, but require significantly more preparation than sticking to the textbook. Another challenge, addressed later, is that a balanced treatment of traditional and Lean methods simply expands the course content, and teaching time.

As educators, we clearly want students to understand the principles of the theory, but our goal should also be to encourage confidence in application, and ultimately competence. The ideal learning outcome is that a student not only has some skill in applying the principles of Lean, but especially the confidence to do it in the workplace. For students to become practitioners there should be a greater outcome than 'I read about Lean in a book'. We should have them practice the principles and leave our courses with the confidence to give it a try.

Comparing traditional versus Lean throughout a course provides ample opportunity for students to consider and discuss the differences between the approaches. Yet theory and discussion are not sufficient. Students need to do it. Hands-on, student-active simulations provide a laboratory for students to experience Lean principles in a way that will persist in their memory long after the course.

4.4 Eliminate Waste

A big challenge of education is that there is never enough time. To make more time available for the simulation, we must eliminate waste. Anything that does not contribute to the simulation learning exercise of students making decisions and taking action is waste. To eliminate waste, remove complexity, cost, or activity that does not add value.

4.4.1 Removing Complexity

It is said in product design that the most elegant design is the simplest. Elegant simplicity is an important objective in teaching simulation design. There is a natural inclination of educators to make examples and simulations as accurate to real systems as possible. We often feel that a classroom experience is not "real" and so we try to simulate the actual working system as realistically as possible. This is a noble objective but any simulation is always a relaxation of reality. Students understand it is a classroom so attempts to make it "real", no matter how admirable, should not be a great concern. Rather, educators should focus on maximizing the teachable moments and design the simulation to reinforce the principle of the course to the greatest degree possible.

Complex simulations have disadvantages for the educator and the student. The complexity of a simulation will require substantial preparation time for an exercise. The amount of preparation for a complex exercise increases the likelihood that something is lost, forgotten, or missing that compromises the simulation. Complexity often injects mistakes or other issues during a simulation that need correction to keep it running and generate interruptions which reduce the student learning experience. Complexity is also intimidating to an instructor which tends to reduce the adoption of the exercise in courses. Increasing complexity typically means that there is also increased cost. Complexity is subject to the laws of entropy and using a complex simulation requires greater maintenance effort to keep it going. In conducting classroom simulations, strive for the elegantly simple design. Simple works.

4.4.2 Removing Cost

Materials can be costly, so design the simulation using simple, cheap materials like tape, cards, paper, cups, and other craft items. A classic and appealing material for simulations is Lego® construction bricks. However, purchasing enough Legos® for a typical simulation will typically exceed $100 or more depending on how specific the construction is that is simulated and the number of students. Specialized kits purchased for such activities are often cost prohibitive, require special storage, are costly to replace missing pieces, are difficult to transport to the classroom, and reduce adoption of the simulation.

Craft items are effective teaching aids when applied in simulations. Craft items have the advantages of low cost, availability, expendability, and familiarity with students. The key to using low cost materials is to create a simulation that utilizes such materials in a clever, but simple way. Examples of craft ideas are readily obtained by web searches for school activities or hand craft ideas such as on the Pinterest web site. A classic simulation of Kanban is the HP Stockless Production[1] (McCord 1983) video. A good simulation would benefit by emulating this example. It implements the principles presented herein. For a Kanban simulation it is often the objective to build a small vehicle with Legos®. An approach for a Kanban simulation that is just as effective is to make paper airplanes.

A Kanban simulation using paper airplanes is very cost effective and students can create large volumes of production without concern for running out of materials. Figure 4.2 illustrates some of the elements of a simulation including workstation instructions and a box score that outlines the different approaches to operating the airplane “assembly line” using traditional and Lean methods. The materials checklist for this exercise is simply, (1) Standard Work instructions for five workstations, (2) about 100 sheets of paper per line, (3) Green and red dry erase markers to draw dots on airplane wings (good and bad quality), (4) a white board/marker or spreadsheet document for the box score, and (5) a phone or stop watch as a timer.

The simulation is setup on tables with students participating as workers in the airplane production line. A push system is implemented with a batch size. After producing large inventory, and consequent defects for rework, the system is reset to produce in a pull system with a batch, and later as a flow system with a lot size of one unit. Through this exercise the principles of traditional push production are contrasted with Lean pull systems as well as the Quality at the Source (Jidoka) principle, the value of Small Lot Sizes, and an example of Standard Work.

A final benefit of low cost simulations is that they are easily scalable. Expensive or specialized equipment for simulations will tend to be short in supply so as the class size increases fewer students may get the opportunity to participate. Using low cost materials allows for broad participation.

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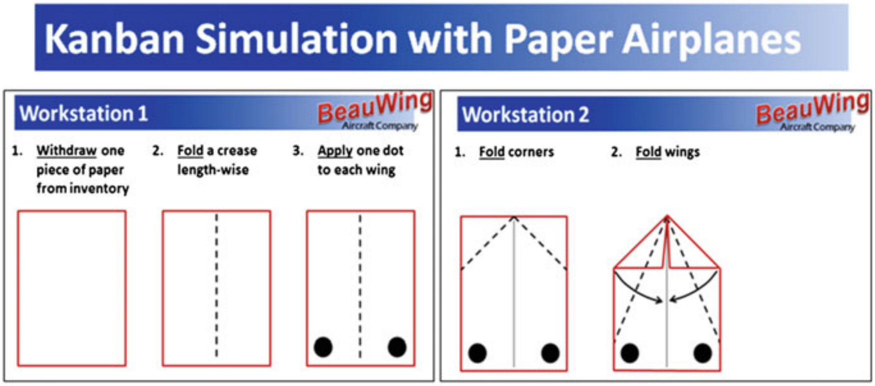
[1]The Stockless Production video by Hewlett Packard is a good example of using simple materials to teach a complex Lean principle. Instead of simply watching the video, create the simulation and run it for the students.



BeauWing Aircraft Company
Lean Systems Exercise Box Score

	Push: Lot=4	Pull: Lot=4	Pull: Lot=1
Work Rules	Keep Busy	Pull Work	Flow
Space	2.5	2.5	1
WIP Units	20	16	4
Cycle Time	15	15	15
Lead Time	6	6	1
Productivity	240	240	240
Rework	20		

Fig. 4.2 Elements of a Kanban simulation using paper airplanes

4.4.3 Removing Non-valued Added Activity

Activities in a simulation that have relatively low value should be eliminated. For example, as much as it is appreciated to hand draw a VSM or hand write an A3, it is very time consuming in class. Of course such tasks could be assigned as homework out of class, but often the results are mixed without the benefit of the "sensei" instructor providing examples and advice as the activity is conducted. As such, a template document with preformatted structure and palette of icons allows students to focus on substance.

Calculations take time from simulation exercises. As instructors we want students to do such calculations to practice the math. Yet, in a rapidly moving simulation that is short on time, eliminating such repetition is very important. After several calculations, the value of such practice is negligible and simply disengages the learner from the larger principle to be learned. Finding a way to automate calculations by using a spreadsheet template prepared for the task is an effective way to eliminate non-value added activity.

The Beer Distribution Game is another classic example of an effective simulation. Although the principle of System Dynamics presented in the Beer Game predates Lean, the concepts of System Dynamics, Systems Thinking, and variation reduction are often cited in Lean. As an introduction to Lean SCM, the Beer Game

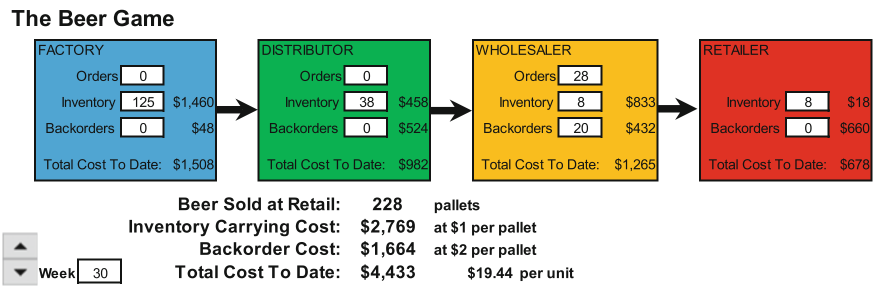


Fig. 4.3 Dashboard for the beer distribution game

is a very effective teaching tool that was created by Professor Jay Forrester and his colleagues at the Massachusetts Institute of Technology and has been in use for over 50 years. Typically, the Beer Game is implemented as a table top board game using physical tokens for inventory and manual scorekeeping. A decision cycle, to determine how much beer to order in a given period, may take several minutes, and the entire simulation often requires 90 min.

Faced with a time constraint, the author created a spreadsheet document to automate the student calculations of inventory and backlog. This presents the student with a "management dashboard", from which to make ordering decisions, as illustrated in Fig. 4.3. Movement of inventory, inventory balances at each participant in the supply chain, and any backlog is automatically calculated. Charts visually demonstrating the performance of each participant in the supply chain are automatically prepared for review in the simulation. In this way the learner is free to focus on making the decision for ordering product which is the heart of the lesson. Obviously, it also greatly quickens the decision cycles of the exercise. By using the spreadsheet it is common to complete the Beer Distribution Game simulation in less than 45 min.

A tool such as the Beer Game spreadsheet serves to eliminate the drudgery of repeated non-value added activity in a simulation, as well as speed up the student action. Making a simulation operate more quickly has the obvious benefit of reducing the class time for the exercise, but it also provides additional student learning benefits.

4.5 Quick Cadence Learning Cycles

A quick cadence in the simulation may seem chaotic at first, but has proven to improve the student learning experience. By quick cadence, it is meant to cycle the fundamental learning decision rapidly during the simulation. This is the principle of rapid learning cycles in Lean Product and Process Development, but applied at a micro level in the simulation. Once waste is removed, then the focus should be on cycling the learning decision as quickly as possible to maximize learning opportunities.

Using rapid learning cycles in a simulation has several benefits. The obvious one is that your total time for the exercise is less, or for a given time the learning opportunities are greater. Rapid learning cycles also allow for more experience with the skill. Students get better by doing more cycles each with less time. Logically, the more a learner practices a skill, the more familiarity, confidence, and competence they will retain afterward.

Perhaps the best benefit of a quick cadence is that it keeps student attention. This is a common attribute of student-active learning, but simulations need to be constructed to ensure a fast-paced learning experience. Slow moving exercises can backfire causing students to question the value of the exercise consuming class time, as do educators.

An example of a rapidly moving simulation is one that implements the principles of Lean Materials Handling from the Lean Enterprise Institute workbook *Making Materials Flow* (Harris and Harris 2003). In this exercise a simple product is assembled in a flow cell. A material handling system to replenish the flow cell and deliver finished goods is prepared to service the operation.

Students setup, a receiving purchased parts market, prepare a load leveling box to schedule material movement Kanban, and setup the flow cell to receive the materials and make the product.[2] As shown in Fig. 4.4, low cost materials are used extensively including 3×5 cards for Kanban, a whiteboard to draw the Pitch locations for the Load Leveling Box, and small plastic food storage bins as material containers. The flow cell in this exercise does use Legos® to construct a product, but only one rectangular brick type is used and the product assembled is a very simple “X” shape.

Once setup, Kanban are needed so each student is tasked with preparing a material movement Kanban to understand what it represents. This simulation utilizes a lot of students to run a timer for the Takt Time, schedule the Load Leveling Box and release Kanban, deliver materials to the flow cell, operate the flow cell to make products, deliver products to shipping, and “recycle” or disassemble the product to return the materials to receiving inventory. One particularly enjoyable role in the exercise is to simulate a lift truck operation with one student seated in a rolling chair and a second student pushing the chair to drive the “lift truck” around the room in the conveyance route (Fig. 4.5).

With so many roles for students, it is easy to scale the exercise to larger classes. Having multiple simulations running simultaneously is also readily achieved due to the low cost materials. Rotating roles of the students is encouraged as this keeps students engaged and teaches them the different tasks of the entire system. To achieve this rotation while allowing enough practice for learning, quick cycles are

[2]Flow cells by their very nature are actually quite complicated and are not necessary to specifically teach Lean Materials Handling. However, flow cells and a simulation for operating a flow cell are conducted in a previous course and already familiar to the students thereby reinforcing prior learning while teaching a new principle.

Fig. 4.4 Lean materials handling exercise load leveling box and Kanban scheduling

Fig. 4.5 Lean materials handling simulation showing from *left* to *right*, the "lift truck" operators, the purchased parts market material storage attendant, and the takt time scheduler with phone timer

essential. The exercise begins with a relatively slow Takt Time of about two minutes. Soon the students get very good at running the system and want to reduce the Takt Time. Explaining that “customer demand has suddenly increased” the Takt Time is progressively reduced to the point where students are busily running around the room delivering materials, building products, recycling materials, and controlling Kanban in a matter of seconds.

Finally, moving the simulation along with a quick cadence can improve the experience by not allowing students to think too much about it. Students don’t have time to game the exercise; they simply focus on doing the task well. This allows the educator the opportunity to present a challenge.

4.6 Success After Challenge

The best learning experience is to present a challenge that is overcome by the application of a course principle. Indeed, it is noted that a best practice of college education is the idea of “expectation failure” as cited by Ken Bain in *What the Best College Teachers Do* (Bain 2004). Having students fail at a task is often a very valuable teaching lesson. In fact, in the Beer Distribution Game explained earlier, the whole point is to fail at managing the supply chain. That is the lesson of the simulation.

Designing simulations so they start with a challenge, even a failure, and then follow up with success is a very powerful learning experience. One can see the power of such an experience in computer gaming. Everyone in the game is trying to “level up” but repeated failure is the path to learning how to win the game. This is a phenomenon that is very familiar to young people of the typical student demographic. The emerging discipline of Gamification is being applied to many aspects of business, science, and even education (Werbach and Hunter 2012).

One way of implementing these principles is to compare and contrast traditional operations with Lean methods of operational excellence. In the Kanban simulation previously mentioned, there is a clear attempt to demonstrate the limitations and inefficiencies of a typical mass production push system, before applying Lean principles. To strongly reinforce a principle, it is very effective to run a simulation again and apply improved methods.

In the example of the Beer Distribution Game previously mentioned, the lesson ends by a failure to operate the supply chain. Indeed, this is a powerful lesson that sets up references throughout a course in SCM in variation reduction, collaboration, inventory management, and systems optimization. However, to make the point of how to operate using the principles of modern SCM, the educator can run the simulation a second time. Now knowing and applying the principles of SCM students are encouraged to communicate a forecast, collaborate on production, order only the product that is needed, and match output to the demand rate of the customer. The result is typically a 70–80 % reduction in cost per pallet of beer distributed through the supply chain. When students succeed after the challenge, students understand the lesson.

4.7 Implementation

Although several of the approaches that have been recommended above reduce the amount of time to conduct a simulation, many educators will not be convinced they should reduce course content to conduct a simulation. Perhaps only one or two student-active simulations would be implemented in any course. But what if you wanted to implement one or more exercises each *week*? What if you wish to balance the traditional textbook treatment of operational excellence with Lean methods? What if you want to spend more time in class with students doing real work together on practical applications of course principles? With all this "extra" class time expended on activities with students, how can we possibly teach the actual coursework?

This opportunity requires a substantially different perspective on how to deliver a course. In recent years, there has been a trend toward the application of technology to deliver education. On-line courses and Massively Open On-line Courses (MOOC's) have both the promise to transform as well as the threat to disrupt traditional higher education. But there is a path to co-opt this technology and apply it to classroom teaching that has the potential to transform higher education in a way that adds a much greater value than ever before.

Although the idea of course "flipping" has been applied somewhat in K-12 education, it remains relatively uncommon in higher education. Jose Bowen in his book Teaching Naked (Bowen 2012) challenges us in face-to-face, on-campus higher education to use this technology to make our work product better. The idea is to move the pure content delivery of our course "outside class" so that we can do more with students "inside class".

Flipping is the course structure of delivering course content lecture through video viewed by students before they come to class. Delivering course content can be achieved by many other methods than viewing a video, but delivering some of your basic course content in videos is well received by students. The demographic of the current college-aged student is highly receptive to video. Long before modern lecture recording or video capture software, Kettering University had a Distance Learning program enabled by a high quality Video Operations Department. Initially supporting recording of VHS tapes mailed to students, now a capability exists to capture lecture by a web video application. Recording video is not trivial or even intimidating for an instructor, but the opportunity to remove pure content delivery from the classroom has great potential for on-campus education.

If you provide notes or a presentation that supports your video delivery as well as readings from your text or sources, you will achieve “rich course content”. This idea is simply accommodating the student learning styles. Many educators are good at reading the written word and understanding theory. Many people are not, which is why there are four learning styles. Your video provides a personable delivery of course material in your voice that supports the Auditory learner. Your notes, presentation, and readings support the Reader learner. Your use of graphics in your presentation or video, as well as in your simulations supports the Visual learner. Finally, the in-class exercises and simulations support the Kinesthetic learner. Providing “rich course content” allows students to learn in a way that is best for them.

Moving some of your content delivery outside class removes time from the class room so that an educator can be less of the Sage-on-the-Stage and more of the Guide-on-the-Side. Is that a reasonable trade-off for more active classes? Most students seem to find that a good bargain. Likewise, would you like to enjoy classes more and have time for an interpersonal relationship with students? Many educators would agree that such an outcome is worth the effort.

4.8 Summary

Lean concepts can be difficult to understand. The Lean approach to operational excellence is often not what the average person has come to know through their familiarity with Mass Production principles of traditional management. The student-active simulation is a very effective method to give students a deep learning experience to *Practice the Principles* of Lean in the classroom.

Student-active simulations are improved by *Eliminating Waste*. Waste in a simulation is anything that does not add value to the learning experience and can include complexity of the simulation, costly materials, and non-valued added activities such as repetitive calculations.

Quick Cadence Learning Cycles are a means to rapidly improve skills as well as retain student engagement during the simulation. This also supports the reduction of class time for a simulation.

A proven way to ensure achievement of a learning outcome is to structure the simulation with *Success After Challenge*. This idea of starting with a challenge, even a failure, and then follow up with student success is demonstrated to be a powerful learning approach.

Implementation of student-active simulations is often considered to be time prohibitive. Use of new education delivery technologies and methods can allow an educator to move course content “outside class” to allow more time “inside class” for activities like simulations that greatly improve the value to students of on-campus higher education.

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Chapter 5
Lean Teaching Experiences in Universidade NOVA de Lisboa and the TRIZ-LEAN Model

Helena V.G. Navas and V. Cruz Machado

5.1 Introduction

The Lean Philosophy and Continuous Improvement continue to be the day's agenda of organizations.

The universities feel a growing and increasingly widespread interest of undertakings in engineers and other staff with good preparation in this area. The students realize up search, and attempt during the courses at the Faculty or immediately after taking courses or disciplines related to Lean.

The Faculty of Science and Technology, *Universidade NOVA de Lisboa*, attempts to offer students a wide and updated education, according to the need of a good generalist academic background and, at the same time, provide students with opportunities for learning new techniques and approaches.

In the Department of Mechanical and Industrial Engineering a Course of Postgraduate Studies in Lean Management was created and, later, the discipline "Lean and Six Sigma Methodologies" was created as an optional discipline for students of the Masters in Industrial Engineering and Management. With this, Lean is no longer the exclusive subject matter of post-graduate courses, becoming accessible to the Master of Science regular students.

In recent years in the Department of Mechanical and Industrial Engineering several studies were developed that aim to investigate the joint deployment opportunities of different methodologies. This study reflects the search of a model for the joint use of the TRIZ methodology with Lean philosophy.

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The publications described in this chapter are related to various practical applications of some techniques and analytical tools of TRIZ together with Lean, Lean Maintenance approach in several industrial companies. These case studies were based on the students work who did a traineeship and their M.Sc. Dissertations in respective companies.

Our experience confirms the usefulness of joint use of methodologies.

5.2 Post-graduate Studies in Lean Management

Lean has entered the everyday life long ago at the Faculty of Science and Technology of *Universidade NOVA de Lisboa*, Portugal.

For several years the Department of Mechanical and Industrial Engineering has ministered a Course of Post-Graduate Studies in Lean Management.

This course is addressed to entrepreneurs, managers, middle and senior managers of companies, consultants, trainers and other professionals with Bachelor's degree. Through the years, the course has passed dozens of graduates from various fields of academic education and professional activity. This type of graduate degree attracts not only industrial engineers, but also engineers from other numerous different branches of engineering, as well as economists, pharmacists, doctors, etc.

This course provides an introduction to the principles, methods and practices underlying the Lean Management and aims to provide knowledge necessary for the implementation of its principles.

The program structure has been evolving over time, however, always contains certain key elements:

– Lean Thinking;
– Strategy Deployment;
– Leadership;
– Lean Production;
– Lean Tools;
– Value Stream Mapping;
– Lean in Services;
– Lean Six Sigma;
– Lean Supply Chain.

At the end of the program the participants should be able to:

- Interpret the concepts inherent to the philosophy of Lean Management,
- Identify obstacles and waste,
- Dominate the knowledge underlying the Lean thinking,
- Know the tools and methodologies of Lean operation,
- Develop methodologies for strategy deployment,
- Understand the methods of analysis and mapping of value streams,
- Develop Lean projects in their organizations.

The specialized training in Lean Management is dedicated to make available technical knowledge of great professional applicability in the field of process management, providing access to a set of practices and knowledge for increasing productivity in industry and services.

5.3 "Lean and Six Sigma Methodologies" Discipline

There has been a great interest amoung regular undergraduate students for more knowledge about Lean. A few years ago a new optional discipline has been established titled "Lean and Six Sigma Methodologies". So the teaching of Lean ceased to be one of the exclusive themes of post-graduate courses, and began to be ministered in the regular courses of the Faculty.

It is an optional discipline of the M.Sc. in Industrial Engineering and Management.

This curricular unit provides an introduction to the principles, methods and practices underlying the Lean Six Sigma Management and aims to provide knowledge necessary for the implementation of its principles and methodologies.

At the end of the program students should be able to:

- Interpret the concepts inherent to the Lean Management philosophy,
- Know the Lean's tools and methodologies,
- Value stream mapping,
- Understand the implementation requirements of Lean projects.
- Know the Six Sigma methodology in the improvement of existing processes
- Know the DFSS methodology (Design for Six Sigma)
- Know the metrics associated with Six Sigma and DFSS methodology
- Know the tools to support the implementation of Six Sigma and DFSS
- Apply the DMAIC cycle for Six Sigma projects
- Apply the DMADV cycle (redefinition) or IDOV cycle (innovation) in DFSS projects.

