Developing lean competencies through serious games

Gabriela Witeck[1], Anabela C. Alves[1]

[1]ALGORITMI Centre, Department of Production and Systems, School of Engineering, University of Minho, Guimarães, Portugal

Email: gabiwiteck@gmail.com, anabela@dps.uminho.pt

Abstract

Lean Production is a methodology largely implemented across industries and services. This methodology adds value to companies, as it derives from the main idea "doing more with less", where less means with fewer resources, less product development time, less human effort, among others to provide high performance in daily activities. As a company requires adequacy of Lean Thinking, the philosophy behind Lean Production, it leads to a concern in the manner of training and educating of its employees. Lean Thinking requires competencies to be successfully understood and pursued all the time. Partly due to human and social capital being key factors for the functioning of society and economy, in recent years there has been an increased interest in competencies, as knowledge and skills are not enough anymore. In this context, higher education engineering and innovative organizations seeks to complement the training of theirstudentsandprofessionals, through specific courses with serious games simulating typical day-to-day issues in business matters. The serious games methodology involve "learning by doing", in which students can develop and improve skill sets in real-world context, recognizing themselves as protagonists of their learning. Experiential learning or "learning by doing", does notonly implyexposition of the theory, but the resolution of an unstructured problem, it also proposes decision-making to solve such a problem. Thus, the Lean Thinking mind-set needs serious games and other active learning methodologies to become truly meaningful and to provide new competencies to the professional. This mind-set is a valuable differential in the current market, with increasingly flexible job rotations, more on-demand jobs than long-term contracts, and its demand of skills incompetitions, like quick learning and logical reasoning. This articlediscussesthe importance of serious games for Lean students and professionals to acquire competencies. The research was, predominantly, based on a conceptualreview of papers that described serious games and hands-on activities. Based on these, some evidence elements from the papers that match essential competences of Lean Education: System-thinking, Environment and Ethics were collected.

Keywords: Lean Education; Competencies; Serious Games; Hands-on Activities.

1 Introduction

Lean Production (LP)has been a prominent strategy methodology in the past three decades (Alves et al., 2019; Krafcik, 1988; Samuel et al., 2015; Schonberger, 2019; Womack et al., 1990).Lean Thinking (LT) is the philosophyunderneath LP that adds value to companies as it derives from the main idea "doing more with less". To concretize such idea, Womack and Jones (1996) identify five principles that should be followed: 1) Value; 2) Value Stream; 3) Flow; 4) Pull Production and 5) Pursuit Perfection. This philosophy is a consistency of knowledge whose essence is the ability to reduce costs and increase productivity by eliminating wastethrough problem solving, in a systematically way. This implies rethinking how to lead, manage and develop people. It is through the full engagement of people with their jobs that are able to identify improvement'sopportunities with sustainable gains. Their roots are in Toyota Production System (TPS) tenets that is based on Respect-for-People and continuous improvement (Monden, 1998; Ohno, 1988; Shingo, 1989) till today (Toyota Motor Corporation, 2018).

LT associated with operational excellence at all levels follows guides for the success of any organization in a long-term sustainable viability. As a company requires adequacy of LT, the philosophy behind LP, it leads to a concern in the manner of training and educating of its employees. The Lean Education (LE) requires contents, but, mainly, competencies to be successfully understood and pursued all the time(Alves, 2019; Alves et al., 2020; Alves et al., 2017; Flumerfelt et al., 2015).Such competencies are related to: System-thinking, i.e. being capable to comprehend the whole picture, not just a part of it(Flumerfelt et al., 2016; Flumerfelt et al., 2014; Kahlen et al., 2013); Sustainability as they will be aware of how Lean wastes (transports, inventory, motion, waiting, overproduction, over-processing and defects)impact on environmental actions (Abreu et al., 2017; Alves, 2018; Moreira et al., 2010); Ethics by adopting an ethical behaviour that starts with Respect-for People,

as main tenet of TPS (Flumerfelt et al., 2013, 2012). This implies motivation, collaboration and cooperation through teamwork, transparency and fluidity of information as a fundamental basis as well problem-solving, critical thinking, communication, negotiation and analytical skills, creativity, and intercultural skills.

A competency includes knowledge, skills and attitudes(Council of the European Union, 2018; Rychen & Salganik, 2000). Knowledge is related to facts and figures, concepts, ideas and theories which are already established and support the understanding of a certain area or subject. Skills are the ability and capacity to carry out processes and use the existing knowledge to achieve results. Attitudes are the disposition and mind-sets to act or react to ideas, persons or situations (Council of the European Union, 2018, p. 14). Knowledge, skills and attitudes when integrated, is capable of generating high standard performance (Amorim & Barros, 2011).