The course program includes the following topics:

- Lean Thinking: lean principles and values in the new paradigms of corporate management; Time based management; Waste identification; Value and the value creation process; Value flows and business processes; The lean diagnosis. (Shingo model).
- Lean Manufacturing: The Toyota Production System; The JIT and Kanban; The cell production and leveling of production; The takt time; The TPM system.
- Lean methods and tools: 5S and visual control; problem solving techniques; poke-yoke; SMED; standard work; POUS; Value stream mapping; A3 methodology.
- Six Sigma: The philosophy of Lean Six Sigma; from simplification to the reduction of process variability; DMAIC method; tools and metrics of Six Sigma; Kaizen events and continuous improvement; DMADV method in redefining of products/processes; IDOV method in innovation of new products/processes.

5.4 Education and Research of the Joint Use of Systematic Innovation with Lean Management

At the Department of Mechanical and Industrial Engineering, Faculty of Science and Technology, Universidade NOVA de Lisboa, there is a group of researchers who in recent years is devoted to teaching and research at the Joint Deployment of Systematic Innovation with Lean Management.

Several theoretical and practical studies on the subject were conducted. In the study several dissertations were developed, some with practical applications in industrial companies.

The Lean implementation environment requires advanced analytical tools and methodologies (ex. VSM and A3), but there is not much work done on tools for generation of solutions (Melton 2005). Theory of Inventive Problem Solving (TRIZ) systematizes solutions that can be used for different technical fields and activities (Terninko et al. 1998). The inconsistencies are eliminated by modification of the entire system or by modification of one or more subsystems (Savransky 2000).

This study intends to propose a conceptual model that explores the relationships between LEAN and TRIZ practices and methodologies. As a potential solution generator, the researchers believe that the use of TRIZ may help to promote improved Lean management environments.

Lean Philosophy is a systematized approach to continuous improvement (Holweg 2007). Its extent is a methodical search of process improvement through reduction of wastes and inefficiencies (Demeter and Matyusz 2011). Lean can be applied to all areas of enterprise and it supposes improvement of efficiency and effectiveness.

Lean has been adopted in a large number of companies from different industrial sectors. It has moved away from being merely a "shop-floor focus" on waste and cost reduction to an approach that consistently drives to increase value for customers by adding product or service features and removing wasteful activities (Cruz Machado and Tavares 2008).

Lean Production is focused on the value stream that originates the product, aiming at maximizing value and eliminating Muda (waste in Japanese), optimizing the whole and not just parts of the process.

The idea is that the value should flow continuously over all the organization, to reach the costumer as quick as possible. A Lean thinking environment requires a "learning to see" approach, in order to find obstacles (waste) to be removed. This means that it is vital to research a problem solving methodology which improves the value stream.

Lean Thinking includes all employees and requires significant changes in their attitudes and professional behavior. Lean has a profound effect on both the organization and the people that make up the organization.

Systematic innovation is crucial for increasing organizational effectiveness, enhancing competitiveness and profitability (Navas 2013a). The Lean management philosophy depends on the creation of systematic innovative solutions to improve processes.

At the start of Lean implementation, the vast majority of improvements can be achieved by simple solutions. While Lean implementation process moves forward, it depends more and more on the really innovative solutions and radical changes.

Traditional engineering and management practices can become insufficient and inefficient for the implementation of new scientific principles or for radical improvements of existing systems (Navas 2013b). Traditional ways of technical and management contradiction solving is through search of possible compromise between contradicting factors, whereas the Theory of Inventive Problem Solving aims to remove contradictions and compromises (Fey and Rivin 1997).

Traditionally Lean tools are Value Stream Mapping, Quick Changeover/Setup Reduction, Single Minute Exchange of Dies (SMED), Kaizen, Flow Manufacturing, Visual Workplace/5S Good Housekeeping, Total Productive Maintenance (TPM) and Pull/Kanban Systems (Ikovenko and Bradley 2004).

The TRIZ method consists of a set of different tools that can be used together or apart for problem solving and failure analysis (Altshuller 1995). There are many techniques and concepts within Lean where TRIZ might be applied (Campbell 2004).

Generally, the TRIZ's problem solving process is to define a specific problem, formalize it, identify the contradictions, find examples of how others have solved the contradiction or utilized the principles, and finally, apply those general solutions to a particular problem (Altshuller 2001).

It is important to identify and to understand the contradiction that is causing the problem as soon as possible (Altshuller 1999). TRIZ can help to identify contradictions and to formalize problems to be solved. The identification and the formalizing of problems is one of the most important and difficult tasks, with numerous impediments. The situation is often obscured.

The problem can be generalized by selecting one of the TRIZ problem solving tools. The generic solutions available within TRIZ can be of great benefit at choosing corrective actions.

The merger of Value Engineering Analysis (VEA), Root-Cause Analysis (RCA), Flow Analysis (FA) and several other engineering analytical methods with TRIZ, originated several integrated methodologies based on TRIZ: ITD, TRIZ Plus, I-TRIZ.

The integrated methods combine the analytical tools with the inventive ability of TRIZ, so they present real advantages, specially integrated on applications with organizational methods like Lean.

There are several key principles for successful application of Lean techniques into a business environment (Womack and Jones 1996):

- Value
- Value Stream
- Flow
- Pull
- Perfection

The approach to value in TRIZ Plus has the same objective as Lean Value Principle: to determine the value of different operations of the process or components of the product.

The traditional Lean seven types of Muda are:

- Overproduction
- Inventory
- Extra Processing Steps
- Motion
- Defects
- Waiting
- Transportation

After the value has been specified, the next step is to identify the value stream.

TRIZ Plus tools can be used in the approach to the value stream and the Lean Value Stream Principle.

Flow is defined as a fabrication process from raw material to final product without interruption or delay.

The key tools for Flow implementation are (Ikovenko and Bradley 2004):

- "Takt Time"
- Standardized Work
- 5S
- Work Balancing
- Leveled Production

The Pull Principle identifies the need to be able to deliver the product to the customer as soon as he needs it.

The TRIZ tools cannot be applied directly to Perfection Principle, however some Inventive Principles and Standard Solutions are appropriate here (Ikovenko and Bradley 2004).

The implementation and deployment of Lean Thinking in organizations will be more sustainable if the Lean approach be supported by a set of TRIZ Plus tools.

TRIZ can support Lean product development by strengthening a team's ability to leverage and reuse knowledge across the enterprise and pull in knowledge from other companies and industries.

Lean Thinking is a highly evolved method of management and organization that aims to improve the productivity, efficiency and quality of products and services. Lean Philosophy focuses on streamlined work process without delays, with maximized production, minimized nomenclature and bureaucratic proceedings.

The current lean approach is to use sensitivity analysis to try to find the best compromise. The TRIZ approach is to find out how to avoid the compromise or trade off (Campbell 2004). While TRIZ tends to focus more often on smaller problems, lean is used more for systems level examination (Bligh 2006).

TRIZ and Lean Thinking are both ways of improving the operation of a system. Both TRIZ and Lean look to optimize the use of available resources. TRIZ focuses on individual elements to optimize, where lean takes in the entire system to find potential efficiencies.

TRIZ could be useful to find solutions that utilize available resources currently seen as waste ("muda" in Lean) (Bligh 2006).

5.5 Students Internships and Dissertations in Lean

Teaching at the Faculty of Lean and a high demand for experts in Lean encourage students to perform academic and professional internships related to the topic of Lean and Continuous Improvement. This phenomenon has led to the significant number of master's degree dissertations developed in Lean and related matters. It was also observed an increased interest of students to perform internships and dissertations on topics related to the joint implementation of Lean with some other methodologies, for example, joint implementation of the Lean Philosophy with Six Sigma Methodology.

In the past, several dissertations (some of them more theoretical, the other more practical) on the joint application of Lean and TRIZ methodologies were developed.

Another trend that was noted in internships and dissertations is the enlargement of Lean application areas. If at first the Lean was further applied to production systems, over time more and more applications appear in services, consulting practice, etc. Also different functional areas within companies began to be the target of continuous improvement/Lean studies, for example, maintenance management, logistics, etc.

The internships and dissertations in Lean as much appear related to important national and international companies, such as cover small and medium side enterprises of different sectors of economic activities.

In most cases the students in Lean are invited to work in the company when they had finished the traineeship.

Sometimes our former students become responsible for continuous improvement/Lean in companies and provide internships in Lean to current students.

The study carried out under internships and dissertations in Lean has produced a significant number of presentations at national and international congresses and other scientific events by students and faculty advisers. It has also published a significant number of articles in national and international scientific journals based on the results of theoretical studies and practical applications of Lean by our students and their faculty advisers.

Some of the students work was awarded in national and international competitions and events. For example, the project of the team consisting of professors and former students, won the bronze medal at The 5th Global Competition on Systematic Innovation (GCSI) held in July 2015 in Hong Kong. The project “TRIZ and Lean in an Industry of Air Handling and Ventilation” was developed under the collaboration between the Department of Mechanical and Industrial Engineering, Faculty of Science and Technology, Universidade NOVA de Lisboa, Portugal, and Sandometal—Metalworking company and Air Conditioning S. A., based in Alverca and in Castanheira do Ribatejo, Portugal.

The project was based on the work done under the traineeship held in Sandometal and the Master’s Thesis of a former student, a recent graduate of the M. Sc. in Industrial Engineering and Management. After the traineeship and the conclusion of the M.Sc., the young engineer was invited to work in the Sandometal company. Thus, this traineeship and the thesis gave one paper in an international conference and an award-winning project, which was also presented and defended in an international scientific event.

Another Master’s thesis, a M.Sc. in Mechanical Engineering thesis, was seen by many as revolutionary for its time, since it aimed at applying Lean for improving the production processes and operations in a pharmaceutical company. Back then the pharmaceutical companies did not yet know and did not apply Lean. Nowadays it would be nothing new.

In our faculty, we have had several dissertations related to the implementation of Lean Maintenance. Some of these dissertations were more theoretical, others were of a more practical application. Maintenance Lean has a lot of demand. Students many times begin to do an internship in a company that initially did not give importance to maintenance management, amounted in practice a modern maintenance service, implement correct and modern procedures and after the internship are to head the service.

5.6 Conclusions

Lean and Continuous Improvement have become unavoidable issues in the education of future engineers, especially industrial engineers. The graduate students seeking to enroll in disciplines related to Lean, the demand for postgraduate courses in Lean and similar is very high. The graduate students are looking to get diplomas and certificates in lean, even during the last years of Faculty or soon after, before entry into the labor market.

Students know that entering into the labor market is easier for recent graduates who acheived the dissertation or an internship in Lean. Thus, there remains high demand among the finalists of internships and dissertations related to Lean and continuous improvement.

The Faculty of Science and Technology, Universidade NOVA de Lisboa, accompanies this demand and interest with post-graduate courses, thematic optional courses, offering themes and scientific support in carrying out dissertations related to Lean.

The Department of Mechanical and Industrial Engineering along with organizes conferences, seminars and other events in Lean and other related topics.

In recent years, in the department and in the research center (UNIDEMI), valences were developed under joint deployment of Lean with other methodologies (6 Sigma, Agile, TRIZ, …). These methodologies complement each other.

The Systematic Innovation can be used in Lean environments with success, as illustrated by the case study presented in the chapter. The TRIZ methodology, with its vocation of solutions generating and with its creative and innovative approach to problem solving, can contribute positively to evolution and development of organizations.

Lean maintenance is being increasingly studied and demanded by companies. The TRIZ methodology could significantly contribute to improve and accelerate the processes of Lean Maintenance, to create more innovative solutions.

Several case studies, developed by students, reflect an importance of the application of TRIZ together with the techniques of Lean, Lean Maintenance in various industrial companies and organizations. The results were very positive, so the teaching model was validated.

Some Lean education initiatives have already been implemented, others will be implemented in the short or medium term. Thus, the focus on Lean teaching clearly wins.

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Chapter 6
Lean Learning at Oakland University

Shannon Flumerfelt, Wendy Ross and Dennis Wade

6.1 Introduction

Many Higher Education Institutions (HEI) have acknowledged the value of the Lean Production (LP) System (Womack and Jones 1996) and have integrated Lean content into student coursework. These LP learning opportunities in all of their forms promote Lean Education (Alves et al. 2014). Lean initiatives begin with industry experts who learn the techniques necessary to make strategic decisions about diversification and, most importantly, develop employees to be key contributors and analytical thinkers in growth strategies. Lean training programs can help leadership and employees learn to improve and align processes through problem solving techniques while effectively using resources. In addition, HEI has become a significant contributor to promoting understanding and application of LP. Students of these institutions are able to present valued Lean credentials in the job search.

Emanating from the presence of the Pawley Lean Institute, Oakland University has continued to demonstrate a strong commitment toward LP learning and sustained student success as early practitioners of LP. This paper aligns with advocacy for Lean Education based on shared concerns around LP as an essential element for the workforce of the new industrial age. By offering Lean Education to students, HEIs are preparing students for the workplace who are capable of meeting job demands (Flumerfelt et al. 2015). LP and Lean Leadership and other programs are noted focus areas of the Pawley Lean Institute and various academic program offerings of Oakland University.

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6.2 Pawley Lean Institute

6.2.1 Mission

The Pawley Lean Institute (PLI) at Oakland University (OU) was founded in 2002 with a $1 million endowment from Dennis Pawley. The PLI holds the mission, "To provide instruction, research and further development of interdisciplinary principles and practices of Lean organizational improvement for business, education and public service" (Oakland University 2014). The PLI focuses upon three main strategic areas including academics, student engagements, and continuous improvement. These strategic foci are described next. They are important to this chapter because they reflect heavily on what OU offers to students as Lean programming.

6.2.2 Student Academics

The first obvious strategic area of focus for the PLI is Academics. It is obvious that this focus is about Lean programming for OU students. Oakland University currently has three certificate options available in Lean training for students that include a Black Belt, a Green Belt, and the Lean Startup. Each of these offerings target different aspects of functional Lean knowledge. In 2015, OU's Professional and Continuing Education (PACE) partnered with the Macomb-OU INCubator to support these layers of work. PACE is leading the search for certified training partners to support programs at the Macomb-OU INCubator, based out of OU's Macomb Campus. These partners are now in place with both groups and with great expectations for future program development and practitioner enrollments.

Oakland University's Schools of Education and Human Services (SEHS), Business Administration (SBA) and Engineering and Computer Science (SECS), in association with the Pawley Lean Institute, continue to promote an interdisciplinary model of Lean coursework. The development of an undergraduate Lean Leadership Minor, for example, has been launched in 2015 and is associated with SEHS' Human Resource Development division within the Department of Organizational Leadership. However, the Lean Leadership Minor is currently available to any undergraduate student within Oakland University. Because the PLI promotes an interdisciplinary perspective for Lean courses, student enrollment for the entire Lean Leadership Minor or any of the individual courses in the Lean Leadership Minor comes from SEHS, SBA and SECS. In addition, within SBA there is a Lean Knowledge Pathway option within the Project and Operations Management undergraduate degree. Some courses are cross-listed from the SEHS Lean Leadership Minor to the SBA Lean Knowledge Pathway. Also, SECS students may take any of the Lean Leadership Minor courses and many do enroll in at least one course. Besides enrollment in the Lean Leadership Minor or Lean Leadership

Minor courses, both SBA and SECS offer selected courses that include an emphasis on Lean content within the various business and engineering curricula. The undergraduate Lean Leadership Minor coursework is listed in Table 6.1.

Currently, a Lean Leadership Professional-Graduate Certificate (three semesters) and the Lean Leadership Ed.D. Cognate (four semesters) is on target for 2017 completion. The cognate is one of several cognate options that will be offered for a Leadership Ed.D. degree. The Lean Leadership Professional Certificate may be used as a terminal experience or it may feed into the Lean Leadership Ed.D. cognate.

Program design is complete and course development is underway, all pending approval within the university's academic policy. The PLI has also partnered with outside organizations for support of these new Lean programs, pursuing possible organization-based cohorts. The value in this type of channel marketing of graduate Lean programming is that employers and the university can coordinate developmentally sequenced job-embedded Lean projects, mentoring experiences, internships and project-based work. Table 6.2 below describes the proposed graduate Lean Leadership program design.

An interesting approach is being used for these Lean Leadership Professional Certificate and Lean Leadership Ed.D. Cognate programs. These two Lean graduate programs are focused on Lean Leadership for Lean Production (LP). What is new about this approach for OU is that these programs will spiral principles and tools of Lean under a Lean leadership competency-based model. This competency-based model of Lean leadership is an adaptive and interrelated learning system that includes development of knowledge, dispositions, and applications for both content and competencies (Halpern 1998). Stemming from common knowledge that technical knowledge of any domain is insufficient to ensure workplace success (Kivunja 2015); the Lean leadership competency-content spiraled model is believed to be necessary for future workplace success of OU's Lean leader graduates.

Table 6.1 Undergraduate Lean leadership minor

Lean leadership minor		
HRD core courses	**Credits**	**POM knowledge pathway courses**
Principles of leadership	4 credits	
Change processes	4 credits	
Group and team development and leadership	4 credits	
Total core credits	**12 credits**	
Lean leadership minor courses		
Lean principles and practices in organizations	4 credits	
Lean Kaizen in organizations	4 credits	Special topics operations mgmt
Lean green belt	2 credits	Lean green belt
Total HRD Lean leadership minor credits	**22 credits**	

Table 6.2 Graduate Lean leadership programs

Program description			
Semester I	Semester II	Semester III	Semester IV
Professional certificate credits-16 credits			
Prof certificate-6 cr	Prof certificate-6 cr	Prof certificate-4 cr	
Professional certificate courses			
Lean course I-4 cr	Lean course II-4 cr	Lean course III-4 cr	
Internship I-2 cr	Internship II-2 cr		
EdD Lean leadership cognate credits-24 credits			
EdD Cognate-6 cr	EdD Cognate-6 cr	EdD Cognate-6 cr	EdD Cognate-6 cr
EdD Lean leadership cognate courses			
Lean course I-4 cr	Lean course II-4 cr	Lean course III-4 cr	Lean course IV-4 cr
Internship I-2 cr	Internship II-2 cr	Internship III-2 cr	Internship IV-2 cr
Program attributes			
Flipped, Hybrid, PBL	Flipped, Hybrid, PBL	Flipped, Hybrid, PBL	Flipped, Hybrid, PBL
Lean leadership competency-based	Lean leadership competency-based	Lean leadership competency-based	Lean leadership competency-based
Weekend intensive	Weekend intensive	Weekend intensive	Weekend intensive
Team taught	Team taught	Team taught	Team taught
Cohort, possible site partnerships	Cohort, possible site partnerships	Cohort, possible site partnerships	Cohort, possible site partnerships
Faculty use of Lean for program improvement	Faculty use of Lean for program improvement	Faculty use of Lean for program improvement	Faculty use of Lean for program improvement

For some, the inclusion of Lean leadership content is most likely easier to understand than Lean leadership competencies are for these programs. For example, common content topics such as, Lean Tools, Lean Principles, etc., are included in this aspect of the program (see Table 6.2). These content areas have been culled from surveys and Lean training experts. In addition, however, three Lean leadership competencies have been identified as the foundation of the graduate Lean leadership programs. A review of the extant literature on leadership and Lean was conducted to identify these competencies. Three Lean leadership competencies for the program have been identified as; communication, critical thinking and change management.

Both of the three Lean leadership competencies and various Lean leadership content topics are further defined in program and course descriptions and delineated with 4 × 3 matrices. The competency and content rubrics provide 12 descriptors using a matrix of four developmental levels (self, confidants, team and mastery levels) and three areas of holistic growth (knowledge-head, dispositions-heart, and applications-hands areas of growth). The 4 × 3 rubrics of content and competency subsequently inform student learning outcomes, teaching and learning activities and essential program processes (Ipperciel and ElAtia 2014).

6.2.3 Student Engagements

Student Engagements is another area of strategic focus for the PLI that inform Lean programming and student learning. Student Engagements involves partnering with outside organizations for Lean projects used within the classroom as required coursework, as well as for the development of undergraduate internships. The PLI assists in those engagements by reaching out to various outside organizations for classroom participation, at no cost to those organizations. Paid internship offers to students from various departments (Industrial and Systems Engineering/SCES, Human Resource Development/SEHS, Process and Operations Management/SBA) through the PLI have also led to partnerships with multiple organizations including Comerica Bank and DTE Energy, for instance. The primary intent with these internships is to provide students with strong job credentials and to provide employers with strong potential job candidates. Consequently, the relationships formed with outside organizations may also develop into fundraising opportunities to support PLI's sustainability plans as a self-funded unit beyond its endowment capacity.

6.2.4 Continuous Improvement

The third strategic focus of the PLI is to support Continuous Improvement initiatives at OU itself. There are implications for Lean programming within this strategic focus as well. For example, two of the Lean undergraduate courses in the Lean Leadership Minor, Lean Kaizen in Organizations and Lean Green Belt, allowed students to work closely with various operational and functional areas at the university. Students worked with the Registrar's Office team, for instance, to address issues associated with graduation processes. The focus of this project was to provide improvements in transcript articulation, graduation certification, student experiences, and process improvements across multiple departments, with the hope of ultimately increasing graduation rates. In addition, endowed Lean faculty not teaching these Lean courses per se are broadly available to assist OU with process improvement in this regard. For example, one faculty member held a series of Lean Workshops for technical-clerical staff and for administrative professional staff. This work informs Lean faculty of practitioner interpretations of Lean and its implications for use. Future initiatives at the PLI to engage Continuous Improvement include: (a) developing an Advisory Council with representatives from external organizations, informing faculty of workplace perspectives; (b) implementing an internal Institutional Processes Task Force, informing course design; (c) fundraising through partnerships for sustainability initiatives, advocating for Lean programming for the workplace; and (d) a recognition event for organizations that have partnered in Lean projects with OU and OU students, advocating for university-community initiatives to enhance Lean programming.

6.3 Other Initiatives

In addition to the three strategic foci, the PLI has continued to support various OU faculty. This work is helpful in Lean program and course development as it serves to add to the body of knowledge of Lean. These initiatives include the awarding of five faculty fellowships in the 2015 calendar year and several fellowships in previous years. These fellowships, normally three years in length, have focused on several projects. For example, graduate assistant research support and travel for the development of a new systems-based Lean organizational tool, the CX Tool, has occurred. Fellowship funding for the development of the previously described undergraduate Lean Leadership Minor has occurred. Dual fellowships for the previously described graduate Lean Leadership programs and course development have been enacted. Various fellowships have allowed faculty to participate in the management of the PLI and to facilitate Strategic Planning for the PLI. Further, PLI representation has been requested and provided for OU's Strategic Planning process, with the option to draw attention to the need for Lean programming. One Lean faculty fellow received the coveted Shingo Prize for his book, *Leading and Managing the Lean Management Process*. An international faculty scholar was invited to the PLI for one semester as a fellow and further opportunities for international scholarship work are sought in the future. The international scholars program serves to bring international perspectives to Lean programming at OU. All of these initiatives indicate the degree of confluence between the PLI's three strategic foci and the varied involvement of faculty through PLI fellowships and HEI Lean programming.

6.4 Faculty Scholarship

Partly supported through PLI fellowships and partly emanating from scholarly interests, faculty of the PLI engage in scholarship, including Lean research, scholarly presentations and publications, and book publications. This work is worth mentioning because it informs HEI in regard to Lean programming by adding to the Lean body of knowledge.

For instance, one study of employer views of Lean graduate programming was conducted by Flumerfelt et al. (2016). This study examined three questions important to HEI Lean programming: (1) "What do organizational leaders need from Lean graduate programming?" (2) "What are the preferable methods of delivery for Lean teaching/learning?" and (3) "What are the main learner outcomes and do how these impact organizational and continuous improvement outcomes?" Findings from this study provided the foundation for the Lean Leadership Professional Certificate/Lean Leadership Ed.D. Cognate described above. For example, in this study respondents indicated that Lean Continuous Improvement Thinking and Lean Process-Project Management were the most desirable Lean leadership content options. These findings strongly informed program and course design. Another point learned from the study was that the method of delivery most valued was a job-embedded, project-based approach. This information was critical to the attributes of Lean programming at OU. Learner outcomes pointed to the mastery of Lean issues and organizational issues, followed by the learner's ability to impact organizational and continuous improvement outcomes. These conclusions informed critical student and learning objectives for the Lean program.

Another example of the impact of faculty scholarship on HEI Lean programming comes from the international collaboration of Flumerfelt et al. (2015). An examination of results from a survey taken by engineering employers, early graduates and faculty conducted by the American Society of Mechanical Engineers was interpreted for engineering education. The book *Lean Engineering Education*: *Driving Content and Competency Mastery* advocated for the use of Lean in HEI in two ways: (1) as a program/course improvement method and (2) as a source of engineering content. Both of these suggestions provide the framework for rethinking HEI's engineering education and for assisting those faculty already engaging in improvement pedagogy and methodology in HEI's engineering schools.

A third example of the impact of PLI faculty scholarship on Lean programming comes from the work of Fliedner and Mathieson (2009). They conducted a survey designed to understand what business practitioners thought about their Lean knowledge needs for graduates. Their results indicated a high level of interest in the Lean body of knowledge, specifically relating to graduates possessing a systems view of organizations and value streams. They also found that it was important that HEIs carefully matched organizational needs with students' learning experiences in Lean program and course design.

6.5 Conclusion

Oakland University is dedicated to providing quality programs leading to student academic success and achievement. With the support of the PLI, OU has been able to extend its academic scope to include various forms of Lean programming. It is imperative that a firm understanding of best practices and industry demands are accounted for when developing new Lean programs or when improving current Lean offerings in HEI. Therefore, many strategies for adding to the Lean body of knowledge need to be enacted. A strategic plan and fostering resources to support faculty has aided in ensuring quality in Lean programming at OU. Under development at OU is Lean graduate programming designed around both competency and content mastery expectations for students. The future is bright in HEI in regard to Lean programs and in the ability to develop effective practitioners of Lean.

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Chapter 7
Application of Lean Education in ECAM Lyon for Development Lean Management Training

Zahir Messaoudene

7.1 Introduction

ECAM Lyon is a precursor engineering school, in France, in the field of Lean Education. Since 2004, Lean Education became a strategic axis. We launched the Lean Management among education initiatives for our students but also for company employees. These activities around Lean Education helped us to develop strong partnerships with different companies. Our pedagogy is oriented on learning by doing. Our teaching is characterized by real-life situations (in companies) or by situations reconstructed using a platform. Our educational teachings have been enriched by the implementation of research programs. These research topics have focused on issues for the sustainability of the continuous improvement process. We are interested lean manager job. Indeed, we train our learners in an uncertain and complex environment. These simulations set goals to understand the aspects of cognitive and sociologic of lean management. This understanding gives scientific results. These results are subsequently used in the continuous improvement of our educational activities.

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7.2 Lean Education: An Efficient Response for the Development of Responsible and Sustainable Organizations

Faced with the pressure of increasing international competitiveness, companies need to hire expert staff in lean management. Companies need to share best practices for problems solving. Companies are also obliged to quickly spread the lean management principles into teams of workers and managers.

This has been verified with companies of Automotive Cluster of the Rhône Alpes region. Indeed, a survey was conducted among sixty companies about their need to adopt the lean management approach. Over 70 % of them are ready to welcome internships and graduation projects on the topic of lean management.

These companies want to start lean management projects or sustain their development in this area. In conclusion, there is a need to create dedicated training in Lean Management.

From 2004, the report "*A new impulse to the industry in France*" identifies the Lean Management as one of the ways to strengthen industrial competitiveness. This report recommends launching initiatives around training Lean Management to perform with competitiveness.

In 2009, the Ministry of Industry decided to launch a deployment plan for operational excellence in the French industry, called "*Quality Plan and Performance 2010*". The purpose of this plan is to help SMEs to improve their competitiveness through the mastery of continuous improvement program.

This includes a capitalization on the educational experiences of Lean Education. The goal is to allow a better dissemination of these teaching practices in the French Engineering Schools.

ECAM Lyon was selected because of its experience of Lean training deployment. Therefore, the Institute of Operational Excellence was founded in 2009. The aim is to strengthen our skills which allows the transfer to companies' culture.

7.3 Lean Education: A New Approach to Construct New Business Case and Continuous Improvement—The Inputs from the Business Community

To meet this need for French companies, ECAM Lyon made a commitment to implement appropriate responses.

We used a deployment strategy for teaching Lean Management in the form of Kaizen. The goal was to make experiments. These educational experiences must meet different student audiences.

These experiments were established according to scientific principles of PDCA. With the Lean deployment model, our teachings have enabled us to develop educational activities and also to amplify our response within French companies.

Since 2004, we have developed research programs and educational innovations around Lean Management to improve our knowledge to better train French companies.

The consequence has been to develop new partnerships with industry. Our deployment strategy of teaching Lean started in 2004 and was deployed for 6 years. Our strategy was developed with the methodologies: Hoshin Kanri and A3 report.

We formed a team of four professors, teachers and researchers for the development of lean management teaching activities.

7.4 Typologies and Methodologies for Lean Education

Since 2004, ECAM Lyon has developed different types of training to a variety of learner profiles.

7.4.1 The Training of Engineering Students (Lean Education Methodology/Learning Methodology)

First, we developed a new training for students. In 2004, ECAM Lyon has launched awareness training modules (40 h).

The aim was to enable learners to acquire a set of tools and techniques from Lean Manufacturing and therefore to understand the context of companies competitiveness.

In 2006, the investigation results of the "Cluster Automotive Lean Rhône Alpes" identified a growing need for expertise in the Lean approach. ECAM Lyon has increased the number of hours (100 h) to train its students with a reinforcement of problem solving and team management.

We have created educational simulations to improve our teaching of Lean Management. For this, we designed 10 educational games that simulate problem solving and continuous improvement (Jidoka, Pull Flow, standardized work, TWI, PDCA Animation and visual Management, A3 problem solving).

The purpose of these scenarios in the form of practical work is to position our learners in the context of problems—root causes—improvement. Our students are grouped by team where everyone plays a special role (operators, production leader, quality service, method service, production manager). Educational content are reinforced with videos (filmed in companies) to enable our students to learn to observe and identify the sources of progress (Muri, Mura, Muda).

We offer conferences with managers of companies which have implemented the Lean approach. We strongly use learning by error as a training model. This educational model allows our students to effectively learn the PDCA methodology. This approach is very useful because it puts our students in situations in a pragmatic, empirical and scientific implementation of Lean Management principles. The reader will find below examples and illustrations of our pedagogy (Fig. 7.1).

7.4.2 Advanced Training for Students and Employees: Lean Education Methodology/Learning Methodology

In 2007, the need for supporting companies to long term was identified in mastering managerial, behavioral, and cultural dimensions in the sustainability of the Lean system deployment. During this year, we demonstrated that only the mastery of tools and techniques was not sufficient and that the real problem was the business transformation of a managerial and organizational perspective. That is why we created an advanced training: Advanced Master in Lean Management and Continuous Improvement.

Organizational learning by problem-solving is a crucial and essential process to ensure the sustainability of Lean Transformation but which is unfortunately not often taken into account or misunderstood by managers. To our knowledge, there is no research program on the pedagogy of organizational learning in the context of Lean Management which responds to the following important question: "How to increase speed within the processes of problem solving and continuous improvement in organizations?". This question is very interesting because is linked to the nonlinear dynamics of organizations.

The Advanced Master in Lean Management and Continuous Improvement at ECAM Lyon (Graduate School of Engineering) helps provide answers to this important question. A big pedagogical and scientific experiment (20 days) was conducted during this program to measure the level of learning of our candidates in the field of Lean Management through organizational learning. In order to understand the factors that impact the evolution of the learning process of the students, we propose to implement a layout within a platform INEXO (a small hierarchical company with different roles, which will be presented at the conference) with several production lines and the possibility to manufacture real products. This interactive educational immersion allows us to provide responses to the following organizational questions:

What are the determinants for adaptive learning for problem-solving?

How can we explain the reasons for generating organizational transformations?

During the simulation, we created a "simulated" company maturity assessment tool (relationship between operational systems and managerial practices) to help groups of students to measure the maturity of their problem solving and continuous

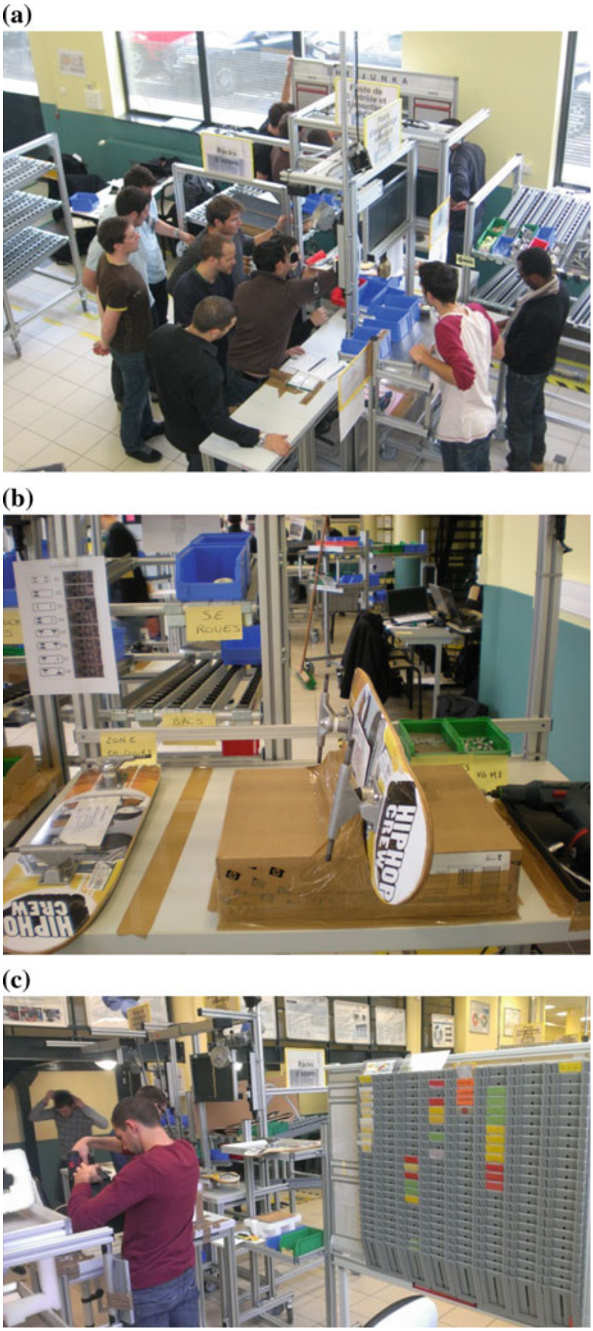

Fig. 7.1 Photos and documents of the pedagogy used: **a** Continuous improvement of an assembly line (TWI + Kaizen team); **b** Design of workstation with the Kaizen approach; **c** Use of Heijunka system to drive the information flow

improvement process (called Problem Solving Value Stream Mapping: PSVSM©). Participants must not only identify the ways to improve the technical aspects of their process, but also understand and master human behavior in the context of organizational learning (continuous improvement of the continuous improvement process: [CI]^{2}P©). The purpose of this interactive and practical simulation is to better understand individual and collective human impacts (social, psychological, cognitive, and behavioral), and organizational impact-induced changes (level and decision-making, accountability, hierarchy, multidisciplinary working groups, deployment of the tools for continuous improvement…) made by the Lean transformation.

To do this, we simulate the roles of the Lean Manager, who must also be the "problem solving chain manager". Another goal is to understand better the obstacles blocking the culture of continuous improvement. It is in fact subject instability in the management of the problem solving process and result in the students' lack of cognitive 'flexibility'.

We propose a new educational model that is based on instructor training. Indeed, for 5 days, our students prepare training and train others students on the basics of Lean Manufacturing. The educational innovation is to put our students in the role of trainers.

As part of this training, we dedicate 15 days of the implementation of animation techniques of visual management principles. Indeed, our students spend 15 days in an "unknown company". They must understand the problems of companies and to train the teams of these companies with problem solving and kaizen animation. This educational activity is an innovating pedagogy that confronts our students in a realistic situation. This pedagogy is an effective way to measure the evolution of student's maturity in mastering key principles of Lean Management. The reader will find below examples and illustrations of our pedagogy (Fig. 7.2).

7.4.3 Continuous Improvement of Lean Management Training that Is Certified and Recognized by the French State

In 2008, in response to the issue of sustainability of continuous improvement efforts, our school has created the CERSYL (Centre for Studies and Research on Lean System). This is an observatory in the framework of the implementation of learning organizations.

In 2010, our training programs have been monitored and gradual changes have been realized to meet the response to company's needs. Since 2007, we focus on a certification that builds skills on the strategic axes, managerial axes and cultural axes. In this context, to improve the recruitment of continuous improvement

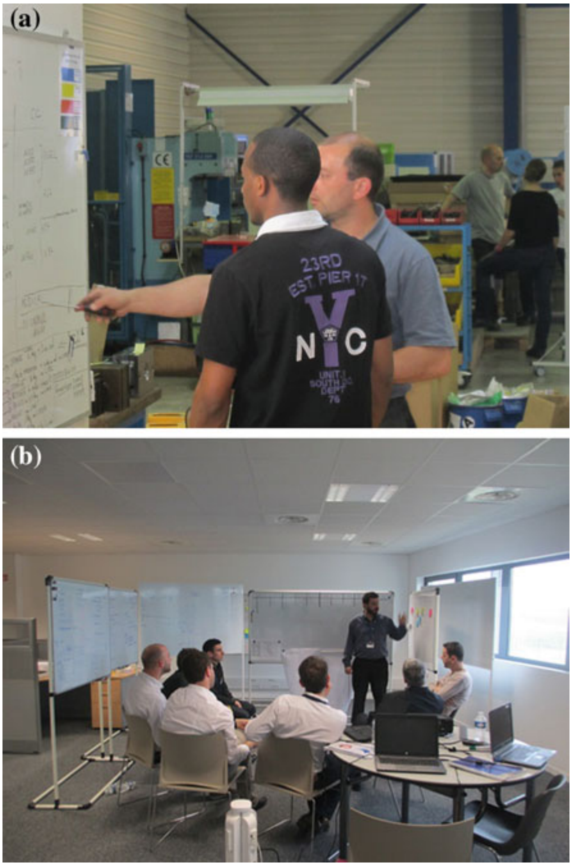

Fig. 7.2 Photos and documents used: **a** Team work (worker and student) in a Kaizen activity; **b** Learning through the training of trainers (our students become trainers)

managers and to better support employees (at SMEs and Groups), ECAM Lyon is involved in a registration procedure for this certification in RNCP (Répertoire National des Certifications Professionnelles). This certification "Manager of Continuous Improvement" is designed to validate the skills to supervising animation activities to improve competitiveness in companies. This certification is the culmination of over 10 years of studies, analysis and reflection on the job of Continuous Improvement Manager.

The "Institut Lean France" (ILF) supported by the "Pôle Productique Rhône Alpes" has supported the creation of this certification. ILF is the organization that guarantees the good practices of missions of the continuous improvement manager in France. This training deployment strategy around the Lean Management has allowed us to create a strong network of partners at the companies' level, regional organizations (CCI, DRIRE, CRITT, and THESAME), the automobile platform (PFA), and CARSAT and research laboratories in the field of management science.

Table 7.1 Results of lean education at ECAM Lyon since 2012

Students trained	758
Employees trained	243
Partnerships	10
Research topics	7
Industrial contracts	23

The Table 7.1 below summarizes the integration of Lean Education in acquiring new business and the impact on the business community (number of learners trained, number of partnerships created, research topics and industrial contracts).

The impact of the training program is to better train our students to the issue of business competitiveness. For this, your training meets the needs of company's changing (recruitment of future employees and improving the skills of their employees). Thanks to Lean Management, our school has become a reference in France in terms of teaching and research on performance of continuous improvement in different companies. We have signed agreements with companies (Manitowoc, Bosch, PSA, Volvo, Ugivis, Faurecia, Joint Technique, and Remy Barrere) and public organizations (Thésame, ILF, and CARSAT). Also through this program, we were able to develop research around learning organizations and organizational learning (CERSYL). It must be added that this program allows (through research developments) to raise the teachers skills in sociological problems of Lean Management implementation.

7.5 Lean Education: A Means for Development of the Student's Employability and Employees Skills

7.5.1 Research Chair for Students and Employees

In order to develop the employability of our students and employees in an uncertain and complex organizational environment, we have developed a research chair: "Companies Dynamics and processing skills using the Lean Education". This research chair is supported by the Center for Study and Research of Lean System (CERSYL: founded in April 2008) with companies and partner organizations.

The originality of CERSYL revolves around a scientific culture based on human science, management science and engineering sciences. This multidisciplinary approach allows the embracing all aspects of the transmission, practice and dissemination of Lean in companies. CERSYL uses his ability to imagine new managerial models of the Future for the benefit of french companies and future generations of lean management practitioners.

Research should focus on two closely interrelated issues (Fig. 7.3):

- Action-research;
- multidisciplinary research.

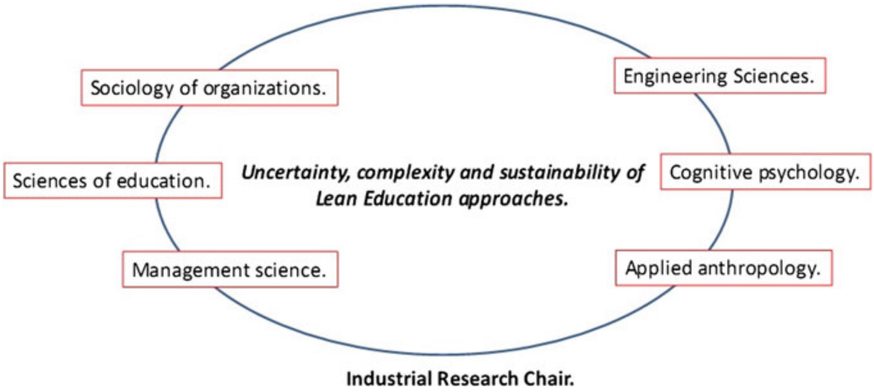

Fig. 7.3 Interdisiplinary research chair

7.5.2 *The Employability of Students*

The Institute for Operational Excellence (INEXO—2009) and the Center for Study on Lean System (CERSYL—2008) were developed to study in depth the Skills of developments of Lean Manager Job. These two structures have a tool of pedagogical management and a monitoring system for the development of employment and training.

The monitoring system has the following objectives:

- to analyze operational and managerial practices in companies which develop lean management (publications and surveys);
- to create partnerships for the dissemination of good practices of lean management;
- to examine the conditions of adequacy in employment/training (survey annually renewed);
- to anticipate the evolution of the profession of continuous improvement manager in SMEs;
- to publish scientific articles on the sociology of the continuous improvement manager (technology transfer);
- to develop new teaching practices and training engineering responding to economic change (Platform and educational games).

The main tasks of the CERSYL are:

- to capitalize the initiatives on the Lean at the international level
- to design innovations and know-how around Lean Management
- to train the future generations to dissemination, practice and sustainability of Lean

- to develop researches based on industrial issues in sustainability practice
- to study the conditions of practice diffusion on the maturity of companies
- to innovate for better dissemination and Lean adaptation at different hierarchical levels in organizations
- to anticipate and manage new educational engineering.

Evaluation of training is conducted within the development council. The development council's role is to enable participants to obtain a high level of knowledge and expertise in the area of continuous improvement. The development council will ensure the quality of training to meet the requirements of companies. The development board is the guarantor of the relationship between science, education and industry. Each development council member brings their advice, both scientifically and pedagogically. The means of action are:

- the scientific expertise;
- the monitoring and management improvement actions;
- the determination of the communication strategy;
- the consolidation of relations with industrial partners;
- the adaptation of training with the scientific advances.

The development council has established and has operated a training assessment procedure whose performance indicators are:

- number of candidates;
- number of selected participants;
- number of participants employed after training;
- number of partner companies;
- number of companies for internships;
- QoS level (number of satisfied participants and number of satisfied companies);
- courses level;
- level of the case studies and projects;
- level of training from good practices;
- industrial satisfaction level;
- scientific quality of training.

These indicators make proposals to improve training.

An alumni association following the certification was built from the beginning of the creation of the training. This association organizes various events in order to follow holders who have completed this certification. The first event is the sponsorship between the holders of the year (n) and alumni of the year (n−1) upon graduation. This sponsorship is held every year around the month of November. The purpose of this sponsorship is to connect graduate students in building work days around the development of the certification.