Competencies have three main characteristics: they are linked to a particular work and organizational context; they are associated with superior performance; and can be described in terms of behavioural patterns or results that can be observed during the tasks executions (Hirsh & Strebler, 1994). On the other hand, Stokes and Oiry (2012) call attention to facts that are not forbidden to interpret and that can be replicated in a robotic way; otherwise, the competency model can become, in practice, a behavioral manual.

The competencies enable the user to handle new behavioral strategies to find solutions to complex problems. This is the reason to support LE learning system in competencies. According to the Council of the European Union(2018)competencies are acquired through active learning methodologies such as project and problem-based learning (PBL), experiential methods, serious games, hands-on activities, flipped classroom, among others. Such methodologies promote the participation of all the students, encouraging the self-critical feeling, the identity and the feeling of belonging, the teamwork, the problem-solving and critical thinking, among others. Through these methodologies, studentsbecame more active and adopting a protagonist role in their own education. This allows, not only skills related to the main theme of the studies to be performed, but also the ability to make decisions and toexecute actions in an entrepreneurial and autonomously way (competencies), addressing complex problems with results orientation.

Although adult education, e.g. companies professionals have a different way of learning, it is also based on a need to understand the meaning of their own experience. Such understanding should be facilitated by education, more concisely, transformative learning (Mezirow, 1997). Methods used in the transformative learning includes also an active process that help adults to develop their thoughts, feelings, and disposition, much as the Head-Heart-Hands (3H) taxonomy provides (Brühlmeier, 2010; Flumerfelt et al., 2014).Methods, similar to the ones referred above, includes action research projects because these promote reflective thought, imaginative problem posing, and discourse in a learner-centered, participatory, and interactive, group deliberation and problem solving.

This knowledge on adults learning demands, promote opportunities between academia and the professional industry that facilitate this knowledge transfer through LE (Alves et al., 2017; Alves et al., 2018; Flumerfelt et al., 2016). The companies that already follow Lean approaches leads to concern in the training and awareness process of its employees, as the impact of Lean learning on these changes is noticeable(Alves et al., 2016).Nevertheless, such competencies could be prevented from being learned in work environments if not well trained(Francis, 2016; Khatibi &Khormaei, 2016). This means if the learning methods used were not the correct, the meaning and motivation to learn is not practiced.

In this paper, it is discussed the serious games and hands-on activities in developing lean competencies in students/professionals. To achieve the conceptual review is undertaken, retrieving from scientific papers the lean competencies developed by such methods, according to their authors. Also, as the demand for different and new competencies emerges in the frame of the Industry 4.0 approach, a discussion about these alignments is initiated.

This paper is organized into five sections. The first presents an introduction and the objectives of the paper. The second section presents the research methodology. The section three presents the serious games and active learning approaches, followed by the fourth section where it is discussed the development of Lean competencies through serious games. Finally, the section five outlines concluding remarks.

2 Research methodology

The research discussed in this paper was, mainly, based on a conceptual review. According to (Sangwa & Sangwan, 2018) a conceptual review examines conceptual knowledge and synthesizes different theories, concepts, and phenomena, providing interrelationship among them. Lately, could be used to propose new conceptual framework, model, roadmap or instrument based on existing literature of the specific topic. In this research, lean serious games and hands-on activities are collected from literature review andanalyzed to find elements that evidence the importance of such educational activities to promote lean competences in the apprentices. Provides a theoretical literature review of existing theories and interrelationship among them.

3 Serious games and other active learning approaches

Learning is the process where the knowledge is created through the transformation of experience (Kolb, 1984). In Kolb's experiential model of learning, individuals are encouraged to reflect on the actions and consequences, then to create an understanding and reapplying it to future actions. Kolb defines four possible learning styles: (i) Divergent (feel and watch), (ii) Assimilative (watch and think), (iii) Convergent (do and think) and (iv) Accommodative (do and feel). These Kolb's styles are possibly interrelated depending on individual preferences, and may result in four different outcomes: Concrete Experience (to feel), Reflective Observation (to watch), Abstract Conceptualization (to think) and Active Experimentation (to do).