These workshop days are held every 4 months with a maximum of graduate students (December, March and July). The objectives of these working days are:

– Presentation of the career paths of students graduating classes (n−2) and (n−3) to map the career development
– Upgrading of knowledge on key elements provided during the certification with the training experts
– Visit businesses which have hired graduate students to analyze continuous improvement projects completed.

The goals of the workshops are to understand the changing needs of companies that hire our graduate's students. It is also permit to translate the thematic development axes and change pedagogy. A survey is sent for capitalizing on the experience feedback (positions held, wages, type of organization) graduate students.

Finally, we organize a conference every year (in May) with the theme of lean manager skills which last two days. Participants are graduate students, business leaders as well as experts working in our training. The aim of this conference is to understand the changing needs of companies to develop effective and innovative solutions.

By tracking our graduate students (sponsorship, workshop days and conference), we analyze macroscopically changing the needs in training new students to prepare medium-term developments of certification. For example, we identified the need to strengthen the "Organizational Coaching competence" for driving change in companies. These axes of change allow us to take into account the needs of new skills.

The annual conference allows us to understand the new methods, practices or tools provided by existing companies (through senior experts). This allows us to integrate them into the certification program (examples: TWI practice, VSM of problem solving and strategic A3). The system for monitoring student graduates allows us to develop educational axes of about 30 %.

7.5.3 The Development of Employee's Skills

Within the Research Chair, we have implemented a program to better understand human impacts (social, psychological, cognitive, and behavioral) and organizational impacts caused by changes (level and decision making, hierarchy, multidisciplinary working groups, deployment of continuous improvement tools…). Therefore, we focus more deeply on the skills of Lean Manager or Agent of change. We believe they must have a role of "manager of problem solving chain" (agent of the transformation of problem solving process). Another objective is to better understand the obstacles from the variability of the management of problem solving process and a lack of "flexibility" cognitive agents of change. Finally, cultures are specific to different types of situations; we focus on the correlations between culture (national, companies and personnel). These cultural patterns influence the learning culture of continuous improvement.

We propose to formalize best practices animation. They are carried out using a modeling approach on the mechanisms of interaction between managerial tools, change management and organizational learning (capacity models of visual management systems).

We propose an approach of observation and evaluation of cognitive activity during problem solving approaches (Kaizen workshop). This is to identify the sources of progress in the ability to solve problems of the actors within companies (strengthening activities of Kaizen Teian type).

We have also developed a mapping of learning of cultures of continuous improvement. This mapping can identify correlations with corporate cultures and business (building organizational activities of continuous improvement).

In order to develop the skills of employees (including managers and leaders) we propose a mapping of Lean Manager Skill fields under difficult work situations, uncertain and praxeological (learning to learn). For this, we used the TWI model (Training within industry) developed for the supervisor competencies. This model is suitable for lean manager function. It consists of 3 professional areas: Job Method, Job Relations and Job Instruction.

- Job Method: being able to teach people to engage in problem-solving process;
- Job Relationship: being able to identify sources of stress for employees and to take action to eliminate these sources of stress;
- Job Instruction: be able to support management teams in the development of the culture of continuous improvement.

This competency framework is derived from the organizational learning and learning organization to assist employees in their mission to be lean manager.

Employees are trained to be future experts in problems solving of competitiveness. The contents of the training accompany our candidates to be change agents and animators of the Lean approach. The key principles taught bring to our students the following skills:

- <u>Development of continuous improvement strategy.</u> They learn to drive change in companies with implementation policy of continuous improvement. Our teaching philosophy allows them to learn to coordinate transformation projects and provides solutions to the competitiveness problem. Learning by solving problems within our training gives them the key elements for understanding the business strategy dynamic.
- <u>Coordination of projects for continuous improvement</u>. They learn to identify the mechanism of progress and quantify their limits. Our training content allows them to define the implementation of progress operations. Our training philosophy advises them in the definition of the rules and the standards work to improve. They also learn to define the indicators to measure progress.
- <u>Accompaniment teams for problem-solving.</u> They learn to train people through the principles of animation. To do this, our teaching philosophy guides to

Table 7.2 Activities developed and skills

<table>
<tr><th colspan="2">Activity 1: Develop a strategy of continuous improvement deployment</th></tr>
<tr><td>Task:
Identification of competitiveness problem
Conduct research to understand the current situation of the organization
Conduct of factual analyses of the root causes
Design of countermeasures to address the root causes
Targets development for improvement</td><td rowspan="2">Content:
History of performance and industrial strategy
Business and performance
Economic strategy, growth and development
Value and value management
Value stream management (VSM)
Punctual Kaizen, flow Kaizen, Kaizen system
Strategic A3
Value-added direct (VAD) and Activity-based costing/management (ABC/ABM)
The observation of value chains, wastes, variability and overloads mental/physical
Techniques and observation tools
Analysis of value chains and identification of the root causes
Techniques and analytical tools/Tests of hypotheses and experimentation</td></tr>
<tr><td>Skills:
Diagnose the performance of a product licensing process or service
Define the axes of priority progress contributing to the strategic objectives of the company
Propose the levers or actions most relevant improvements</td></tr>
<tr><th colspan="2">Activity 2: Coordinate continuous improvement projects</th></tr>
<tr><td>Tasks:
Creation of action plans
Development of plans for monitoring with planned results
Discussion of plans for monitoring with all affected parties
Obtaining approval for the implementation of the actions
Implementation actions</td><td rowspan="2">Content:
Working standard and standardized work
Performance indicators
Stability of the processes and visual management
Planning and visual scheduling (Heinjunka)
Construction of the quality in the process (Jidoka)
Flexibility of organizations (SMED)
Just in time (Kanban, Pull Flow)</td></tr>
<tr><td>Skills:
Pilot actions for improvement of the performance of process
Measure the performance of the process
Detect and implement corrective actions</td></tr>
<tr><th colspan="2">Activity 3: Accompany the teams to problems solving</th></tr>
<tr><td>Tasks:
Evaluation of the results
Standardization to ensure results
Stabilization standards
Improvement standards
Continuing education at problems solving</td><td rowspan="2">Content:
Training within industry (Job training and job relationship)
On job training (field training activities)
Gemba walk, indicators and visual management control
Individual and collective behavior, changes in enterprises
A3 report, problem solving (QRQC, red bin, PDCA)
Information systems and Lean
Actors, roles and responsibilities
Participatory projects and teamwork
Health and performance</td></tr>
<tr><td>Skills:
Prepare teams for the methods and tools of Lean improvements
Enhance the results obtained and the actions implemented
Standardize best practices</td></tr>
</table>

change management methods in order to make people to be actors in the process. Our vision of Lean Management accompanies them to become real strength of proposal. Our pedagogical approach helps them to be animators and actors of change.

The following table Table 7.2. presents the Lean Manager activities with its missions and the content of our training.

Chapter 8
Sawhney Lean Educational Maturity Model at the University of Tennessee

Rapinder S. Sawhney and Enrique Macias de Anda

8.1 Lean System Failure to Sustain

For many years, Lean manufacturing has been Industry's key initiative to develop a competitive advantage. Researchers have documented substantial evidence about Lean's benefits; however, its sustainability over time has been questioned, as not many organizations have kept an on-going effort.

Several studies have reported the inefficiencies of Lean, where organizations often have followed an unplanned approach rather than a systems approach. As a result, the overall performance is adversely affected while the waste (non-value added processes) just transfers from one part of the system to another. Furthermore, the initiative is often misunderstood as a cost-reduction project that generally fails to produce the anticipated results.

A study has reported Lean implementation efforts to fail 95 % of the time (Ransom 2008), as any favorable results achieved in a short term tend to dissipate over the years. Professionals in the area have dedicated significant efforts to explain the reasons, from attitudinal perspectives to more technical approaches. What they have found is that focus in short term gains, the pressure of inventory reduction that let unreliable processes emerge and continuous change lead to a loss of motivation.

The Lean Enterprise Institute reported in 2008 (Sawhney et al. 2010) that the main factors for failure are:

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1. Backsliding
2. Middle management resistance
3. Lack of implementation know-how
4. Lack of critical thinking.

The question that comes to mind is how can this be avoided or prevented? From our perspective, both Industry and Academia have their stake in providing the ground for new approaches, testing and replicating successful practices.

8.2 The Role of Educational Institutions in Developing Lean Maturity

Our starting point as a proposed solution is the implementation know-how. The philosophy in the Department of Industrial and Systems Engineering at the University of Tennessee—Knoxville (UTKISE) is that both, higher education institutions and industry, share the responsibility for mentoring and developing Lean professionals that have developed a sufficient "maturity" in the field, providing relevant system based solutions and engaging stakeholders with vested interest in the implementation.

However, a tremendous variability exists on how organizations qualify individuals as Lean professionals since there is not a precise definition of public domain or no standard. Hence the irony, as this lack of standardization, in a philosophy that promulgates it as a foundational concept, prevents providing a guarantee that everyone in this field possesses the necessary level of maturity to design and implement a sustainable Lean practice (environment).

This minimum maturity can be articulated, but not limited, by three dimensions: social, technical and cultural. Social maturity implies that the Lean professional aligns the Lean design to enhance the quality of life of the impacted stakeholders, especially the employees. Is it possible that the middle management resistance and the backsliding identified by the Lean Enterprise Institute partially occur because stakeholder well-being is not secured?

Technical maturity does not mean certifications. It rather focuses on a fundamental mastery of the prerequisites and the implementation of Lean in context to the systems that already exist within the organization. An example is to fundamentally understand the role of other disciplines, such as reliability, in the design of Lean systems.

Cultural maturity implies understanding, adapting and consolidating different environments into a singularity. Sharing a vision and pursuing a common goal, breaking up with old and outdated organizational patterns, but with the sensitivity to understand factors of influence, such as national and corporate culture, helping to progressively develop this new culture.

8.3 The Sawhney Lean Maturity Educational Model

The Sawhney Lean Maturity Educational Model (SLMEM, Fig. 8.1) is designed to develop four different levels of skills that build on each other to define the required skill sets of Lean professionals. SLMEM is presented by its four key phases of education: Core Lean Skills, Critical Lean Problem Solving Skills, Systems Skills and Leadership Skills.

- Core Lean Skills: The key focus of this phase is to allow the Lean philosophy and the requirements of the specific situation to drive the implementation rather than nurturing a tool-centric approach. The first phase of SLMEM is to develop core skills which are defined by three key components: an understanding of metrics, their alignment with the value proposition from a customers and organizational perspective, and the appropriate application of core Lean concepts and associated principles.
- Critical Lean Problem Solving Skills: The key focus of this phase is to supplement the Critical Lean Skills with the ability to define the problem from a total systems perspective and integrate the concept of Lean's sustainability into design and implementation. This is accomplished via the DRIVES model (explained in Sect. 8.3.2.4), which is comprised of three objectives: defining the right Lean problem, implementing a relevant Lean solution (core Lean skills) and proactively sustaining the Lean solution.
- Systems Skills: The third phase of the Lean education is to develop Systems Skills by introducing Lean practitioners to different complex systems providing insight into similarities and differences between them from a Lean perspective. Systems Engineering plays a fundamental role in developing the systemic view and identifying the patterns that characterize different environments.
- Leadership Skills: The fourth phase of SLMEM utilizes Boeing's definition of Leadership (Sawhney and Macias de Anda 2014) to allow Lean professionals to refine their Lean approach based on the values and culture of an organization. Womack and Jones, in their book "Lean Thinking" (2003), state that values and

Fig. 8.1 Sawhney Lean Maturity Educational Model

culture are present in the organization, but the proper observation of these principles is a must for a successful implementation of Lean. We place especial emphasis in Leadership as it allows a Lean professional to become more independent and creative, tying up all the previous concepts together, reaching the required maturity for successful Lean implementations.

8.3.1 Core Lean Skills

The central purpose of SLMEM is to develop the core Lean skills that would allow practitioners to design and improve systems, possessing a solid know-how of all the tools. This knowledge is intended to be utilized throughout the rest of the model on a strategic perspective, preventing forced applications, misaligned efforts, and subsequently, failed initiatives.

Therefore, the development of core skills requires a systematic curriculum introducing the system in a stepwise approach. We have achieved this approach through a modified version of Monden's Toyota Production System model (Monden 2011), as illustrated in Fig. 8.2. This framework reflects not only the structure of our coursework, but also the way we approach Lean system implementations.

Nonetheless, the core skills have to be aligned with other attributes beyond this model, those that play an important role throughout the framework implementation. Students are reminded constantly and consistently to pay special attention to these attributes in order to reach the maturity necessary for core skills.

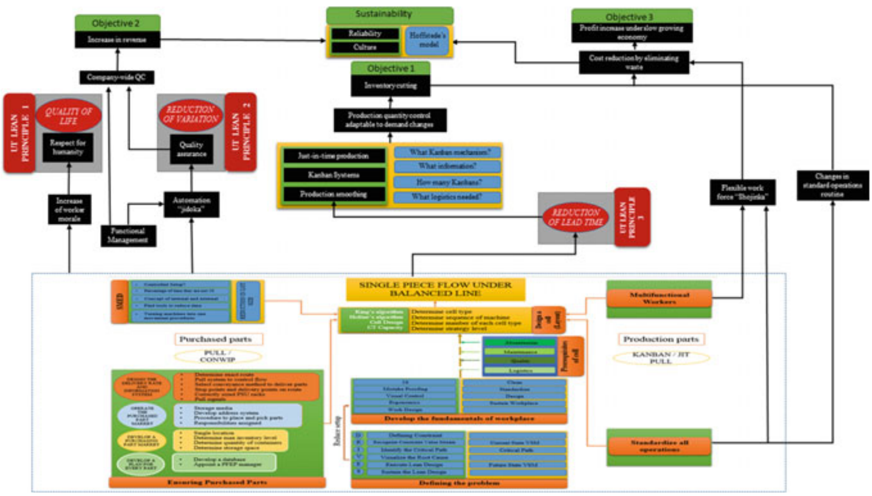


Fig. 8.2 Modification of Toyota production system (A larger version of the model is depicted in Appendix)

8.3.1.1 The Role of Metrics

Metrics are the first attribute, driving the success or failure of any implementation. In our lectures, students are constantly reminded of Drucker's fact: "you can't improve what you can't measure." It is only through the understanding of metrics that goals can be set, strategies can be aligned, and monitoring can be possible. However, it is important to focus only in the relevant metrics, those who will speak the language of the desired implementation.

Additionally, metrics in Lean are often considered in isolation, where our approach is to consider the systemic vision that can put them altogether. Here is where we introduce the concept of *effectiveness versus efficiency* of a system.

In practice, the effectiveness of a Lean system is commonly measured by the overall efficiency of the system, using metrics like throughput, inventory, and time. Therefore, the success of Lean is associated with the output of the system where it has been implemented. We must understand that in this sense, metrics must observe three characteristics: reliable in nature, hierarchical in structure, and their relevance has to be determined by the lag or lead of the dimension they are expressing.

Our approach then, is that the effectiveness of a lean system can be measured using the efficiency, reliability and other factors that become relevant in the system being improved. In other words, effectiveness becomes a function of other metrics, which subsequently can be broken down with relevant indicators:

$$\text{Effectiveness} = \text{f}(\text{Efficiency}, \text{Reliability}, \ldots, \text{others})$$

However, we should be careful understanding these metrics, as sources of measurement data frequently exceed the capacity of organizations to process and analyze the information generated. A mature Lean practitioner would not get lost in the sea of information. On the contrary, would apply a leaner approach for measurement records and their analysis, using only those who are relevant for both the implementation and the goals of the organization. Here is where alignment, the second attribute, plays an important role.

8.3.1.2 Aligning Values with Lean Implementation

Lean is a paradigm with a measurable set of principles and associated tools that should be implemented with respect to the goals pursued by the organization. It also has to be in line with traditions and norms of the culture where the implementation is taking place. It is not the intention to violate the principles of Lean, but to understand that the environment (with its cultural values) determine the success of the initiative.

In this context, practitioners need to be aware of the purpose of Lean, using critical thinking to design systems that effectively address the needs and expectations of customers, either internal or external (or both). Common measurements such as throughput, inventory or TAKT time might not be applicable in some scenarios. The only way to determine relevant metrics is understanding the nature of the process with a magnifying glass, and discriminating those metrics which are not pointing in the direction of the strategic goals of the organization.

Value identification is critical. The voice of the customer (with its different gamut of tools) needs to be heard, demonstrating a thoughtful meaning for Lean practitioners identifying value and providing the initial steps that cure the "blindness" for relevant, measurable and aligned improvements.

Let's consider organizations A, a fast food chain, and B, a fine dining restaurant chain. Imagine that we were required to implement Lean in both. It would be a mistake to infer that since both organizations are in the service sector and both serve food, the same metrics are to be utilized with the same magnitude. We must understand the nature of each business sector, as well as the priorities that define the strategic competitive advantage for each. Speed of service from order to delivery would be completely different between the two scenarios, by the definition of their business. As well, each brand would be different in how they decided to compete. Hence, reduction of serving "lead time" would have completely different targets and priorities. Organization A most likely would work to have orders completed as fast as possible even at the stake of customer's experience. On the contrary, organization B would probably pay more attention to quality of food, attentiveness of servers, and other indicators over how fast they serve food. Again, alignment of the improvement should observe the environment and appropriate metrics.

8.3.1.3 Core Lean Principles

The reference we consider to identify the core of Lean Systems is the Toyota Production System (TPS) as presented in Fig. 8.3. The model was compiled in the

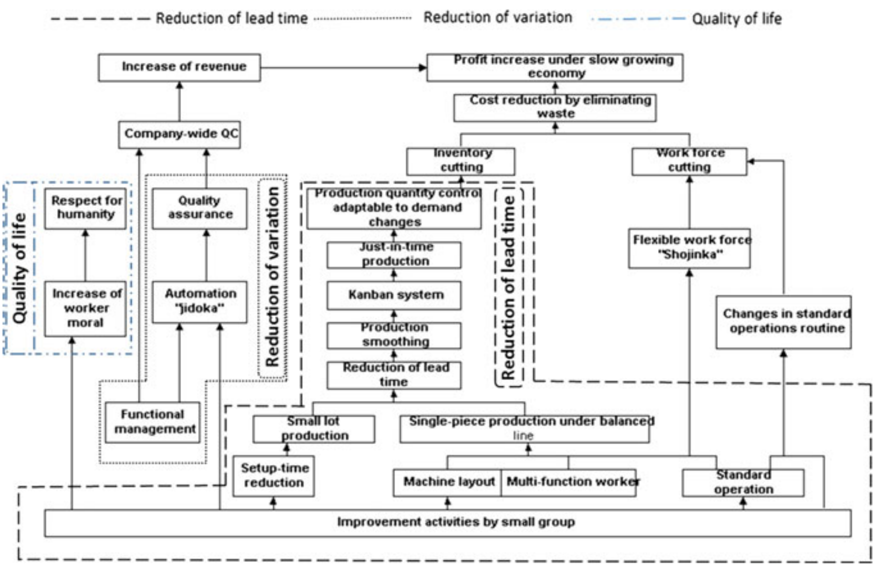


Fig. 8.3 Toyota production system (Monden 2011)

eighties by Profr. Yasuhiro Monden at the University of Tsukuba in Japan. It supports the logic behind TPS with a comprehensive and sequential approach to achieve the Lean goals.

The perspective for the analysis of the model is to understand the motivations of its elements, as every concept (box in the roadmap) represents a tool or methodology leading to a particular goal. Our initial step is to identify the categories of waste associated with each concept, introducing the students to the rationale behind the implementation (why) and the relevance of the preceding concepts (what is needed).

For example, *single-piece flow* is a parallel objective with *reduction of the lot size*, both of which are necessary for the reduction of time. Achieving them may not be possible until setup time is reduced to an acceptable level, ideally pursuing a Shingo's *Single Minute Exchange of Dies* (SMED). In similar fashion, toolsets are introduced and connected to the various areas of the TPS, for students to learn and understand a generic roadmap of implementation.

The other concepts can be introduced once there is understanding of the complete roadmap. Three principles are explained as the core of any implementation, enhanced by a combination of Six Sigma concepts and principles of civility. In other words, students learn that these principles are universal within organizational systems, and must be introduced in order to create a sustainable and relevant implementation:

- Reduction of lead time
- Reduction of variation
- Improve the quality of life of people.

The combination of the three principles allows to generate resonant improvements throughout the organization, as measurable operational objectives improve and sustain over time with the enhancement of people's quality of life. In our educational model, this is the premise that encourages our students to embark in the Lean journey for the achievement of a greater good.

8.3.1.4 Requirements for Successful Lean Implementation

The most important objective of the Core Lean Skills is to allow the students to develop their Lean framework using a tiered approach. The modified TPS model (Fig. 8.2) presents, from bottom-up, the first tier of Lean understanding by evaluating multiple requirements that Lean professionals may have to address:

1. *What are critical communication and organizational requirements before initiating a Lean effort?*—It requires students to consider the importance of communication and leadership in a Lean initiative to reduce the anxiety, uncertainty and resistance to change.
2. *What are the critical requirements in designing the work area? and, what are the critical requirements in designing flow?*—We introduce fundamental Lean concepts, but distinguish between those that help to design the work area and those that focus on the design of flow, even though these concepts are interrelated.

3. *What are the critical requirements for controlling variation?*—The intention is to illustrate the different types of variation, their impact on a system and the need for their control and, if possible, mitigation.
4. *What are the critical support requirements from internal functions?*—We discuss the need of aligning the Lean design with the organizations' internal ability to support it.
5. *What are the critical supply chain requirements?*—It helps us to create awareness on the suppliers' importance to support the Lean initiative.
6. *What are the critical factors for sustaining the solution?*—This question forces the students, eventually implementers, to address the issue of sustaining the Lean design.

In the second tier, the associated logic and roadmap are utilized to provide insight into how to address these concerns. For example, the modification of the Toyota Production System illustrated in Fig. 8.2, is utilized to teach students the fundamentals of flow. This should give the Lean professional the ability to create solutions based on solid foundations.

The third level introduces the details associated with implementing each of the six requirements discussed above. Typically, many Lean implementations focus on questions 2 and 3 with supporting roles for other requirements, based on the maturity level of the implementer and the organization.

This provides the Lean professional a systematic approach based on precedence to implement different aspects of Lean as defined by the scope of the initiative.

8.3.2 Critical Lean Problem Solving Skills

The motivation to explicitly define Lean initiatives via a systems approach allows the Lean implementation process to be Lean in itself. Lean results impacting organizational competitiveness and performance should be achieved with the least amount of effort and resources, challenging the rationale that simply increasing the number of Kaizen events, produce leaner systems. Hence, the opportunity for the Lean practitioners to start with a clear goal in mind, to "work in the right problem."

8.3.2.1 Defining the Problem

It is part of human nature to jump to conclusions without a clear understanding of the picture, frequently leading to the wrong direction. Defining the problem before assigning a set of tools or techniques helps reducing time and efforts required to analyze and resolve a specific problem.

Critical thinking supports the formulation of the real problem. Through our experience, this element seems to be the most challenging. Frequently, finding the difference between a symptom and the issue's root cause is ignored. The negligence to understand and define the situation properly will mislead the efforts resulting in immediate failure.

Think of the student that has a headache, preventing him from proper concentration in class. At first instance, the headache seems to be the reason why the student has not demonstrated proper learning in that class. The instinctive solution is to recommend the student to take a headache pill before each session. In the beginning it seems to provide results, but eventually the pills stop relieving the pain. This solution was focused on the symptom, but not on the root cause of the problem.

An exploratory understanding of the whole context in which the headaches happen could have been a better approach. Maybe only a physician would be capable of determining the real root cause, which could be vision loss, hence requiring prescription eyeglasses; lack of a certain nutrient, requiring proper eating habits; or increase in blood pressure, requiring exercise and stress control. This is the perspective that a mature Lean practitioner would be able to understand and practice.

For this purpose we utilize a structured step-wise methodology that helps in defining the problem, aligning the proper tools and techniques required for its solution.

8.3.2.2 Implementing the System

Once the right problem has been identified, we work on developing the right solution. That is approached with a full understanding of the conditions that bound the system being designed. Here is where we make the connection back to the modified TPS, and utilize the concepts depending on the needs:

- *Develop the fundamentals of workplace*: The purpose is to use the concepts of clean, standardize, design and sustain in the workplace. Standardizing problem solving along with defining and developing the fundamentals helps reducing the overall set up time.
- *Ensure purchased parts*: Determining and defining the logistics of purchased parts by developing or integrating an information system that keeps track of parts and operate the purchasing market with a plan for every part helping to keep inventories at the minimum level.
- *Reduce lot size*: The above fundamentals along with reducing lot size using SMED and one-piece flow in a manufacturing cell support the changeover downtime, increasing flexibility for changes in production. In order to design a cell that can completely eliminate the downtime, standardization of all operations involved in the process and having multi-functional workers would act as an added advantage.

The expected outcome of the system is the design and execution of multiple processes that aim for a single-piece flow under balanced workload (under *takt* time) as an evidence that the system has been standardized.

8.3.2.3 Sustaining the System Design and Implementation

Proactively sustaining Lean solutions requires an introduction to the concepts of Reliability Engineering and the impact of culture on Lean implementation. Lean professionals are generally aware of the impact of reliability and culture on Lean, but do not have any significant approach or "toolset" to allow them to be effective.

A common definition of reliability is the probability that a given product, process or system will successfully perform its intended function without failure, under specified environmental conditions for a specific period of time. We can introduce the same definition in the context of a Lean system, focusing in the required function, stated condition and specified time (Iwuchukwu and Sawhney 2012).

In general, system design methodologies fail to recognize the period a task can perform without failure, assuming that the conditions will not change. Thus, the outcomes start to deviate from the optimal performance within a very short time without making an impact on the overall goals of the organization. This also results in a bad return on investment as it does not sustain and the capital investment on the project nullifies its benefits.

Incorporating reliability supports the robustness of the system, while enhancing its sustainability. However, it is not the only factor needed. The other element we consider relevant is culture. The term culture has been used in various disciplines to identify specific aspects of human interaction. Systems design must pay special attention to employee involvement in the process, otherwise without their buy-in it will fail.

As discussed in Sect. 8.3.1.2, culture plays an important role in transforming practices and implementing strategic plans in both business and manufacturing environments. Deeply rooted and systematic problems do not go away with the introduction of just principles. These are critical issues that must be recognized and addressed early in any transformational process if that process is to sustain. People order their universe through social biases by bringing them out into the open. It is then that we will understand better which policy differences can be reconciled and which cannot. Cultural analysis shows how a given cluster of values and beliefs makes sense out of various positions people take and the practices they employ. This unique perspective incorporates cultural variation in the perception of task improvement to allow insight into resistance to change.

For example, there are certain cultures that inherently are team oriented, while other cultures are more independent. There is no question that Lean success is based on teamwork, however, understanding these cultural differences becomes an important factor in the approaches and mechanisms utilized to develop the necessary teams. Therefore, it is essential to allow Lean practitioners to identify the value system of the organization from different approaches.

We understand cultural alignment from a societal perspective, based on Hofstede's et al. (2010) model. He articulates national culture based on six dichotomous dimensions: masculinity versus femininity, long versus short term orientation, individualism versus collectivism, long versus short power distance, high versus low uncertainty avoidance, and indulgence versus restraint. This model becomes useful when we isolate the organizational environment from the geographical context. Therefore, focus on effective intervention for implementation of system design can have a significant impact on reducing resistance among workers, and nesting a new culture that would favor continuous improvement.

8.3.2.4 The DRIVES Model

In order to address each step in alignment with the sequential implementation of Lean systems, we developed the DRIVES model (Fig. 8.4). On one part, this model provides a breakdown of the addressed issue at three different levels: system, process and design; this perspective helps to identify the right problem from the broader view to a specific context. On another part, it provides a methodology in a sequential set of steps by framing the problem in a structured way and facilitating critical thinking, applying the proper tools for a long term solution.

We use the DRIVES model as the framework for which the metrics will reveal certain capabilities for both the individual and the collective (teamwork) basis in the design, model and implementation of process improvement. Its name comes from the acronym that describes each one of the steps:

1. *Define* the constraint of the system as internal or external.
2. *Recognize* the value stream (VS) of the constraint.
3. *Identify* the critical path within the VS using the critical path method (CPM).
4. *Visualize* the specific constraint within the CPM to find the root cause.
5. *Execute* the design and implement the Lean based system to address root cause.
6. *Sustain* the implementation through reliability, cultural adaptation and training.

The first four phases of the model (DRIV) focus on problem identification and definition, whereas the fifth and sixth steps (ES) focus on the implementation and sustainability of the solution.

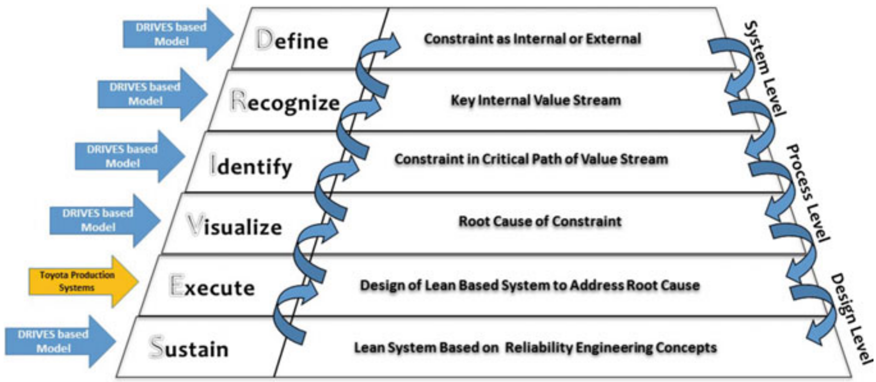


Fig. 8.4 DRIVES model specified for different levels

8.3.3 Systems Skills

It is essential for practicing professionals to understand the diverse scenarios of cause and effect relationships that a new design comprises. Furthermore, these designs won't always obey a replicable pattern, as we migrate from manufacturing to other domain areas. At a conceptual perspective Lean could be applied, but from a tactical standpoint, adaptation would be necessary.

For example, can hospital management and healthcare delivery be efficiently and effectively improved by Lean? There is no argument that Lean plays an important role understanding healthcare processes, as it explicitly addresses the design and improvement of healthcare systems. However, at a tactical level a more robust set of tools are required to effectively design and improve healthcare processes. This is not evident for the common Lean practitioner.

Decomposing healthcare processes into three categories as Discrete, Stochastic, and Bayesian processes highlights the limitation of Lean tools. Value Stream Mapping (VSM) is very applicable to discrete processes because of their repetitive nature with minimal time variation; however it is not the most effective tool. An example is the preparation of surgical tools. Value Stream Mapping does not provide the necessary depth to analyze systems that route entities in a probabilistic fashion through different parts where process times vary significantly for each entity.

An example of a Bayesian process is highlighted by the variability of how patients are "processed" in the emergency room. Imagine a person that has come to the Emergency Room with substantial pain in his abdominal area. The process of waiting and determining how critical his condition is can only be based on the initial assessment performed by the nursing staff appointed at that moment. From that point, the waiting time, subsequent examinations or procedures, treatment, dismissal, and any number of variables and decisions that happen in the hospital are big unknowns for what Lean tools can only support fractions of it making the "flow" of the patient the shortest possible to bringing him back to a healthy condition. Nonetheless, Lean systems do not address these types of situations if applied rigorously by the book.

8.3.3.1 Cause and Effect: Systems Engineering

The common definition for a system is a group of elements interrelated that form a whole with a specific purpose. Any system would have inputs and outputs, interacting in fulfillment of their purpose. It is the difference in these elements that would characterize the system. Therefore, a very broad range of phenomena could be represented as a system, with very simple and recognizable elements in some cases, yet not understandable.

Systems Engineering is the discipline that helps modeling that structure to understand the different phenomena, allowing to further study the elements and their interactions. Its objective, as described by the International Council on

Systems Engineering (INCOSE), is to enable the realization of successful systems with aid of its interdisciplinary approach (Haskins 2007).

Systems Engineering provides the framework that is supported by critical thinking to provide an understanding of different situations, providing a holistic approach before considering a particular solution. This becomes essential for the Lean practitioner, as not every scenario will be the same, and relevant problems won't necessarily always be within the same specific boundaries.

Therefore, maturity is reached when the principles of Lean can be used and applied in different contexts and with foreseen effects that deal with higher accuracy and precision.

8.3.3.2 Non-conventional Environments for Lean Implementation

Lean was conceived within the manufacturing domain, but its philosophy and principles transcend to other contexts. Take as an example the aforementioned healthcare sector, where it has become a highly sought after methodology for care improvement in recent years, but also other areas such as services and government have been reached by Lean's influence.

However, there is a greater opportunity that practitioners need to test in order to achieve a measurable maturity by looking at relevant demands for the improvement of our society, such as those compiled by the National Academy of Engineering (NAE) (Fig. 8.5).

It is important to mention that the Grand Challenges for Engineering are implicitly intended to be addressed by their own disciplines among all engineering fields, but could serve as a framework to transcend the conventional applications of Lean. It will be, therefore, a bigger challenge for practitioners to understand the essence of Lean, its core, which can be adapted to different environments for the achievement of relevant solutions among different systems.

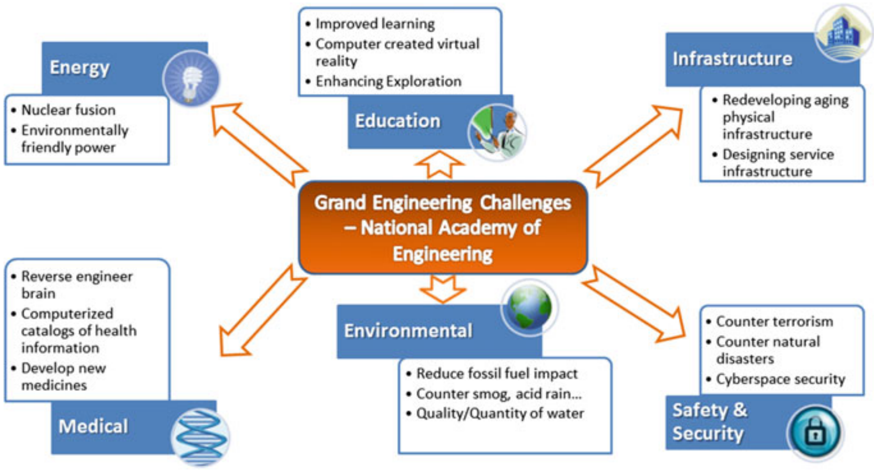


Fig. 8.5 Adapted engineering challenges (Perry et al. 2008)

8.3.4 Leadership Skills

The next stage involves the development and understanding of the soft elements within Lean implementations. Edwards Deming created his model of continuous improvement with the PDCA (plan, do, check, act) cycle in order to systematically address problem solving in an evolutionary approach. Similarly, we present the framework that serves for the alignment of people, and the systems they are part of, in the pursuit of transformation initiatives that sustain over time. This framework is illustrated as the Leadership development loop (Fig. 8.6). Figure 8.6 shows a Leadership development loop that starts with the values.

8.3.4.1 Values

In Lean we commonly come across the term "value added", referring to the activities that add value to products or services. But from a societal context, value refers to a descriptive factor of perception and behavior for the person, a quality or a principle. There are certain desired values for individuals that define how good a person is, named "ethical norms".

Every individual and every organization must define their own value system in concordance to their beliefs. Those likely define their behavior and their personality, as they dictate their decisions and course of action. Consequently Lean practitioners should be congruent between the values of Lean and those of their own. Moreover, implementations should be considering their own belief system, as it is only then that sustainable solutions commence to emerge.

Fundamental reasoning when participating in implementations should be if one is willing to do the work as designed for the amount of time. As mentioned in Sect. 8.3.2.3, a reliable process is the one that performs its intended function under specific environmental conditions for a specified period of time. Hence, the need to address the question: are we designing processes in the name of value added from a material or work perspective without considering the value of the person doing the job?

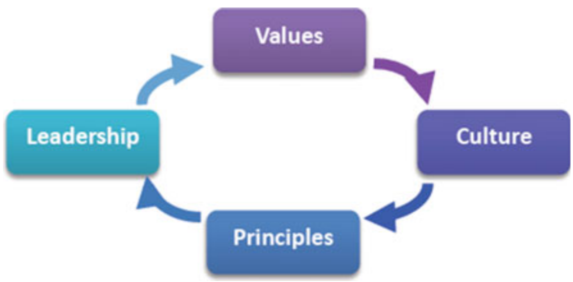


Fig. 8.6 Leadership development loop

Defining a clear set of values determines achieving a certain level of maturity, not only in the practice of Lean, but also in life. When these values are understood and practiced collectively and constantly, they provide the ground for the development of a particular culture.

8.3.4.2 Culture

The term 'culture' is used by multiple disciplines and is often redefined to identify a specific aspect of human interaction. In business and manufacturing, culture has been recognized as an important agent in transforming practices and implementing strategic plans.

Organizations often believe that when implementing continuous improvement methodologies easily recognizable problems will be solved. This is seldom the case. Deeply rooted and systemic problems do not go away with the introduction of just principles. These are critical issues that must be recognized and addressed early in any transformational process if that process is to succeed and be sustained.

In a similar fashion, individuals cannot change their course of action by following principles only. We consider culture as the ability of individuals to accomplish a constant behavior based on their values (beliefs) aligned to accomplish defined goals. Therefore, it is first required to have a clear definition of values in order to set a culture.

Lean practitioners will frequently face the issue of developing solutions in organizations where values are not clear and a favorable culture has not been set. This is one of the primary reasons why critical thinking becomes relevant. Lean can provide substantial benefits to an organization when introduced in an environment that has a culture capable of change.

We commonly utilize the metaphor of what would happen when a high value item (a piece of jewelry) is left in a confined and underdeveloped neighborhood (slum), and another one is left in a high-end area (a members-only country club). We could assume that the likelihood of the item disappearing faster in the first scenario compared to the second is higher. The question is why. It would probably be silly not to take a valuable item where people struggle to go through life on a daily basis. The environment is shaping the culture of that particular area. Peer pressure, need, perceived value, and consequences differ from one setting to another. The tradeoff for the precise same situation determines the course of action, influenced by the environment.

In other words, to make Lean work, the practitioner has to be sensitive with the culture of the place, allowing mechanisms to support the development of an environment favorable to sustain a Lean culture.

John Shook, sharing his years of experience working for Toyota in his particular analysis of the joint venture with GM (New United Motor Manufacturing Incorporated, NUMMI), concluded that “to change a culture, it is needed to define the actions and behaviors they desire, for then design the processes that will reinforce those behaviors”.

8.3.4.3 Principles

The principles that shape the system (introduced in Sect. 8.3.1.3) focus on reduction of lead time, reduction of variation and change the quality of life of people. Following the roadmap of the TPS, the first steps towards reducing the lead time are achieved through setup time reduction by Single Minute Exchange of Die (SMED), which in turn reduces the lot sizes. On the other hand, redesign of the machine layout and standardized operations would allow single piece production under balanced flow which contributes to reduction of lead time. This process flow involves Lean techniques such as cellular manufacturing under design of machine layout and multi-functional worker training.

Variability is considered to be unwanted in any process or system as it causes degradation in their performance with impacts to work in progress (WIP), cycle time and throughput. TPS focuses on automation and functional management to improve overall quality of products. This ensures that the rework is minimized in the process and in consequence, a reduced variation in the system.

The rest of the framework focuses on human factors and workforce. Setup of standard operations and multi-functional worker training allows for a flexible work force. Working in small groups for improvement activities would allow a substantial increase in worker morale thereby improving the lives of the people.

In summary, TPS meets the objectives of increasing revenues through cost reduction and improving profits under slow growing economy. Ideally the system strives to produce the highest possible quality, at the lowest possible cost, with the shortest possible lead time.

Lastly, in order to close the loop, not just values, culture and principles are required. The last component, and the most commonly found in the literature is “leadership”, being the attribute that puts it all together, and essential of the Lean practitioner (at least for the desired level of maturity).

8.3.4.4 Leadership

One common requirement of leadership is critical thinking and, critical thinkers are frequently expected to perform leadership roles in their environment. Kotter identified six principles that relate to effective leadership:

Fig. 8.7 Leadership model

- Motivation
- Personal values
- Development of abilities/skills
- Development of reputation
- Relationships/networks
- Organizational/industry knowledge.

Kotter (1995), explaining why transformation efforts usually fail in organizations, identified an eight step methodology to ensure success, which includes the creation of a vision and the communication of that vision. The leader is the one that takes on that responsibility, making sure that the vision is clearly defined, effectively communicated and meticulously executed.

A true leader is recognized by his ability to define, model and mentor others on the particular knowledge he possesses about the situation under analysis (Fig. 8.7). This means that a leader must be able to articulate and define a thinking process, which requires critical thinking for problem solving, and should be able to generate a model that can be instructed and passed to others. In other words, creating resonance that will help to develop the desired culture.

The individual responsible for this action can be acknowledged as a leader. That is the ultimate goal of a Lean practitioner, to provide relevant solutions in changing environments. Only then, solutions can be implemented in a sustainable way.

8.4 Lean Curriculum for Higher Education

The Lean program at the University of Tennessee's Industrial and Systems Engineering department has attempted to address the need for Lean maturity. We propose two categories for enhancement of existing traditional Lean education that may provide industry the type of Lean professionals that they are seeking.

The first category relates to *approach*. Primarily, we do not focus on which process needs to be designed. Instead, we focus on a process to design. In other words, an organization must possess the ability to design systems that are sensitive to the actual business environment, rather than designing based on the ideal business environment.

As an example, many systems are designed based on assumptions such as timely arrival and correct quantity of parts, equipment working without failure, all personnel being present, and compliance with established schedules. If such assumptions are not practically realistic, it may lead to an organization backsliding to its original mode of operations due to the lack of accuracy associated with the system under improvement.

The second category deals with *sustainability*. The current body of knowledge does not take into consideration reliability of the designed process nor include cultural variability among employees (as mentioned in Sect. 8.3.2.3).

8.4.1 Teaching Methodology

Teaching is the common denominator that connects every activity associated with being a professor at a university. A faculty is inherently in a position to influence all students and therefore the required ability to teach through every action. At an aggregate level, it can be discussed in terms of in-class and out-of-class teaching. Both of these components are necessary in order for the faculty to fulfill their obligations with the students, to prepare them for successful lives and careers.

The prerequisite for in-class teaching is that the faculty must be passionate about the material and excited about the opportunity to mold the minds of the students. The in-class teaching has five critical components.

First, the faculty must provide the student with fundamental/theoretical background in the subject matter. This requires the faculty to be knowledgeable about recent developments in the subject matter assuming the responsibility to continuously improve/update their class material.

Second, the faculty must have the ability to challenge the status quo and provide the students with a unique interpretation of the material. This is where they bring in their experience, in particular their research, into the class.

Third, the faculty must demonstrate the relevance and application of the topic that they are teaching. This allow the faculty to bring in their work experience to the students.

Fourth, the faculty should allow the students to pilot what they have learned. The opportunity for students to apply their knowledge in the business world allows the student to solidify their learning. The faculty must develop the network to establish these “real life” laboratories for the students.

Fifth, the faculty has the responsibility to connect the material taught with the rest of the student's curriculum. This promotes the student's ability to articulate their education rather than reiterating the set of courses that they took. As discussed previously (Sect. 8.3.4.4), leaders are those individuals that can define, model and teach what they have learned to others. Our students should be such leaders.

One essential element, as addressed initially, is the joint responsibility of industry and academia to provide the ground for developing mature Lean practitioners. The Industrial and Systems Engineering department (ISE) at the University of Tennessee, Knoxville (UTK) provides an opportunity for students to utilize industry as a laboratory to learn and develop research ideas. Our goal is to create leaders that have the expertise in Lean to tackle complex global challenges and to create value for the society.