Piaget (1973) argues that the stages of learning are involved in a constant process of adapting man to the world. In the active learning process,through which learners build new ideas or concepts based on their old or current knowledge, the student selects and transforms constructive hypotheses as information and makes decisions based on his own cognitive structure(Wood et al., 1976).

The serious games approach gained impulse as a positive perspective of learning published in business reviews, as opportunities to apply games in large companies, to allow innovation and motivation of the employees (Erdős & Kallós, 2014).Wouters et al. (2007)mentioned that serious game aims to educate, put learners in situations in which they are responsible for decisions made, reflected and evaluated (Geithner & Menzel, 2016).During the game, apprentices can learn based on their own experience (Lopes et al., 2013).A result of the serious games is impulse a more interactive, participatory, inductive, reflective and exploratory learning environment (Tao et al., 2015).Furthermore, games based in problems, appear to be promising instructional approaches in different areas, including production and engineering education (Pourabdollahian et al., 2012).

The virtual serious games, in a simulation platform can be used as a virtual laboratory to perform experiments. According with Gadre et al. (2011) the virtual simulation assignments can give students an overview of how to apply lean tools to an existing production line, while also bolster students' learning through problem solving. Once that students would immediately see the effects of their suggested changes in the production line. Thus, the virtual platform would help students in lean and related courses to learn through their work, improve retention, and visualize the otherwise costly effects of commonly made mistakes in real-time(Gadre et al., 2011).

Additionally, some authors considered that the game-based learning (GLB) promote a hands-on qualification of the learners(Alves, Sousa, et al., 2017; de Vin et al., 2018; Flumerfelt et al., 2015, 2016). Another function of environmental learning, especially in the academic area is the usage as a test area for new technologies and processes (Municio et al., 2018; Schallock et al., 2018). The authors Kuriger et al. (2010)and Badurdeen et al.(2010)confirm that serious games are useful tools for teaching Lean concepts, as participants can see and experience what they learn in regular lecture sessions and other teaching techniques.

Although it is not possible to learn Lean exclusively through games, Bicheno(2014) stated thatthis is a quick experimental learning that no one cannot, reading or watching in an expository class. Additionally, this author claimed that the games can interact and promote discussion, participation and the decision to decide what the essential requirements for a successful Lean implementation are.

Also, Flumerfelt et al. (2015; 2016b), Alves et al. (2016; 2017b), Bicheno (2014), Sousa et al. (2014) among others, argued that Lean learning should follow active learning methods such as Project Based Learning (PBL) and also in the context of a final course project as identified in Alves et al. (2014). Only by this approach the benefits of

learning Lean can reflect on concrete actions with quantitative and qualitative values for companies (Alves et al., 2017; Alves, Flumerfelt, et al., 2017; Kahlen et al., 2011).

4 Development of Lean competencies through serious games

Lean Education should be focused on the values of the Toyota Production Systems (Ohno, 1988), following the five principles defined by Womack and Jones (1996): 1) Value; 2) Value Stream; 3) Flow; 4) Pull Production and 5) Pursuit Perfection. According to Bauer et al. (2018), these could also be supplemented by the principle: 6) Respect for People - which the founders of the Toyota Way (Liker, 2004)regard as a fundamental basis for a trusting cooperation of all employees.Therefore, these principles refer to knowing the customer well and how her/his needs are, the point of view that increases the value of the product and what she/he is willing to pay, as a result of eliminating everything that may be in the way of a delivery on time, quality and right amount. This requires learning from everyone, employees, internal and external customers, and through a culture where is permanent the need to improve, making them aware of all errors, when identified, always being solved. According to Powell & Reke(2019), it could be no lean without learning.

Among educators, there is a consensus that Lean education approaches should contain the practical experience (De Vin et al., 2018; Flumerfelt et al., 2015; Flumerfelt et al. 2016; Alves et al., 2017). The objective should be to promote and develop as learners' skills and competencies to think lean and to act in the long term. Partly due to human and social capital being key factors for the functioning of society and economy, competencies are increasingly valued by companies and, for that same reason, they must be present in what they are and what those skills are necessary for successful of job tasks. Attending to this, many authors have been developing actives approaches for teaching Lean, in the academic and even in the industrial environments. The Table 1 presents some of these authors and relates the three main Lean competencies discussed, highlighting some evidence elements from these that match the competencies and/or skills embed in these competencies. Due to the paper dimension limitation, just a few publications were collected and presented in the Table 1.