These experiences concentrate in enhancing three areas of skills:

1. Academic Skills
   - Abilities and Skills
     - Encourage them that they have skills and abilities to succeed
     - Send students for any necessary training on or outside campus
     - Suggest courses or experiences the student needs to improve skill sets
     - Assist students to develop grant writing skills
   - Networking
     - Create opportunities for students to demonstrate their competencies. Take them to meetings and conferences so they can gain exposure. Encourage them to display their work in public
     - Refer the student to colleagues inside and outside the University who could serve as additional mentors
   - Organization
   - Communication
     - Provide extra help for students by setting up meetings on Saturday mornings
     - Let students know about my travel schedule
     - Discuss my work style and interaction with graduate students
     - Before beginning a project, clarify who owns the data that is being collected, and discuss issues of copyright
     - Share impressions about strengths and areas of improvement
2. Values
   - Motivation
     - Motivate students to write articles for journals and conferences
     - Encourage students to try new techniques and expand their skill sets
     - Encourage students to discuss their ideas

- Personal values
  - Team work
  - Respect for diversity
  - Responsibility to others

  Analyze what students need and help them develop taking on more responsibility as they develop professionally

3. Well Being
   - Reputation
     - Promote the student's work within and outside the department.
     - Supply students with information about employment opportunities and encourage them to plan toward an employment goal as early in their course of graduate study as possible.
   - Financial
     - Support students through internal or external sources
   - Support structure

The skills desired in our students are developed through different areas that support the diversification and achievement of maturity, with the application of the methodologies mentioned in the previous sections:

- Consulting—Implement existing productivity models to existing domains of application. An example of this type of project would be the application of operational excellence to an existing manufacturing concern.
- New Applications—Application of existing productivity models to new domains of application. An example of this type of project would be the application of operational excellence to babies born with drug addiction with a focus on reducing their weaning time.
- New Models—Develop new productivity models for existing domains of application. An example of this type of project would be the development of the new concept of "Releanability" (Lean and Reliability Engineering) and the application of this concept to manufacturers, hospitals, and government organizations.
- New Body of Knowledge—Creation of new bodies of knowledge related to productivity improvement. An example of this type of project would be the development of Natural Interaction which is the application of technology to human capability to enhance productivity by reducing learning curves.

It is through our curriculum that this program enhances the leadership attributes of the students by allowing them to develop their skills, reputation, relationships within sponsoring agencies and organizational knowledge. This additional development enhances the competitive edge, that if applied with all Lean pupils, would support the achievement of maturity in different contexts: the university, government, and industrial world.

8.4.2 Curriculum Design

The teaching methods have been exercised and implemented in the design of our curriculum. We have been supporting the instruction and practice of Lean methodologies for a reasonable time in a diverse set of ways:

- University courses:
  - Undergraduate level

    Introduction to Lean Systems
    Lean Enterprise Systems Summer Program
  - Graduate level

    Lean Production Systems
    Reliability of Lean Systems
- Research areas:
  - Lean Communications
  - Lean Healthcare
  - Lean Energy and Sustainability
  - Natural Interaction

We have achieved the culture where the department promotes and stimulates among these activities a well-rounded experience, as most students have the chance to participate in real world industrial projects in companies, with solutions to real issues. In this sense, the value that the program brings to all participants is based on practical experience, exposure, as well as stimulation to innovate in new approaches using diverse tools with Lean principles to achieve relevant and current solutions.

We encourage discussion and initiative from students. They are embedded in a multicultural environment, providing an opportunity to share ideas which usually derive in an entrepreneurial attitude, generating a change on their way of thinking, by considering a global and systemic perspective to approach problems using Lean.

These different settings, such as classes, projects and research activities, provide a learning experience not only for students, but also for us, as new opportunities always arise. This has generated a change of paradigm with an "eye-opener" experience, by working, studying, researching and practicing these principles on an everyday basis.

We have been successful in transmitting this experience to students by following five steps:

- Providing fundamental/theoretical background in Lean
- Challenging the status quo and providing the students with a unique interpretation of Lean
- Demonstrating the relevance and application of Lean Systems
- Allowing the students to pilot what they have learned in practice
- Connecting the "dots" by developing new areas of research and providing framework for relevant projects, thesis and dissertations

Our vision of the future of Lean goes beyond the current approaches, as we believe that we have a social obligation to help. We have embraced this idea and have put it into practice by creating this model to enhance the learning and application of Lean principles among all students.

8.4.2.1 Introduction to Lean Systems

When a system is being designed in lieu of creating an effective and efficient process, it has inherently the risk to fail. Especially when the fanfare of showing improvements slows down their inertia after time has passed, making it part of a trend, like fashion garments that quickly become outdated.

It is the responsibility of the designers to be conscious of this risk and plan accordingly to avoid it. We have identified two main failures and developed particular approaches to these failures: failure of focusing in the right process, and failure to sustain the design overtime. Lean principles, DRIVES model, cultural factors and reliability to sustain the efforts are the approaches developed within the existing body of knowledge as well as innovative methodologies and concepts conceived at the Industrial and Systems Engineering department of the University of Tennessee.

Participants are able to understand how UT-ISE proposes viewing the design of systems from an improvement perspective (Lean) and how to methodically approach avoiding failures assuring results over time. The focus of the course will be to enable students to design complex processes and systems based on the physical system and the associated information system.

8.4.2.2 Lean Enterprise Systems Summer Program

Lean Enterprise Systems Summer Program is intended to allow students to work together to accrue the technical knowledge of Lean, based on the philosophy of experiential learning. Students work with companies around the region applying the right tools for the right processes and developing a sustainable culture. Students present their reports to companies' leaders, where they demonstrate the proper application of the methodologies such as DRIVES and the modified TPS.

The majority of participants in this program are international students. This is the reason why the program expands beyond technical knowledge, representing a cultural exercise for both, the foreign nationals and the residents of East Tennessee (where the Knoxville campus is located). It is through the development of their projects that participants learn and share cultural perspectives on problem solving, and converge in the proper critical thinking approach for Lean implementations.

8.4.2.3 Reliability of Lean Systems

This course is divided into two major components. The first half of the course focuses on introducing the students to the concepts of reliability and maintainability manufacturing and service sectors, as well as the impact of Lean on the reliability of complex systems. The concepts of reliability engineering are utilized to address Lean system failures, including equipment failures, human failures, material failures and scheduling failures. Students will develop the ability to design systems that are both lean and reliable.

The second half of the course introduces students to specific case studies of systems failures and asks students to develop solutions by considering different dimensions including financial, technical feasibility, risk, safety, security and others. Multi-criteria decision making methodologies are presented to allow students to make decisions when different criteria lead to conflicting solutions.

Basic Lean topics such as Value Stream Mapping, 6S, visual controls, mistake-proofing, Single Minute Exchange of Dies (SMED), cell design, and pull systems are covered. In addition, reliability topics such as equipment reliability, human reliability, condition-based reliability, Failure Mode Effects and Criticality Analysis (FMECA), Fault Three Analysis (FTA), Theory of Constraints (ToC), Statistical Process Control (SPC), and Risk Analysis (RA) are explored.

In summary, the course highlights the critical role that the Lean expert plays and the impact of his/her decisions in designing Lean systems with respect to customers, employees, and society.

8.4.2.4 Lean Production Systems

The course is intended to provide participants with the strategies to plan, develop and implement Lean initiatives. Special emphasis is made on integration of people, technology, processes and information dimensions (including product development, production and extended supply chain) into unified frameworks.

The analysis of principles from Little's Law, Queuing Theory, Flow (push, kanban and conwip systems) and Variation are thoroughly covered with mathematical fundaments.

8.5 Conclusions

In our perspective, maturity of Lean professionals is achieved by enhancing the education of Lean, utilizing the concepts provided by other disciplines to complement the tools and methodologies. We share the model we utilize in our curriculum development which takes students through four essential skills that fulfill the maturity of the Lean practitioner.

In each of these steps, we have adapted the common Lean body of knowledge to provide a structured and sequential approach that considers a clearly defined framework for problem identification, solution implementation and sustainability.

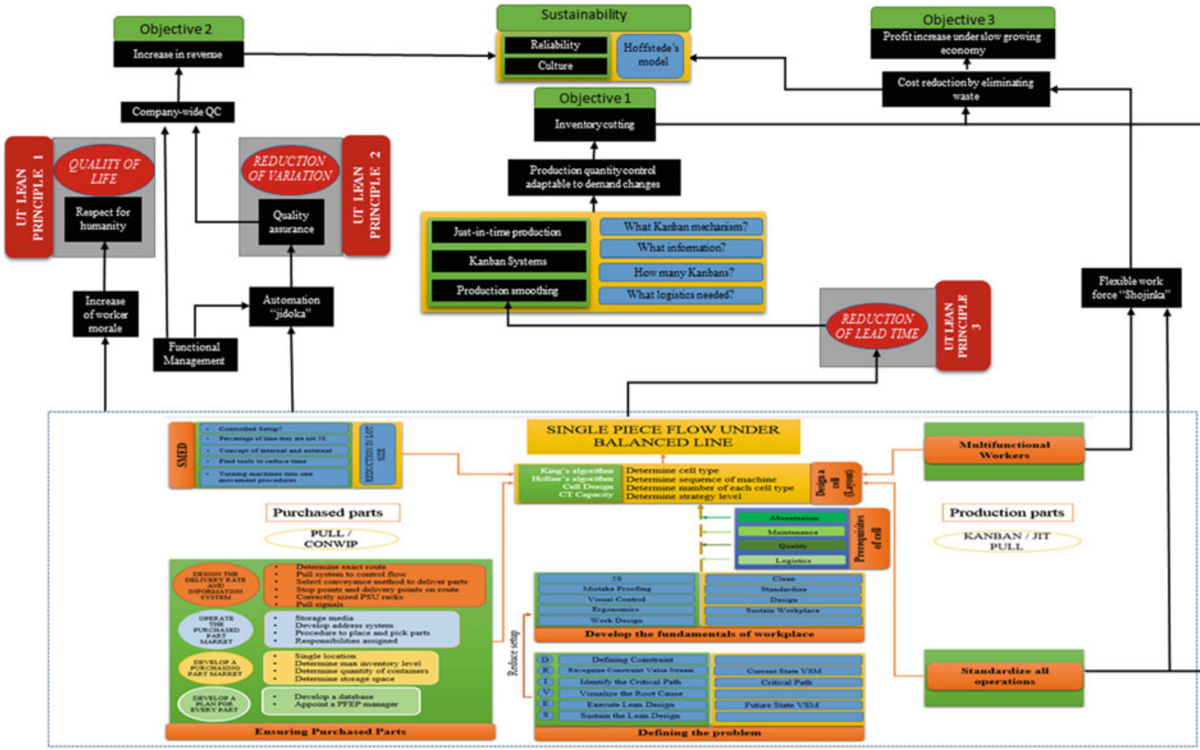
Our curriculum incorporates each one of those concepts in different courses, as illustrated in Table 8.1. It is by following that instructional sequence that we provide the training necessary for mature Lean professionals.

Adopting Lean does not guarantee the solution of all 'evil', its success depends on the efforts around its use. Ensuring commitment and active participation of stakeholders is one of the biggest barriers to adopt the changes. A mature Lean leader must be sensitive of the challenges presented, with the vision to instill the necessary culture that drives the organization towards a sustainable continuous improvement environment.

Table 8.1 Educational curriculum and skills developed

	Core skills	Problem solving skills	Systems skills	Leadership skills
Introduction to Lean systems	✓	✓		
Lean enterprise systems summer program	✓	✓	✓	✓
Reliability of Lean systems		✓	✓	✓
Lean production systems		✓	✓	

Appendix: Modified Toyota Production System



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Chapter 9
Lean Education in the Faculty of Mechanical Engineering and Aeronautics of Rzeszow University of Technology, Poland

Dorota Stadnicka

9.1 Introduction

In order to subsist companies have to meet customers' requirements and expectations. Particularly nowadays, when they have to compete on the global market. Companies have to focus on some issues which are most important, and these are: production or service costs reduction, decreasing the lead time and increasing quality. All these issues are directly connected with lean management and lean manufacturing. For these reasons, lean education of the company present and future employees is justified and really necessary. Many of lean tools are simple and their implementation doesn't involve additional resources. It is only a way of thinking and attitude which will enable to use available internal resources to make an improvement. Unfortunately, the knowledge concerning lean is still not widely known in Polish companies. Therefore, it is a great challenge for Higher Education Institutions to propagate the knowledge concerning lean manufacturing and lean management among students as well as in enterprises.

The lean concept has been well known for many years (Liker and Meier 2006; Shingo 1981; Taiichi 1998) and it has been introduced into course programs at Rzeszow University of Technology step by step. Since Lean Manufacturing is based on common sense, the transferred knowledge corresponded to the main lean principles even before such terms as 5S or Just in Time appeared. However, a degree course on Management and Production Engineering was started at the Faculty of Mechanical Engineering and Aeronautics as a response for industry needs in 2001. WSK "PZL Rzeszów" S.A. (now Pratt & Whitney Rzeszów S.A.)—a United Technology Company, operating in aviation industry, had a great influence on opening this new degree course. This company as one of the first companies in the

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region started the lean concept implementation. The courses have been improved along with the development of the university staff's knowledge and experience, what was partly due to the cooperation with Pratt & Whitney Rzeszów S.A. and taking part in the trainings ran by the specialist in lean manufacturing.

Then, in 2009, Erasmus Multilateral Project "Lean Learning Academy" was started. This international project (Erasmus-LLP No 503663-LLP-1-2009-1-BE-ERASMUS-ECUE, 2009–2011), co-financed from ERASMUS program, was realized in the cooperation with the following universities: Katholieke Hogeschool Sint-Lieven (Belgium), University of Skövde (Sweden), Instituto Superior de Engenharia do Porto (Portugal), Universitatea Transilvania din Brasov (Romania) and enterprises: Volvo Cars Gent (Belgiuem), Volvo Powertrain AB Skövde (Sweden), PRZEMOT H.P.T. Chmiel s.j. (Poland), Associação Comunidade Lean Thinking (Portugal) and Siemens Program and System Engineering S.R.L. (Romania).

The main goal of the project was to build a strong relation between the local academic and the industrial partners in each of the participating countries as well as developing course modules and a serious game based on up-to-date knowledge on lean manufacturing in order to incorporate them into education at universities. As a result of the project, Lean Learning Academy Polska was established at Rzeszow University of Technology. Since 2011, it has continuously been engaged in the actions concerning the dissemination of the lean concept among students and company employees in different kinds of activities. Besides, the developed course modules and the game are currently a part of students' education.

Establishing Lean Learning Academy Polska had also a considerable positive influence on the continuous improvement of the program of the degree course on Management and Production Engineering.

9.2 Necessity of Lean Education Implementation in the Region

Rzeszow University of Technology is the biggest technical university in the region of Podkarpacie, Poland. The Faculty of Mechanical Engineering and Aeronautics, among others, provides a degree course on Management and Production Engineering. The Faculty is the main "supplier of engineers" to the industry in the region of Podkarpacie.

According to the Statistical Office in Rzeszow, in July 2015, 164,456 business entities of the national economy including 11,250 trading companies, including 1,610 companies with foreign capital were registered in the region. In June 2015, the investments of the companies equaled 1,195.1 million PLN (i.e. about 284.34 million EURO) and 132 % of the amount spent in the same time in 2014. In July 2015, 223,200 people were employed in companies. The unemployment rate in the region equaled 13 % in June 2015 and it is decreasing. The unemployment rate equaled 16.3 % among young people under the age of 25. The average salary equaled 3,429 PLN (i.e. about 804 EURO) (Statement on the socio-economic situation in the region of Podkarpackie 2015).

In 2010, 202 large enterprises, 1,230 medium enterprises, 6,757 small companies and 144,429 micro companies (Diagnosis of the socio-economic situation in region of Podkarpacie 2013) were registered in the region. The companies in the region operate in the industry sectors such as: aviation, automotive, food, chemical, wood and paper, metal processing, electric and electronic, furniture and others. The companies need employees with good qualifications.

Eleven clusters associating companies in different industry sectors such as e.g.: aviation, casting, IT, plastics, chemical, renewable energy and food industry (Clusters in Podkarpackie Voivodship 2012) exist in the region. The biggest cluster in the region is the Cluster of Aviation Valley. This is a Key National cluster. At present, 125 companies operating in aviation industry are associated in Aviation Valley. Hence, it is easy to notice that aviation industry has a strong influence on the development of the region.

Lean manufacturing systems such as e.g. ACE (Achieving Competitive Excellence), existing in Pratt & Whitney Rzeszów S.A. and in other companies from United Technologies Corporation, is only one example of the lean concept implementation in industry. Therefore, graduates can be employed in a company where a lean manufacturing system is well developed, hence, they have to possess adequate knowledge and skills to work in such a system.

On the other side, many SMEs companies operate in the region as well. Obviously, graduates can be also employed in such companies and they may be faced with the necessity of lean concept implementing there, especially when they graduated in Management and Production Engineering degree course. Therefore, they need the knowledge concerning the whole process of the lean concept implementation to know how to start the implementation and how to implement lean step by step. They should also be prepared for different difficulties which can appear during the implementation process. Many regional SMEs, as suppliers, deliver materials and components to larger manufacturing companies e.g. from aircraft industry, and in order to ensure a smooth value flow it is necessary to disseminate the knowledge concerning the lean concept also among these companies.

Besides, it is easy to notice that an average salary in the companies in the region is very low, and many young people decide to leave the country looking for a better paid job. One way to face the problem is to improve the companies economic condition e.g. by the lean concept implementation. However, the region is probably mainly competitive because of the low costs of labor force.

9.3 Business Community Input in Lean Education

More and more companies realize that lean thinking is a way for the true improvement. The conferences concerning the lean concept have been organized at Rzeszow University of Technology since 2011. The conferences are organized by Lean Learning Academy Polska.

Topics connected with the lean concept e.g. till now there were discussed topics concerning identification of differences between the lean theory and the companies practice, Kaizen implementation in order to make continuous improvements, employees' engagement in continuous improvement, the application of lean tools in the projects of improvement, and Lean Manufacturing in small and medium enterprises are discussed at the Conference. The Conference consists of two parts. During the first part of the Conference theoretical issues and research results are presented by academic professors. In the second part, practical examples of the lean concept implementation in different companies are presented by the representatives of companies.

People of industry, academic professors as well as students, mostly from the course of Management and Production Engineering, attend the Conference. This way, the theoretical knowledge about modern methods can be promoted among companies. What's more, the real company problems, undertaken analyses and implemented solutions can be studied by academic professors and students. After the Conference, workshops are realized. The workshops concern different lean tools and their practical implementation.

The Foundation for the Support of Education of the Association "Aviation Valley" also exists in the region. The Foundation cooperates closely with Rzeszow University of Technology, and some joint initiatives are undertaken. The main goal of the Foundation creation was to support such initiatives as "Children's University of Technology" where children have the first contact with technical issues and they can develop their interests and motivation to undertake technical studies.

The business community also influences Lean Education in other ways. Currently, a special project is run. It considers the secondary school teachers who participate in the post-graduate studies which are ordered and financed by the industry (a group of companies associated in Aviation Valley). Production Management course connected with Lean Practice is incorporated in the program of the studies as well. The field of study named Integrated Education of Personnel for the Aviation Industry takes two semesters. The main goals of these studies consist in transferring up-to-date knowledge from the University to secondary schools in order to incorporate e.g. the lean mindset in the training program for secondary school students. The course program is supplemented with the visits in factories from the aviation industry.

Moreover, the Economic Council which coordinates actions undertaken together with the business environment as well as it searches for areas of cooperation exists at Rzeszow University of Technology. The Council consists of the representatives of such companies as Pratt & Whitney Rzeszów S.A., Ultratech Sp. z o. o., Nowy Styl Group, PZL Mielec, Hispano Suiza Polska Sp. z o. o., Zelmer Pro Sp. z o. o., Avation Waley, Borg Warner Poland Sp. z o. o., MTU Aero Engines Polska, Port Lotniczy Rzeszów-Jasionka Sp. z o. o., and Zakład Metalurgiczny "WSK Rzeszów".

Business community has also an impact on education quality because the representatives of the industry are in the board of Departmental Committee for Quality Assurance in the Faculty of Mechanical Engineering and Aeronautics, where the course on Management and Production Engineering is conducted. The Committee has also the representatives of students. The responsibilities of the Committee are, among other, the evaluation of the newly designed course programs and changes in the course programs.

The University answer for the industry needs is the creation of modern courses and Lean Learning Academy activities.

9.4 Lean Learning Academy

Lean Learning Academy (LLA), which was developed within the international project, implemented an innovative concept of Lean Manufacturing teaching. The concept is based on six pillars (Fig. 9.1):

- Basic **knowledge** transferred during the lectures to students and company employees—should ensure general understanding of the lean concept and lean terminology (lectures),
- **Targets** which are set for teams to motivate them for undertaking actions (research problems, industrial problems),
- **Simulations** and **serious games** to give a possibility to implement in practice lean tools in order to achieve the targets, (computer simulations, e.g. Fresh Connection, serious games, e.g. ball pen assembly game),

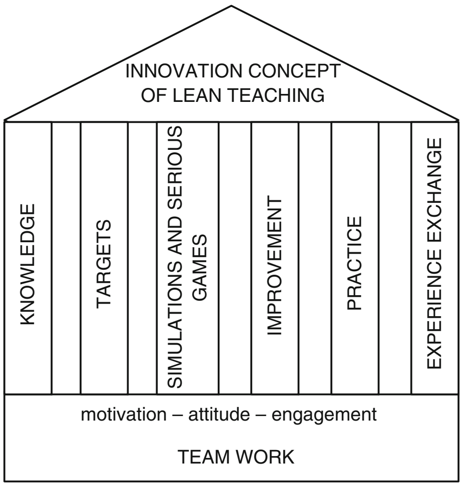

Fig. 9.1 Pillars of Lean Concept Teaching at Rzeszow University of Technology

- **Improvement** implementation to understand a mode of looking for the improvements possibilities and the assessment of achievements (mistakes recording and proposals for Poka Yoke solutions),
- Industrial **practice** to find out differences between the pure concept and real implementations in different industries (projects in industry and for industry),
- **Experience exchange** by the presentation of problems, their analyses and solutions implemented in practice (diploma seminar, LLA Conferences).

At the root of innovative teaching concepts are:

- Motivation (internal and external),
- Attitude shaped during teacher's programs aimed at the use of creativity in order to make improvements,
- Engagement and understanding the influence of one's own actions on the target achievement,
- Team work in order to achieve a synergy effect, to develop cooperation and communication skills as well as team work planning ability.

Only implementation of all of the mentioned elements will allow to achieve didactic goals and establish students' competences.

A state-of-the-art course in lean manufacturing, built in a close cooperation with experienced lean companies and developed in LLA project together with a lean game, are implemented in student courses and trainings delivered to companies.