Moreover, with the digital transformation as Industry 4.0 leads to changed competence requirements in different topics, also in technologies(Dombrowski et al., 2019; Enke et al., 2018).After the changes coming with Industry 4.0, as smart factories are the main resources, where "humans, machines and resources communicate with each other so naturally in a social network".

In this aspect, the current concept of "learning factories", which denotes thereinforcing and construction of "factories that learn", offers potential for the development of skills in the areas of human performance (cognitive, affective and psychomotor), and also for all classes of competencies. The concept "learning factories" mainly aims at people's cognitive performance, professional skills. The development of competencies in these areas does not occur automatically if students do not learn much more in a situation corresponding to daily adversities (Abele et al., 2015, 2017, 2019; Municio et al., 2018; Pascual et al., 2020; Tisch et al., 2016).

Consequently, new forms of Lean teaching and learning are needed in order to keep up with the developments described. In particular, research institutes that collaborate strongly with industry have a responsibility to develop innovative learning approaches that help prepare the current and future workforce to work in the company of the future (Dombrowski et al., 2019). Such approaches go through the learning factories already mentioned and are being implemented in several countries in partnership with companies (Adam et al., 2020; Municio et al., 2018; Pascual et al., 2020). Also, important is to measure how effectiveness this learning is (Adam et al., 2020; Leal et al., 2017; Pourabdollahian et al., 2012).

Table 1. Some publications and Lean competences

Publications/ game type	System-thinking	Sustainability	Ethics
(McManus et al., 2007) Lego airplane	Lean improvement on the "bottom line" even when improvement costs are taken into account; Redesign a fairly complex system.	Eliminate paperwork, eliminate stocks.	Work habits and relationships must change interpersonal effort; working together; team bonds; no cheating; bending several rules; communication; responsibilities; motivation; the importance of being organized and clean; following rules.
(Fang et al., 2007) Lego cars	See the whole picture of how products flow throughout the value stream; lessons learned.	Reduce inventory; eliminate wastes; reduce scrap.	Importance of the "people"; improved communication and worker motivation; importance of teams and appropriate teamwork; interdisciplinary collaboration; importance of the people side; experienced team frustration.
(Alves & van Hattum-Janssen, 2011) Torch assembly	Critical thinking of the production system initial state; see the entire process for the torch assembly; deep learning of all members of the team	Reduce transports and motion; reduce overproduction	Importance of being organized and clean; initiative; being responsible; motivation; respect for the others opinion; help each other.
(Pourabdollahian et al., 2012) Airplane	Make decisions and choose options; task accomplishment	Reduce defects, time.	Motivation; challenge; engagement; interest; team collaboration
(Silva et al., 2013) Electrical plug	Seeing the whole value stream of a product	Eliminate stocks and unnecessary movement.	Necessary that the participants are aware of the rules; seek perfection.
(Sousa et al., 2014) Machine set-up; 5S game; electrical plug	Critical-thinking; Problem-solving; Global learning; Reflexive learners.	Less stocks; reduction of the time.	Teamwork; engagement and motivation; importance of being organized and clean.
(Leal et al., 2017) Lego bricks	Students reflect on the results; theoryvs. practice	Eliminate waste; Less human work in process inventory.	Motivation; teamwork; team discussions and alignments; following rules; importance of being organized and clean; express opinions; confidence.
(Alves, 2018) Operating modes in U-shaped cells	Making-decisions about products to assembly; design the production system; organize people	Reduce transports and overproduction	Motivation; collaboration; engagement; respects for others opinion; be patient; importance of being organized and clean
(Sousa & Dinis-Carvalho, 2020) Mapping	Global understanding of the whole process as well as its interactions; Increase the process performance. Effective to represent the entire process as well as to identify improvement opportunities.	Reduce waste, mainly paperwork.	Conflict management; motivation and engagement; promote the coordination and communication between team participants.

5 Conclusion

This paper researched the use of serious games as a form of active learning methodologies, aiming to developing Lean competencies of System-thinking, Sustainability and Ethics. These are crucial competencies for theFourth Industrial Revolution. Such learning methodology is expected to deliver an oriented way to prepare students and worker's community equipped with competencies required for a complex market,

considering that challenges occurred in the future will be adapted appropriately and in correctly time, in a Lean way.

Along with some examples from the literature, which reports good results while students flow on the games experience, some skills are evolved, like: critical-thinking; teamwork;communication; responsibility; motivation; global learning and concern with wastes elimination actions. Such skills are embedding in the three competencies referred above. Nevertheless, the sustainability competency does not seem deeply explored. This mind-set is a valuable differential for students and professionals.Once Respect-For-People and continuous improvement are the foundations of LT, it is succeeded that some well-developed serious games can be used to achieve the competencies required in Lean Education.

Nowadays, the COVID-19 pandemic, which imposes new patterns of behaviour and changes in habits, the expectations about the future are still uncertain. Therefore, to face this moment, the effects of virtual serious games understanding is relevant in the area of Lean education and in the relationship students and worker's community with digital educational technologies and their virtual nature.

Future plans are to perform systematic literature review of active learning methodologies to develop a model to measure the value-added created by the serious games and other active approaches for students learning and companies sustainability.

Acknowledgments

This work has been supported by FCT – Fundação para a Ciência e Tecnologia within the R&D Units Project Scope: UIDB/00319/2020.

6 References

Abele, E., Chryssolouris, G., Sihn, W., Metternich, J., ElMaraghy, H., Seliger, G., Sivard, G., ElMaraghy, W., Hummel, V., Tisch, M., & Seifermann, S. (2017). Learning factories for future oriented research and education in manufacturing. CIRP Annals, 66(2), 803–826. https://doi.org/10.1016/j.cirp.2017.05.005

Abele, E., Metternich, J., & Tisch, M. (2019). Learning Factories. Springer International Publishing. https://doi.org/10.1007/978-3-319-92261-4

Abele, E., Metternich, J., Tisch, M., Chryssolouris, G., Sihn, W., ElMaraghy, H., Hummel, V., & Ranz, F. (2015). Learning Factories for Research, Education, and Training. Procedia CIRP, 32, 1–6. https://doi.org/10.1016/j.procir.2015.02.187

Abreu, M. F., Alves, A. C., & Moreira, F. (2017). Lean-Green models for eco-efficient and sustainable production. Energy, 137, 846–853. https://doi.org/10.1016/j.energy.2017.04.016

Adam, M., Hofbauer, M., & Stehling, M. (2020). Effectiveness of a lean simulation training: challenges, measures and recommendations. Production Planning & Control, 1–11. https://doi.org/10.1080/09537287.2020.1742375

Alves, A. C. (2018). Lean Education: provider of system-thinking, ethics and sustainability competencies. 4th Edition 2018 - 11th EPIEM Conference on Innovation and Sustainability 2018. http://innovation.pub.ro/archive/2018.pdf

Alves, A. C., Flumerfelt, S., Moreira, F., & Leão, C. P. (2017). Effective Tools to Learn Lean Thinking and Gather Together Academic and Practice Communities. Volume 5: Education and Globalization, V005T06A009. https://doi.org/10.1115/IMECE2017-71339

Alves, A. C., Sousa, R. M., Dinis-Carvalho, J., Lima, R. M., Moreira, F., Leão, C. P., Maia, L. C., Mesquita, D., & Fernandes, S. (2014). Final year Lean projects: advantages for companies, students and academia. Project Approaches in Engineering Education, 1–10. http://hdl.handle.net/1822/30172

Alves, A.C. (2018). U-shaped cells operating modes: A review and a hands-on simulation comparison. International Journal of Industrial Engineering and Management, 9(2), 87–97. https://doi.org/658.5:004.94

Alves, A.C. (2019). Competencies driven by Lean Education: System-thinking, sustainability and ethics. International Symposium on Project Approaches in Engineering Education, 9, 710–713.

Alves, A.C., Leão, C. P., & Sousa, R. M. (2018). Lean education as a platform to close the academic and professional gap. International Symposium on Project Approaches in Engineering Education, 8, 17–19.

Alves, Anabela C., Leão, C. P., C. Maia, L., & Amaro, P. A. (2016). Lean Education Impact in Professional Life of Engineers. Volume 5: Education and Globalization, 5, V005T06A044. https://doi.org/10.1115/IMECE2016-67034

Alves, Anabela C., Leão, C. P., Uebe-Mansur, A. F., & Kury, M. I. R. A. (2020). The knowledge and importance of Lean Education based on academics' perspectives: an exploratory study. Production Planning & Control, 1–14. https://doi.org/10.1080/09537287.2020.1742371

Alves, Anabela Carvalho, Flumerfelt, S., & Kahlen, F.-J. (2017). Lean Education: An Overview of Current Issues (Anabela Carvalho Alves, S. Flumerfelt, & F.-J. Kahlen (eds.)). Springer International Publishing. https://doi.org/10.1007/978-3-319-45830-4