LLA also conduct research among the companies mainly in the region of Podkarpacie within Lean Manufacturing. This is a way for collecting current data concerning company conditions and the state of lean concept implementation. The good source of knowledge concerning lean systems are large enterprises, which are part of global corporations that have been developing their lean systems for many years. Most of the large manufacturing companies in the region of Podkarpacie possess foreign capital and have implemented modern management tools. Therefore, that was the reason why these companies were the subject of the research. The implementation of the lean concept in large enterprises was studied (Stadnicka and Antosz 2013, October), and then particular areas of lean management, e.g. continuous improvement systems (Stadnicka and Antosz 2015), management of technical infrastructure (Antosz and Stadnicka 2013, 2014;.Ciecińska and Antosz 2009) and indicators used in evaluation of undertaken activities (Antosz and Stadnicka 2015) were also considered.

Then research was expanded to SMEs in order to see the state of the lean concept implementation also in small and medium companies, with Polish, or majority Polish or foreign capital (Stadnicka 2015).

Some part of the research results was published. On the other hand, LLA as a platform for communication with the companies uses the Website.[1]

[1]http://leanacademy.portal.prz.edu.pl/.

9.5 Engagement of Employees and Students in Lean Course Development and Implementation

During the LLA project the Resonance Group was engaged in a consultation process. During the periodically organized meetings, the members of the Resonance Group had a possibility to influence the results of the project by adding comments to a prepared course module and to the game. The Resonance Group consisted of the companies employees and students. Therefore, in a development process, it was possible to take into consideration industry standpoint which assessed usefulness of the course modules and the game, as well as the students' standpoint which assessed the ability of understanding the prepared materials.

Lean Learning Academy Working Group had a great influence on the lean course improvements. The group consists of the people employed in different companies which operate in different industries, as well as of academic professors and students. The group meet every few months in a company in order to make some improvements according to their own experience, and to propose some improvements for the company which is the host of the meeting. The group became bigger and bigger, however, one meeting was attend by only about 15-20 individuals. Each meeting consisted of three parts (Fig. 9.2).

During the first part of a meeting, a company representative presents the company and its lean manufacturing system. After that, a tour around the company is organized to see how the system works in reality. The last part of the meeting concerns a current company problem (or problems), which is first presented and next analyzed by the members of the Working Group who work in smaller teams. In order to analyze the problem, the teams use appropriate tools, such as quality

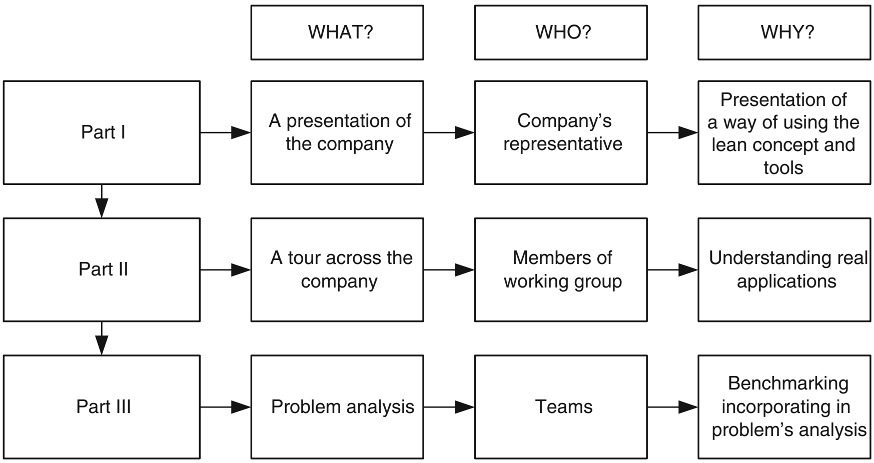

Fig. 9.2 Structure of Lean Learning Academy Working Group meetings

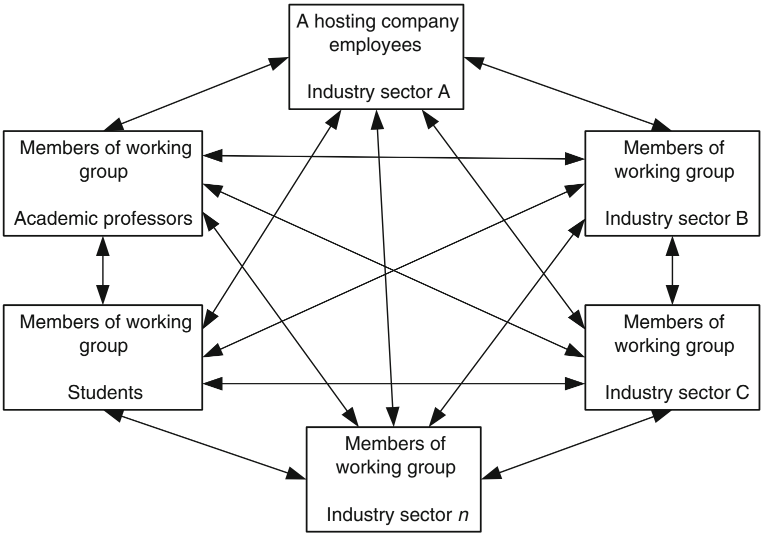

Fig. 9.3 Structure of knowledge and experience exchange during Lean Learning Academy Working Group meetings

tools, brainstorming, lean tools, etc. and they make use of their own knowledge and experience. At the end of the meeting, each team presents proposals of possible solutions of the analyzed problem. During such a meeting, **practical benchmarking** in the most useful form is applied. The participants of a meeting can be employed in a company of the aviation industry, automotive industry, food industry etc., whereas the meeting may take place e.g. in a company of the furniture industry. The added value of such a meeting is that the knowledge from one industrial sector can be easily transferred to another sector, and at the same time to the University, as presented in Fig. 9.3.

This way lean course syllabuses can be continuously supplemented with new practical knowledge and, as a result, students can be better prepared to face real problems.

9.6 Lean Learning Course Modules

In the previously mentioned LLA project, the courses connected with different lean problems were developed, namely: 1—Lean thinking, 2—Continuous Improvement, 3—Standardized work, 4—Policy deployment, 5—TPM, 6—Value Stream Mapping, 7—SMED, 8—5S, 9—Poka Yoke, 10—Just in Time. Kanban, 11—Plant layout, 12—Quality, 13—Lean assessment, audits, benchmarking; 14—Team work; 15—Visual Management; 16—Safety; 17—FMEA. All course materials are available on the Website of the LLA project.[2] Additionally, handbooks presenting lean and quality issues were published (Antosz et al. 2013, 2015; Stadnicka and Pacana 2015).

In a course on **Lean thinking** the concept of Lean Manufacturing is explained. A student must know what is origin of the Lean concept and what reasons were behind the development of the lean strategy. It is also important to ask why the concept is still very significant for the industry from the company viewpoint, from the employees' point of view and from the point of view of the environment. Case studies from different industries representing correct and incorrect understanding of the lean concept and its implementation are analyzed. In addition to the inhibiting factors that slow down, or the obstacles that make lean philosophy implementation in different organizations impossible are analyzed. Naturally, it also very important to underline the role of accelerators which facilitate the lean implementation.

On **Continuous Improvement** course the philosophy based on PDCA (Plan, Do, Check, Act) is presented. Methods and tools used in a continuous improvement process are analyzed. The environment which should be built in a company to foster continuous improvement is studied. The examples of continuous improvement systems and ways to build the culture of constant looking for possibilities in order to implement positive changes coming from industry are presented. The issue concerning employees' resistance to change is also discussed and the possibilities of overcoming the resistance are discussed.

The course of **Policy deployment** includes issues concerning the setting of targets on all levels of the company, starting from the top management level and ending with the level of an individual employee who should also know why he or she is doing his or her job. The strategic objectives should be deployed into lower levels of a company. The coherence of all goals should be ensured on all management levels. The areas which should be monitored in the strategy implementation are discussed. In addition, the ways of monitoring with the use of indicators are presented. The need to focus on things important for a company in the certain circumstances are emphasized. The need to maintain the balance between actions and their reporting, as for the reporting process and the calculation of indicators does not become the main goal of the company, is underlined.

The course of **Standardized Work** presents rules and techniques used in work standardization including time study. Examples of standard documents used in different areas and on different levels of organizations are presented. Standardization is also analyzed in the context of continuous improvement. The advantages of standardization are analyzed. Furthermore, a level on which standardization should be implemented to prevent the formation of the effect when the form is dominated over content is also discussed.

In **TPM** course various strategies of control of the technical infrastructure are presented. Moreover, Total Productive Maintenance strategy, which incorporates machine operators in maintenance activities to keep the machines in constant

[2] http://www.leanlearningacademy.eu/.

readiness to work, is showed. Furthermore, psychological barriers against undertaking additional actions by operators as well as the ways to overcome the barriers are discussed. Additionally, the costs concerning preventive and corrective actions as well as continuous monitoring of the selected parameters of machines are analyzed in order to discover how to determine the optimal costs together with the costs of failures and other costs caused by the machine stoppage. Then, the need to calculate efficiency indicators such as OEE are discussed.

In the course of **Value Stream Mapping**, first of all, the value for a customer is defined. Then, the steps of Value Stream Mapping (VSM) and Value Stream Analysis (VSA) are presented. On the basis of the examples of the data from a company, the value flow is explained. Next, problems in a production line are identified and analyzed. In order to solve the identified problems lean tools, such as Kanban system or FIFO lanes, are proposed to implement for improving the flow. The situation in which Value Stream Mapping is justified, with regards to the range of work to undertake in VSM and VSA, is also discussed. Finally, goals and advantages of VSM and VSA are discussed.

In the course of **FMEA** the Failure Mode and Effect Analysis method is applied for the real data obtained from a company. FMEA is implemented for a product design (DFMEA) and for a process (PFMEA). After the course, students have to know when and how they can implement FMEA, how to assess probability, severity and detection, and which type of data can be useful in such analysis.

In **SMED** course the rules of set-ups analysis and the steps of an analysis are presented. Different practical examples are analyzed in order to explain the possibilities of set-up time decrease by the implementation of organizational and technical solutions. The problem of optimization of costs related to long set-ups and the SMED analysis are also discussed. A definition of a set-up matrix is presented. Moreover, it is argued in which situation a preparation of a matrix is justified and how it can be used in practice.

In the course of **5S** the 5S system is presented as a solution for organizational problems and which also helps to keep work stands in order. This is one of the basic lean tools. Therefore, it should be implemented before any further actions will be taken. Students have to understand why so many companies have problems with 5S implementation, despite that it is very simple to understand and to implement, although really difficult to maintain. The lack of organizational culture is indicated as the main problem concerning 5S implementation. That is why, it should be discussed during the course. Among other things, we can also enumerate the lack of motivation, lack of employees' engagement or lack of commitment to a workplace. Using the wrong policy of payroll results in benefits in the short term, but in the losses in the long term.

In the course of **Poka Yoke** different kinds of Poka Yoke solutions are discussed. Students realize that each employee can make a mistake. Therefore, a company should organize work places in such a way to prevent employees' mistakes. During the course, different examples of Poka Yoke solutions existing in industry practice are analyzed. Problems concerning optimization of costs connected with Poka Yoke solutions implementation and the costs of mistakes are discussed. Different levels of Poka Yoke solutions and their efficiency are studied. The necessity of employee's engagement in Poka Yoke solutions development is underlined, because these are operators who can easily notice the likelihood of mistakes and their consequences as well as propose such solutions to prevent the mistakes. The topic related to the operator's responsibility for the work and positive results of discovering the mistakes as well as these connected to psychological barriers are deliberated.

In the course of **JIT/Kanban**, **FIFO Lanes**, **One Piece Flow**, **Heijunka** different tools, which can be used for the flow improvement, are discussed. The circumstances which favor the tool implementation are described, and each solution is analyzed with respect to advantages and possible difficulties of its implementation. Practical examples concerning the tools implementation and the difficulties met in real companies are discussed.

In the course of **Plant Layout**, among others, 3P method is presented. Issues concerning a proper layout arrangement in new production systems, or in case of production systems reorganization or layout optimization, are discussed. The best industry practices are analyzed. It also concerns the layout of machines and transport paths to ensure the best materials and products flow on a production line. The examples of existing layouts are analyzed and possible improvements are discussed.

In **Quality** course the meaning of the quality of production processes for an external customer as well as for internal customers is discussed. It is indicated that bad quality can disturb a course of production processes and it can influence the internal customer's satisfaction, and finally external customer's satisfaction as well. Good and bad company practices of how they manage the quality problems are analyzed. Standard quality systems e.g. based on ISO 9001 are discussed. The quality tools which can be used in a quality problems analysis and then their elimination are presented.

In the course of **Team Work** the rules of team work are presented. Then, various techniques which a team can use in different problem analyses are discussed. This module is very important because team work is the basis of continuous improvement and the lean concept. Students have to understand the meaning of team work and learn how to work in different teams. They have a possibility to learn a team work in practice during the realization of different kinds of projects. In many cases, it takes much time to learn how to work in a team, how to plan tasks correctly and how to take responsibility for the tasks realization. Students learn how to be a leader, how to motivate a team in practice or what to do in a situation when two leaders emerge in one team, etc.

In the course of **Visual Management** students learn about the possible ways of implementing visualization in different areas of companies. The visualization can be used in visual control and visual management. The advantages of visualization implementation are underlined. Many industry examples are presented. Students learn about visualization concerning work in process, direction of the material flow, internal transport, safety rules, wastes management, work standardization, current production capacity, problems occurrence, and etc.

In the course of **Lean Assessment**, **Lean Audit**, **Benchmarking** student learn how to assess a level of Lean Manufacturing implementation and how to compare their own lean system with other companies systems. A company should know which lean tools will be suitable for the company taking under consideration particular circumstances and products, services and processes realized in the company. This is not a matter of the number of implemented tools, but of the proper implementation of suitable lean tools. Students have to know in which situation which tool should be implemented and how to look for the possibilities of improvement with the right tool implementation. One of the main company mistakes is the implementation of the large number of tools without their proper justification. Such actions consume time and resources, but they don't bring any benefits. Additionally, that discourages employees against their engagement in continuous improvement.

9.7 Stages of Student Education Enhanced with Lean Education

Lean Concept education is realized through all levels of the studies in a degree course on Management and Production Engineering, namely: 1st level—engineering degree (full-time—during weeks, and part-time studies—during weekends), 2nd level—master degree (full-time—during weeks, and part-time studies—during weekends) and postgraduate studies (part-time studies—during weekends) to the extent as follows.[3]

All students of the degree course on Management and Production Engineering studying in engineering degree attend the following courses, which consist of lectures, laboratory classes, individual and team projects and practical classes. Lean Concept is incorporated into some courses as presented:

1st semester—in the course of **Basics of Management** for the first time the lean concept is incorporated in order to motivate students to follow the chosen lean rules and to adopt an appropriate attitude e.g. to be able to work in the future in 5S system.

1st semester—in the course of **Ecology** a pro-ecological attitude is created with the presentation of the industry influence on the environmental pollution and solutions for environmental protection.

1st semester—in the course of **H&S and Ergonomics** issues concerning employees' protection against threats are incorporated, this knowledge will be used later e.g. for the work stands organization to organize work in such a way to prevent accidents.

2nd semester—in the course of **Environmental Management** a pro-ecological attitude is developed with the presentation of possibilities of sustainable development of the companies. Skills of interdisciplinary thinking and reasoning

[3]http://wbmil.portal.prz.edu.pl/en/courses-and-specialisations/.

concerning the relation between the state of the environment and the quality of a human life as well as the whole societies are developed.

2nd semester—in the course module of **Manufacturing and Service Management** the knowledge concerning production, manufacturing and service processes is presented. The skills of production systems design and analyses are acquired. Students learn how to design a production cell using appropriate methods, techniques and tools.

3rd semester—in the course of **Mathematical Statistics and Probability** students learn the basic terminology and methodology of probability and mathematical statistics. This knowledge will be used in lean sigma projects in the future.

3rd semester—in the course of **IT** students acquire the knowledge in the field of specialized software and modern computer systems. They learn about algorithms and programming in structural and object-oriented technology.

4th semester—in the course of **Data Bases** students acquire knowledge and skills necessary for preparing a schema relational database based on the entity-relationship model, creating QBE (Query By Example) queries, formulating queries in SQL (Structured Query Language) and creating forms and reports. It can be useful in collecting data and preparing data for further analysis.

4th semester—in the course of **Operational Researches** students receive knowledge which can be used in a decision-making process when a student applies mathematical methods to solve the basic problems of production and services management, as well as they apply optimization methods.

4th semester—the course of **Logistics in Enterprise** provides basic knowledge of logistics and logistics processes and it develops the ability to analyze logistics systems.

5th semester—in the course of **Manufacturing Processes** students acquire knowledge on manufacturing processes and develop skills concerning preparation of production.

5th semester—in the course of **Automation and Robotization of Manufacturing Processes** students obtain basic knowledge concerning automation, robotics and control systems as well as they discover approaches to the process automation.

5th semester—in the course of **Cost Accounting for Engineers** students obtain basic theoretical and practical knowledge in the field of cost calculation what can be used in costs calculation of lean projects in the future.

5th semester—in the course of **Quality and Safety Management** students will acquire the ability to apply the basic principles and tools for the quality and safety management.

5th semester—in the course of **Fundamentals of Reliability and Operation of Machines** students obtain knowledge concerning reliability of technical objects and the selection of technical equipment from the ensuring the wear resistance point of view.

5th semester—in **Industrial Practice**—during four weeks students have the possibility to apply their knowledge in a certain company and to discover potential gaps in their knowledge and skills to develop better during their continuing education.

Next, depending on a chosen specialization, different students can have different courses which include lean problems as follows:

Specialization: **Logistic of Manufacturing**

5th semester—in the course of **Logistics Management** students acquire theoretical and practical knowledge on the supply chain management. Students obtain knowledge of the organization and functioning of modern supply chains, modern concepts of logistics management, logistics management characteristics and their impact on the level of the company competitiveness on the market and flexibility of the company.

6th semester—in the course of **Supply Logistics** students acquire basic theoretical and practical knowledge in the field of logistics in the supply process. They should understand the essence of logistics supply management processes and know how to use the quantitative methods in management of material resources.

6th semester—in the course of **Inventory Control** students acquire knowledge of the management and control of inventory. They develop the ability to take basic decisions related to inventory, using optimization methods.

6th semester—in the course of **Storage and Transport Systems** knowledge about systems, internal transport and storage processes is transferred.

6th semester—in the course of **Control of Production Flow** students acquire knowledge and skills in the use of production control systems in the organization and in particular in a production design and planning.

6th semester—in the course of **Products Distribution** detailed knowledge of the distribution of products is transferred. Furthermore, students acquire the ability to manage products distribution as well as to design and improve the distribution system by means of optimization methods and computer systems for the supply chain management.

6th semester—in the course of **Logistics Costs and Controlling** the knowledge of logistics costs and controlling is transferred. Students acquire skills concerning tools use in the costs analyses and their results in a decision-making process.

7th semester—in the course of **Logistics of Recycling** students learn to take into consideration environmental aspects in the decision-making process concerning undertaken manufacturing activities. Students will possess the knowledge concerning methods of recycling for different types of waste.

7th semester—in the course of **Computer-Added Manufacturing Systems** students obtain detailed knowledge of the computer-aided management of production processes. They will know how to manage production processes with the use of ERP system.

Specialization: **Quality insurance systems of production**

5th semester—in the course of **Process Management** students acquire knowledge and skills in the field of process management in different kinds of organizations. They learn how to implement the process approach, in particular, how to identify processes in an organization, how to identify relations between processes, how to set targets and assess the processes with indicators as well as how to improve the processes.

6th semester—in the course of **Quality Management Systems** students acquire skills in order to apply basic principles of quality management of ISO 9001. They discover the way of managing the quality of different areas of companies.

6th semester—in the course of **Environmental Management Systems—EMAS** students acquire the theoretical knowledge in the field of environmental management based on the EMAS III regulation.

6th semester—the course of **Cleaner Production and Recycling** includes issues concerning: Clean Production, essential concepts related to the issues of recycling, the basic techniques of waste processing (segregation, crushing, classification, sorting, compaction), the recycling of vehicles, packaging waste, batteries, electrical and electronic equipment.

6th semester—in the course of **Safety Management Systems** students acquire the skills to identify hazards and to evaluate risk as well as to analyze an accident and to develop a post-accident documentation. Additionally, they will know the areas of a safety management system.

All students of the degree course on **Management and Production Engineering** studying for a master degree attend the following courses, which consist of lectures, laboratory classes, individual and team projects and practice classis. In some courses Lean Concept is incorporated as presented.

1st semester—in the course of **Strategic Management** students discuss the concept of strategic management and learn basic techniques of planning and analysis used in strategic management. In addition, they learn about the influence of business surroundings on company decisions and strategy.

1st semester—in the course of **Organization of Manufacturing Systems** detailed knowledge of the design and organization of production systems as well as further improvements by the means of optimization methods is transferred.

1st semester—in the course of **Project Management** students acquire the ability to plan and organize a project, to assess risk, to estimate costs, to develop a project schedule and they learn how to use Microsoft Project for the project management.

1st semester—in the course of **Innovation Management** students learn about systems of innovation management in an enterprise, in particular, how to motivate employees to propose innovative solutions, how to evaluate ideas, how to manage projects concerning innovative solutions implementation.

1st semester—in the course of **Decision Supporting Systems** the main aim of education is to familiarize students with basic modern methods to create decision support systems both in management and production engineering. The basis for the decision-making processes, methods and tools supporting a decision-making process, together with the existing software such as AITECH DSS 4.5 and Comarch Business Intelligence are presented.

1st semester—in the course of **Knowledge Management** students learn about tools for the acquisition, processing and analysis of knowledge as well as the knowledge management. They acquire the basic information on the knowledge management in manufacturing companies.

2nd semester—in the course of **Integrated Management Systems** students obtain knowledge of the structure and functioning of computer integrated production management systems MRP/ERP, and they acquire the ability to use computer applications package MRP/ERP and production scheduling. The SAP system is used in the course.

2nd semester—in the course of **Simulations in Enterprises** students learn about simulation tools which can be used in analyses. They learn how to model decision-making situations with the implementation of an element of uncertainty and risk. Students build and analyze the models, which they develop by using different software.

Next, in the specialization: **Modern Methods of Production Management** the following courses include lean problems:

2nd semester—in the course of **Supply Chain Management** students learn about the techniques and methods of effective supply chain management.

2nd semester—in the course of **Lean Manufacturing** students learn about the basis of Lean Manufacturing and they study how to create work environment in order to develop a lean system in an enterprise with lean tools.