Alves, Anabela Carvalho, Kahlen, F.-J., Flumerfelt, S., & Siriban-Manalang, A. B. (2019). Lean Engineering for Global Development (Anabela Carvalho Alves, F.-J. Kahlen, S. Flumerfelt, & A. B. Siriban-Manalang (eds.)). Springer International Publishing. https://doi.org/10.1007/978-3-030-13515-7

Alves, Anabela Carvalho, Sousa, R., Dinis-Carvalho, J., & Moreira, F. (2017). Lean Education at University of Minho: Aligning and Pulling the Right Requirements Geared on Competitive Industries. In Lean Education: An Overview of Current Issues (pp. 149–175). Springer International Publishing. https://doi.org/10.1007/978-3-319-45830-4_10

Alves, Anabela Carvalho, & van Hattum-Janssen, N. (2011). Hands-on simulation in the classroom to teach new concepts and to prepare future industrial engineers as operator ´ s instructors. Proceedings of the 2011 Project Approaches in Engineering Education, 259–265.

Amorim, T. N. G. F., & Barros, S. L. (2011). Gestão por competências: nuances e peculiaridades. Revista Reuna, 16(1).

Badurdeen, F., Marksberry, P., Hall, A., & Gregory, B. (2010). Teaching Lean Manufacturing With Simulations and Games: A Survey and Future Directions. Simulation & Gaming, 41(4), 465–486.

Bauer, H., Brandl, F., Lock, C., & Reinhart, G. (2018). Integration of Industrie 4.0 in Lean Manufacturing Learning Factories. Procedia Manufacturing, 23, 147–152. https://doi.org/10.1016/j.promfg.2018.04.008

Bicheno, J. (2014). The Lean Games and Simulations (2nd editio). PICSIE books.

Brühlmeier, A. (2010). Head, Heart and Hand: Education in the Spirit of Pestalozzi. Sophia Books.

Council of the European Union. (2018). Proposal for a Council Recommendation on Key Competences for Lifelong Learning.

de Vin, L. J., Jacobsson, L., & Odhe, J. (2018). Game-based Lean Production training of university students and industrial employees. Procedia Manufacturing, 25, 578–585. https://doi.org/10.1016/j.promfg.2018.06.098

Dombrowski, U., Wullbrandt, J., & Fochler, S. (2019). Center of Excellence for Lean Enterprise 4.0. Procedia Manufacturing, 31. https://doi.org/10.1016/j.promfg.2019.03.011

Enke, J., Glass, R., Kreß, A., Hambach, J., Tisch, M., & Metternich, J. (2018). Industrie 4.0 – Competencies for a modern production system. Procedia Manufacturing, 23, 267–272. https://doi.org/10.1016/j.promfg.2018.04.028

Erdős, F., & Kallós, G. (2014). Benefit evaluation model for gamified add-ons in business software. Acta Polytechnica Hungarica, 11(5), 109–124.

Fang, N., Cook, R., & Hauser, K. (2007). Integrating Lean Systems Education into Manufacturing Course Curriculum via Interdisciplinary Collaboration. Proceedings of the 2007 American Society for Engineering Education Annual Conference & Exposition.

Flumerfelt, S., Alves, A., Calvo-Amodio, J., Hoyle, C., & Kahlen, F. J. (2016). Managing systems complexity through congruence. In Transdisciplinary Perspectives on Complex Systems: New Findings and Approaches. https://doi.org/10.1007/978-3-319-38756-7_5

Flumerfelt, S, Kahlen, F.-J., Alves, A., Calvo-Amodio, J., & Hoyle, C. (2014). Systems competency for engineering practice. ASME International Mechanical Engineering Congress and Exposition, Proceedings (IMECE). https://doi.org/10.1115/IMECE2014-40142

Flumerfelt, Shannon, Alves, A. C., & Kahlen, F.-J. (2013). What Lean Teaches Us About Ethics in Engineering. Volume 5: Education and Globalization, 5, V005T05A041. https://doi.org/10.1115/IMECE2013-62393

Flumerfelt, Shannon, Alves, A. C., Kahlen, F.-J., & Siriban Manalang, A. B. (2012). Why Require Ethics in Engineering? Volume 5: Education and Globalization; General Topics, 5, 495. https://doi.org/10.1115/IMECE2012-89392

Flumerfelt, Shannon, Alves, A. C., & Khalen, F.-J. (2014). Lean Engineering Education: The DNA of Content and Competency. Proceedings of the 2014 IIE Engineering Lean and Six Sigma Conference, 2014 Lean Educators Conference.

Flumerfelt, Shannon, Alves, A. C., Leão, C. P., & Wade, D. L. (2016). What do organizational leaders need from lean graduate programming. European Journal of Training and Development, 40(5), 302–320. https://doi.org/10.1108/EJTD-01-2015-0005

Flumerfelt, Shannon, Kahlen, F.-J., Alves, A. C., & Siriban-Manalang, A. B. (2015). Lean Engineering Education: Driving Content and Competency Mastery. ASME Press.

Francis, R. (2016). Learning styles: key to enhance learning among student teachers of the B. International Education and Research Journal, 2(12), 54–55.

Gadre, A., Cudney, E., & Corns, S. (2011). Model Development of a Virtual Learning Environment to Enhance Lean Education. Procedia Computer Science, 6, 100–105. https://doi.org/10.1016/j.procs.2011.08.020

Geithner, S., & Menzel, D. (2016). Effectiveness of Learning Through Experience and Reflection in a Project Management Simulation. Simulation & Gaming, 47(2), 228–256. https://doi.org/10.1177/1046878115624312

Hirsh, W., & Strebler, M. (1994). Defining managerial skills and competences. In Gower Handbook of management development (Vol. 4).

Kahlen, F.-J., Flumerfelt, S., Alves, A. C., & Siriban Manalang, A. B. (2013). The möbius strip of lean engineering and systems engineering. ASME International Mechanical Engineering Congress and Exposition, Proceedings (IMECE), 12. https://doi.org/10.1115/IMECE2013-62354

Kahlen, F.-J., Flumerfelt, S., Sinban-Manalang, A. B., & Alves, A. (2011). Benefits of lean teaching. ASME 2011 International Mechanical Engineering Congress and Exposition, IMECE 2011, 5, 351–358.

Khatibi, M., & Khormaei, F. (2016). Learning and personality: a review. Journal of Educational and Management Studies, 6(4), 89–97.

Kolb, D. A. (1984). Experiential Learning: Experience as the Source of Learning and Development (First edit). Pearson Education, Incorporated.

Krafcik, J. F. (1988). Triumph of the Lean Production System. Sloan Management Review, 30(1), 41–52.

Kuriger, G. W., Wan, H., Mirehei, S. M., Tamma, S., & Chen, F. F. (2010). A Web-Based Lean Simulation Game for Office Operations: Training the Other Side of a Lean Enterprise. Simulation & Gaming, 41(4), 487–510. https://doi.org/10.1177/1046878109334945

Leal, F., Martins, P. C., Torres, A. F., Queiroz, J. A. de, & Montevechi, J. A. B. (2017). Learning lean with lego: developing and evaluating the efficacy of a serious game. Production, 27(spe). https://doi.org/10.1590/0103-6513.222716

Liker, J. . (2004). The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer. McGraw-Hill.

Lopes, M. C., Fialho, F. A. P., Cunha, C. J. C. A., & Niveiros, S. I. (2013). Business Games for Leadership Development. Simulation & Gaming, 44(4), 523–543. https://doi.org/10.1177/1046878112471509

McManus, H. L., Rebentisch, E., Murman, E. M., & Stanke, A. (2007). Teaching Lean Thinking principles through hands-on simulations. Proceedings of the 3rd International CDIO Conference.

Mezirow, J. (1997). Transformative Learning: Theory to Practice. In New directions for Adult and Continuing Education (pp. 5–12). Jossey-Bass Publishers.