2nd semester—in the course of **Lean Tools** students learn about the Lean tools applications. They acquire skills concerning practical application of, among others, visualization, 5S methods, TPM, SMED, Poka Yoke, and 3P.

2nd semester—in the course of **Statistical Methods in Production Management** students acquire theoretical knowledge and practical skills in applying statistical methods in order to analyze machines and processes capacity, to design and analyze control charts, to create mathematical models and to optimize manufacturing processes.

2nd semester—in the course of **Team Work** students acquire theoretical and practical knowledge about teamwork.

3rd semester—in the course of **Six Sigma Method** students learn how to implement practically the six sigma method through the realization of a six sigma project, applying statistical methods as well as quality management tools.

3rd semester—in the course of **Electronic Processing of Production Data** students learn about electronic production data processing to prepare them to work effectively in organizations characterized by a high degree of information technology use. Particularly, they learn how to collect data, transform them into an useful knowledge and how to disseminate that knowledge. The knowledge will be used for quality improvement in companies and improvement of production processes while maintaining an optimal level of raw materials consumption and use of resources.

In the Faculty of Mechanical Engineering and Aeronautics there are also post-graduate studies on Lean Manufacturing with the following subjects in 1st semester: Modern Concepts of Manufacturing Management, Computer Integrated Manufacturing Management MRP/ERP, Basics of Lean Manufacturing, Lean Project Management, Lean Manufacturing Technologies, 5S—Workspace Management, TPM—Total Productive Maintenance, SMED—Set-up Time Reduction, Poka Yoke—Mistake Proofing, Standardization. In the 2nd semester students learn about Value Stream Mapping, Creating a Continuous Flow of

Production, Supply Chain Management, Team Work, Optimization of Decision-Making Processes, Six Sigma Method, Statistical Methods in Production Management, Process Management and Industrial Systems of Lean Sigma.

9.8 Serious Games on Lean Manufacturing

9.8.1 Organization of the Production of a New Product

In the game the students work in a team which consists of 9–15 people. Students obtain a simple ready product and their goal is to start the production of this product. They work on the project during four weeks. They have to plan, organize and manage the project according to project management rules. In a team they decide what kind of activities have to be undertaken and who will be responsible for each task. They have to work under the time pressure in which they have to realize the production and the maximum price, which a customer wants to pay for the product when ordering a certain number of pieces.

The project realization requires knowledge concerning the project management, risk management, product designing, technology designing, suppliers search, costs analysis, preparing an offer, signing contracts with a customer, production line organization, work stands organization, designing the production documents, employees training, work balancing, quality management etc.

The game consists of **three** steps:

Step 1—Students obtain a ready product together with the customer's requirements and they have to plan how to organize its production. They incorporate their knowledge concerning the project management and risk management.

Step 2—Students have to apply reverse engineering to design a product. They use Inventor to make a design. Next, they have to decide what kind of materials have to be used to manufacture the product and they develop the production technology making decisions concerning necessary tools and measurement devices as well. Next, they have to search for suppliers. Then, they make necessary calculations and sign a contract with a customer. Finally, they organize a production line.

Step 3—Students prepare and start the production (Fig. 9.4). If the capacity is not sufficient they have to analyze work and implement improvements as well as Poka Yoke solutions to prevent mistakes. The work is finished when they are able to satisfy the customer.

The game is played in the second semester of master studies in the degree course of Management and Production Engineering, where all students already have an engineer degree and they have engineering knowledge. In the game, the most important is that the students have to plan everything by themselves and they have to organize themselves. Moreover, they have to produce real goods, therefore, they cannot take shortcuts and all activities have to be done properly.

Fig. 9.4 A serious game—a production line of simple products

A ball pen game, which was one of the LLA project outputs is incorporated in the program of master studies in a degree course on **Management and Production Engineering** and in postgraduate studies on **Lean Manufacturing**.

The game is developed to simulate a real assembly process together with the real production conditions. Real products are assembled on the assembly line in response to the certain customer's requirements.

In the game, people responsible for different kinds of tasks take part, such as:

- **Operators**—their tasks include the performance of assembly operations according to work documentation,
- **Controllers** are responsible for ready product inspection,
- **Warehouse employees** are responsible for internal logistics—their task is the delivery of assembly components on the work stands,
- **Production manager** is responsible for assigning production tasks and issuing production orders as well as being responsible for the realization of an adequate number of products to meet a customer's requirements,
- **Process engineers** have to observe assembly processes, identify problems, collect adequate data on the basis of possessed knowledge by using the tools they have chosen.

Each student who takes part in the game is employed on a work stand, depending on predispositions and abilities which are assessed by a coordinator of the game. All students get their own tasks to perform.

The game consists of the following steps:

Step 1—Assembly process realization according to a plan. Tasks are realized on the basis of the present process documentation, current division of work, current scope of work of individual operators and on the established size of a production batch. At this stage, process engineers conduct observations of work. The first stage takes about one hour.

Step 2—Analysis of the problems connected with the assembly process realization and observed on the assembly line. Game participants identify three most important problems. Then, all the game participants are divided into three teams depending on the possessed knowledge concerning the problems, and they analyze the problems with the tools chosen by them and adequate to the problem. The most important thing is to engage operators as the people knowing best what is happening at the certain steps of the process. This convinced about the importance of the engagement of operators in the problem analysis. One of main things is also close cooperation between the teams as their decisions can influence other team's analysis.

Step 3—Proposed solutions of the problems are implemented. Each team introduces their solutions and makes changes in the production organization, material and information flow applying adequate lean tools.

Step 4—Production is realized in new conditions (Fig. 9.5). Game participants realize that by the implementation of changes it was possible to achieve the improvements. However, they had known that the target is for them to achieve. Therefore, it becomes obvious that the improvement process never stops.

Step 5—Students make assessment of the achievements, identify mistakes which they were made during the change implementation. They realize possible consequences of wrong decisions in reality.

Fig. 9.5 A serious game—an assembly line of ball pens

The following rules are applied in the game:

- Students already possess theoretical knowledge concerning all of the mentioned course modules, i.e. knowledge about the production organization, quality management, quality methods and tools, lean management and lean tools,
- Students may freely choose adequate tools to analyze problems,
- Students have the right to make mistakes, but they must also be able to assess the consequences of the mistakes.

During the game, students can learn much more than during the lectures, even if they are illustrated by practical examples. During the game, students can act out and see the results of their own actions.

Examples of wrong decisions taken during the game are:

- Ordering the operators to work faster,
- Ordering the operators not to make mistakes,
- Looking for scapegoats of the problems that have occurred,
- Using wrong tools for the analyses or conducting analyses in a wrong way,
- Lack of communication between the teams, which resulted in making contradictory decisions,
- Not using all opportunities associated to the lean manufacturing tools,
- Implementing too many tools in a situation when there is no such need.

Examples of competences developed during the game are:

- Team work,
- Ability of implementation of tools in a real word,
- Responsibility for undertaken actions,
- Motivation to implement improvements,
- Cooperation and information exchange,
- Understanding employees' work,
- Identification of obstacles in the lean implementation,
- Recognizing possible achievements originating from the lean concept implementation.

In addition to the presented, other games are also played in the degree course of Management and Production Engineering such as: 5S implementation on the work stand, TPM implementation on a machine, Poka Yoke solutions developed to prevent some certain mistakes in a process, SMED analysis etc.

9.9 Lean Learning Academy Involvement in Offering Lean Education

Along with the presented degree courses and postgraduate studies, Lean Learning Academy Polska organizes additional trainings for industry. The training concept is presented in Fig. 9.6.

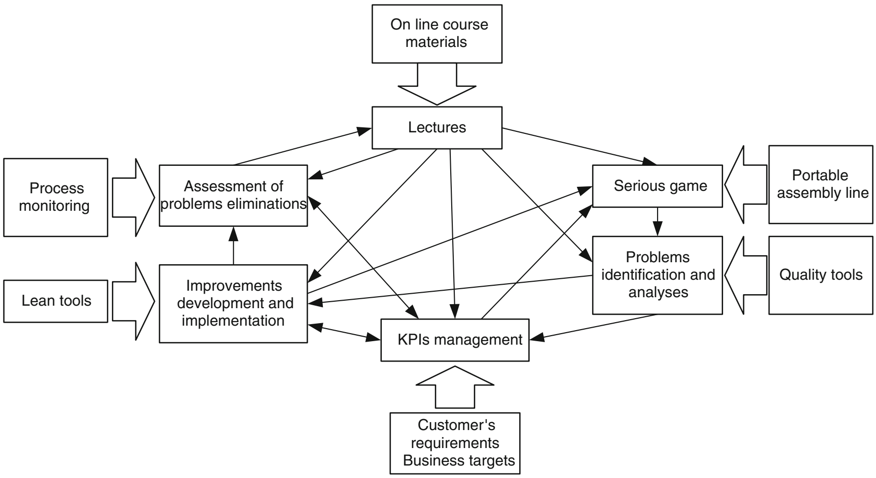

Fig. 9.6 Training concept in Lean Learning Academy Polska

Lectures are given with the use of Power Point presentations illustrated by the examples (e.g. photos) from the company of which the employees are trained to refer to the real company's life and to get better understanding of the presented issues. Trainees have an on line access to all Power Point presentations. The serious game is one of the training elements. The game can be realized in a company or at the University, because all games are portable. During the game, problems concerning the lack of possibility to achieve KPIs adopted for the game are identified and, then, analyzed with the quality tools (e.g. Ishikawa diagram, Pareto-Lorenz diagram, FMEA). KPIs are managed according to customer's requirements and business targets adopted for the game.

Next, improvements are proposed on the basis of the analyses results and on the acquired knowledge about lean tools in order to obtain the established KPIs. Finally, the improvements are implemented and the achieved results are assessed on the basis of the data collected in a monitoring process. Based on the achieved results, KPIs can be developed and additional knowledge can be transferred to the participants of the training.

9.10 Project Realized for Companies

During the last semester of studies all students had to write a diploma thesis. Within the degree course on Management and Production Engineering, it is recommended to prepare a project in a company and for the company. Examples of such project are as follows:

- Value stream mapping of production processes,
- Value stream mapping of service processes,
- Material flow optimization on a production line,
- Improvement of work stands organization with the use of 5S,
- Shortening of the setup times with the use of SMED,
- Solving the problems concerning production processes with the use of Poka Yoke solutions,
- Implementing Kanban system on a production line,
- Implementing the Six Sigma method to improve the quality,
- Total Productive Maintenance implementation,
- Using 3P method for designing a layout,
- Work time standardization.

If the project is realized in a proper way and with the good results, a student gets a job offer, therefore, it is good motivation to make some effort.

9.11 The Program Assessment and Accreditation

Degree courses are periodically assessed at the University in order to maintain up-to-date syllabuses, which are a response for the business community needs. On the basis of the data acquired from the graduates by surveys, it is possible to realize gaps in students' education and company needs, and to modify programs of courses in order to transfer to the students valuable knowledge which can help them to get employment. Six months after the graduation former students are asked to give their opinion on the finished degree course and on the advantages of the skills acquired in this degree course. Next, three and five years after the graduation they have another opportunity to take part in the next survey process again.

Furthermore, students have a chance to express their opinions during the studies. All opinions are taken into consideration in the process of the course internal assessment.

Undoubtedly, the University is open for industry and there are many possibilities to share opinions on the degree course programs mentioned before and offered by the University.

Accreditation of the degree courses is realized by the Polish Accreditation Committee.[4] Every six years each degree course is subjected to accreditation. The Polish Accreditation Committee evaluates the quality of education in the degree course of Management and Production Engineering assessing the quality of study syllabuses as well as complexity, functioning and effectiveness of the internal quality assurance system and the improvements in the quality of education provided.

Polish Accreditation Committee has the status of a full member in the Central and East European Network for Quality Assurance Agencies in Higher Education

[4]http://www.pka.edu.pl/en/.

(CEENQA), European Consortium for Accreditation (ECA), International Network for Quality Assurance Agencies in Higher Education (INQAAHE) and European Association for Quality Assurance in Higher Education (ENQA). Polish Accreditation Committee is registered in European Quality Assurance Register for Higher Education (EQAR) as well.

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

Anabela Carvalho Alves, Rui Sousa, José Dinis-Carvalho and Francisco Moreira

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

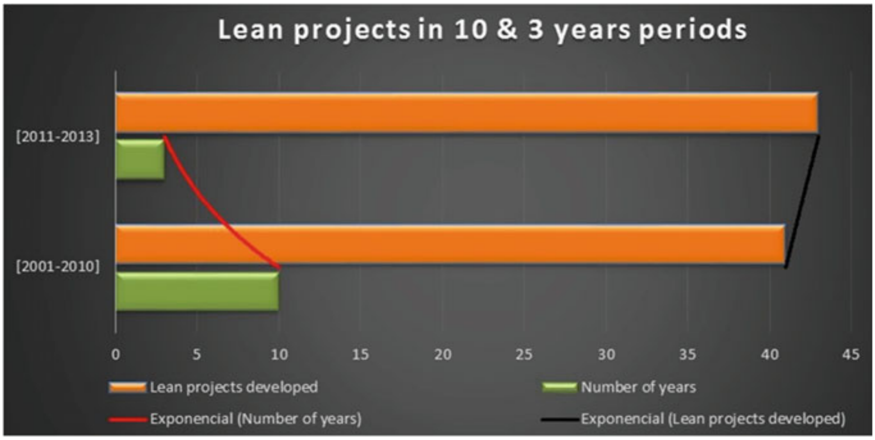

Fig. 10.1 Increase of Lean projects in IEM final year (Alves et al. 2014)

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

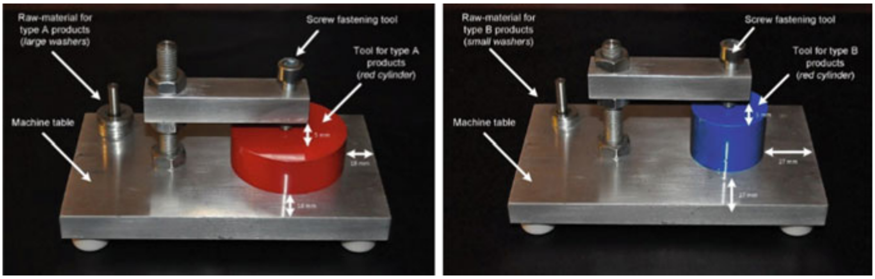

Fig. 10.4 The SMED game (Sousa et al. 2013)

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)

<table>
<tr><th>References</th><th>Lean tools implemented</th><th colspan="2">Main benefits for companies</th></tr>
<tr><td>Araújo and Alves (2012)</td><td>Pull system and FIFO lane</td><td>• 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 %);</td><td>• 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 €</td></tr>
<tr><td>Ribeiro et al. (2013)</td><td>Standard work</td><td colspan="2">• 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</td></tr>
<tr><td>Bragança et al. (2013)</td><td>5S, Visual management and standard work</td><td>• Increase the shop floor area;
• Distances travelled: 90–0 m;
• Reduce errors and non-conform;
• Reduce the required operators;
• Improvement on the organization</td><td>• Reduce energy and material consumption, mainly due to the decrease of defects and reduction of rework
• Total gains: 18,905 €/year</td></tr>
<tr><td>Costa et al. (2013a, b)</td><td>SMED</td><td>• Reduce setup times;
• Reduce WIP and distances travelled by operators;</td><td>• Standardized process, becoming faster and intuitive for the operators;
• Total gains of 1629 € per year</td></tr>
<tr><td>Costa et al. (2013a, b)</td><td>SMED</td><td>• 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);</td><td>• Reduction of 99 % in the distance traveled by the operator (from 136.7 to 1.7 m);
• Gains of about 7315 € per year</td></tr>
</table>

(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).

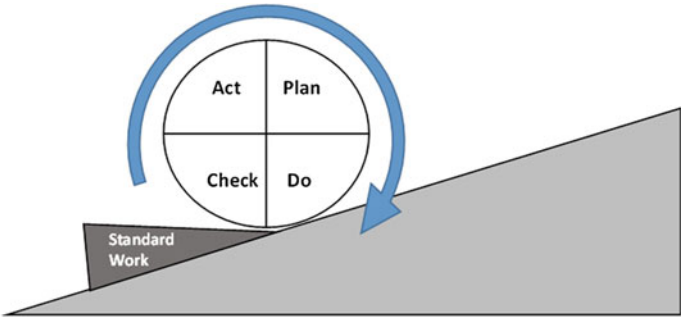

Fig. 10.5 PDCA cycle and standard work

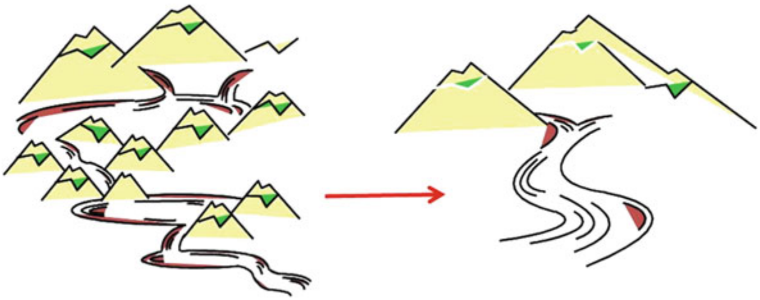

Fig. 10.6 Flow concept (Cousineau 2012)

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

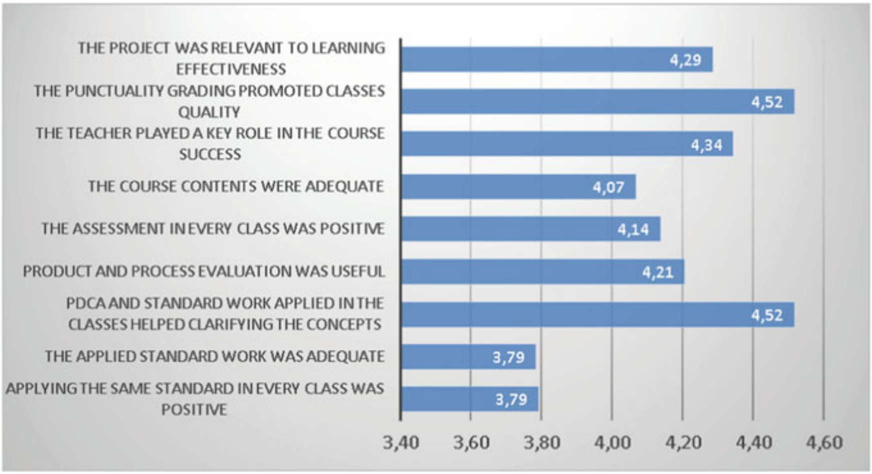

Fig. 10.7 Results from the final enquiry

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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Chapter 11
Conclusions and New Developments

Anabela Carvalho Alves, Shannon Flumerfelt and Franz-Josef Kahlen

The editors of this volume have been collaborating in the field of Lean Engineering Education and competency development in the engineering workforce for several years. Among them, they hold interests in mechanical, industrial and system engineering, organizational leadership, educational leadership and process engineering disciplines, which allows them to carry out research in Lean Education while maintaining an engineering and a social science perspective.

By creating this edited volume, the editors believe that they have provided a platform for authors to share their efforts in building a Body of Knowledge (BoK) for Lean Education. It is expected that the BoK is current as of the year of publication but will be evolving as a result of practice, technology, perspectives or other developments. This edited volume showed that Lean Education is, in fact, being adopted as a Body of Knowledge taught in Higher Education Institutions (HEI), particularly, in universities, where academics (Industrial Engineering (IE) traditionalists' teachers) may continue to perceive Lean as simple 'common sense' or as 'the application of classical IE.' Although LE does apply common sense approaches, most of the time it is very counterintuitive, requiring the discipline of a body of knowledge. In addition, this text showed that many HEIs are adopting Lean Education in their courses

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and projects in valuable interactions with industry. This provides new insights into university partnerships that benefit student learning.

All chapters presented were unanimous in concluding that Lean is an organizational need, encompassing several sectors and organizational types. The workforce development need to be trained in Lean is significant. And if provided independently to engineers, managers, shop-floor employees, academics, administrative personnel, is viewed as beneficial but difficult to offer through internal means. Therefore, the business case for HEI to provide Lean Education is of interest to organizations. This is because the Lean Principles and tools do drive daily workplace improvements when deployed with fidelity. Through problem-solving, excuses for failure and other negative organizational citizenship behaviors can be mitigated with skilled Lean workforce deployment.

This edited book showed the embodiments of Lean Education in the form of courses, projects, training short-courses sessions and specialization advanced programs (what). This demonstrates that Lean Education is offered by HEI (who) using shared Lean Education methodology, active learning, PBL, serious games, scenarios, etc. (how). Lean Education strives to highlight staging of students' development (when). These chapters in total summarize the impact of this type of learning (why) for the students, organizations and society, exposing the reasons various HEIs include Lean in their curriculum.

In this edited volume, readers can see that HEIs are committed to Lean Education. Further, through the use of Lean Education as a methodological improvement approach, HEI faculty will also benefit from the transfer of lessons learned about these highlighted Lean programs. The value in the volume may be found in sharing in the knowledge about various extant Lean Education programs/courses in order to further evolve Lean Education the Body of Knowledge.

The editors also hope that this edited volume intentionally reaches professors, teachers and/or researchers in the Lean Body of Knowledge network in these and adjacent research areas by providing an interdisciplinary platform for jointly developing research proposals. In offering a common platform to discuss Lean Education among scholars, it is possible to identify the multidisciplinary applications of Lean Education.

In this edited volume, new developments are presented that intend to help to propel into action the use of Lean Thinking Principles in the classroom. Lean Thinking Principles constitute critical content, and can be modeled by HEIs to improve teaching/learning, for example, by pulling from the students what they need through active learning like serious games, simulations, and hands-on approaches, among others. This means that when someone educates people in Lean, normally, it is also possible to be "touched" by the Lean spirit by seeing wastes in everything, particularly, in his/her diary activities. This provokes an endless search for perfection.

Therefore, this volume is presented with the hope of both improving the Lean Body of Knowledge and improving HEI education delivery. Much has been accomplished, but there is much more to be done. This is the essence of the pursuit of perfection, always looking for problem-based/needs-based improvements in curriculum/program design and review processes and in quality of curriculum content. It falls to HEI's to share in the commitment to model Lean Thinking and principles to students, for these lessons are valuable in daily living and in the workplace.