Monden, Y. (1998). Toyota Production System: An Integrated Approach to Just-In-Time (Third). Engineering and Management Press.
Moreira, F., Alves, A. C., & Sousa, R. M. (2010). Towards Eco-efficient Lean Production Systems. In IFIP Advances in Information and Communication Technology, Volume 322, Balanced Automation Systems for Future Manufacturing Networks (pp. 100–108). https://doi.org/10.1007/978-3-642-14341-0_12
Municio, A. G., Pimentel, C., & Ruano, J. P. (2018). Lean School: an example of industry-university collaboration. In R. M. Dinis-Carvalho, J., Alves, A. C., Costa, N., Lima, R. M. and Sousa (Ed.), Proceedings of the Fifth European Lean Educator Conference (ELEC2018) "Lean Educator's Role in Lean Development" (p. 10).
Ohno, T. (1988). Toyota Production System: Beyond Large-Scale Production. CRC Press.
Ohno, Taichii. (1988). Toyota Production System: beyond large-scale production. Productivity Press.
Pascual, J. A., Pimentel, C., Mateo, M., Hoyuelos, I., Matias, J., & Gento, A. M. (2020). A Learning Factory for Remanufacturing: A New Configuration at Valladolid Lean School. In Proceedings of 6th European Lean Educator Conference (ELEC2019). Springer International Publishing.
Piaget, J. (1973). Estudos Sociológicos. Forense.
Pourabdollahian, B., Taisch, M., & Kerga, E. (2012). Serious Games in Manufacturing Education: Evaluation of Learners´Engagement. Procedia Computer Science, 15, 256–265. https://doi.org/10.1016/j.procs.2012.10.077
Powell, D., & Reke, E. (2019). No Lean Without Learning: Rethinking Lean Production as a Learning System. In K. D. (eds) Ameri F., Stecke K., von Cieminski G. (Ed.), Advances in Production Management Systems. Production Management for the Factory of the Future. APMS 2019. IFIP Advances in Information and Communication Technology (pp. 62–68). https://doi.org/10.1007/978-3-030-30000-5_8
Rychen, D. S., & Salganik, L. H. (2000). Definition and selection of Key competencies. https://www.oecd.org/edu/skills-beyond-school/41529556.pdf
S. Shingo. (1989). A study of Toyota Production System from an Industrial Engineering.
Samuel, D., Found, P., & Williams, S. J. (2015). How did the publication of the book The Machine That Changed The World change management thinking? Exploring 25 years of lean literature. International Journal of Operations & Production Management, 35(10), 1386–1407. https://doi.org/10.1108/IJOPM-12-2013-0555
Sangwa, N. R., & Sangwan, K. S. (2018). Leanness assessment of organizational performance: a systematic literature review. In Journal of Manufacturing Technology Management (Vol. 29, Issue 5). https://doi.org/10.1108/JMTM-09-2017-0196
Schallock, B., Rybski, C., Jochem, R., & Kohl, H. (2018). Learning Factory for Industry 4.0 to provide future skills beyond technical training. Procedia Manufacturing, 23, 27–32.
Schonberger, R. J. (2019). The disintegration of lean manufacturing and lean management. Business Horizons, 62(3). https://doi.org/10.1016/j.bushor.2019.01.004
Silva, I., Xambre, A. R., & Lopes, R. B. (2013). A simulation game framework for teaching lean production. International Journal of Industrial Engineering and Management, 4(2), 81–86.
Sousa, R. M., Alves, A. C., Moreira, F., & Dinis-Carvalho, J. (2014). Lean games and hands-on approaches as learning tools for students and professionals. 7th International Conference on Production Research - Americas.
Sousa, R. M., & Dinis-Carvalho, J. (2020). A game for process mapping in office and knowledge work. Production Planning & Control, 1–10.
Stokes, P., & Oiry, E. (2012). An evaluation of the use of competencies in human resource development–a historical and contemporary recontextualisation. EuroMed Journal of Business.
Tao, Y. H., Yeh, C. R., & Hung, K. C. (2015). Validating the learning cycle models of business simulation games via student perceived gains in skills and knowledge. Journal of Educational Technology & Society, 18(1), 77–90.
Tisch, M., Hertle, C., Abele, E., Metternich, J., & Tenberg, R. (2016). Learning factory design: a competency-oriented approach integrating three design levels. International Journal of Computer Integrated Manufacturing, 29(12), 1355–1375. https://doi.org/10.1080/0951192X.2015.1033017
Toyota Motor Corporation. (2018). Annual report 2018. https://www.toyota-global.com/pages/contents/investors/ir_library/annual/pdf/2018/annual_report_2018_fie.pdf
Womack, J., & Jones, D. T. (1996). Lean Thinking: Banish Waste And Create Wealth In Your Corporation. Siman & Schuster, New York, USA.
Womack, J. P., Jones, D. T., & Roos, D. (1990). The Machine That Changed the World: The Story of Lean Production. Rawson Associates.
Wood, D., Bruner, J. S., & Ross, G. (1976). The role of tutoring in problem solving. Journal of Child Psychology and Psychiatry, 17(2), 89–100.
Wouters, P., Tabbers, H. K., & Paas, F. (2007). Interactivity in Video-based Models. Educational Psychology Review, 19(3), 327–342. https://doi.org/10.1007/s10648-007-9045-4