International Journal for Quality Research 11(1) 35–50
ISSN 1800-6450

Saveta Vukadinovic [1]
Marko Djapan
Ivan Macuzic

EDUCATION FOR LEAN & LEAN FOR EDUCATION: A LITERATURE REVIEW

Article info:
Received 17.06.2016
Accepted 20.12.2016

UDC – 005.33
DOI – 10.18421/IJQR11.01-03

Abstract: *The purpose of this paper is to investigate and understand how tools and principles of Lean philosophy can be adopted to improve the effectiveness of engineering education by providing services beyond the competition and costs below the competition, and how engineering education can provide better prepared engineering professionals capable to work in dynamic Lean environments by developing multidisciplinary knowledge and skills. Paper will be based on analysis of relevant scientific and professional literature sources, including certain elements of description, classification, explanation and prediction. The authors will use detailed literature review to explain complex relationship and interdependence between Lean philosophy and engineering education and answer the question what benefits modern Lean enterprises may expect from properly educated and qualified engineers and how application of Lean tools and principles can improve the system of engineering education.*

Keywords: *Education, Lean, Engineer, Competencies*

1. Introduction

Lean methodology has its roots in manufacturing, but over the last decade Lean has spread beyond the production and became a methodology for improvement, firstly in service sector and public sector organizations wanting to improve their efficiency and value for customers. Higher Education institutions (HEIs) are among organizations that can benefit from application of Lean tools and techniques at operational, administrative and strategic level. Educational institutions now days are facing groundbreaking competition and competing each other for students, research funds, prestige, quality ratings, incubated companies, fundraising, academicians, skilled workers, etc. Furthermore, reduction in state funding and other external pressures have forced those institutions to consider new modes of operation.

HEIs need to become more effective in what they do and this will inevitably call for adoption of improvement strategies such as Lean to assist in their efforts to achieve more efficient and productive institution that is economically sound (Thomas et al., 2015). It is often stated that 21st century educators are tasked with doing more with less, so Lean philosophy is truly imposed as a logical solution for the significant quality improvement, while simultaneously reducing costs of Higher Education.

On the other hand, readiness of business and production systems based on modern production philosophies (Lean, WCM, and TPM) to fulfil market goals and requirements increases significantly if they

[1] Corresponding author: Saveta Vukadinovic
email: savetavukadinovic@yahoo.com

hire highly educated and highly skilled engineers. Higher education therefore needs to equip engineers with the latest technical and professional skills (Stefanovic, et al., 2009) and with appropriate understanding of the social, economic and political issues that will affect their work. Global engineers of 21st century must meet increasingly complex demands of employers in Lean enterprises and be prepared to solve multidisciplinary problems and challenges in an efficient and creative way.

As the quality of future engineering workforce depends mostly on the quality of engineering education, HEIs need to define the profile of modern engineer and to identify skills and competencies which he has to possess. Incorporating knowledge on Lean tools and principles in engineering education will develop competencies needed by industry, contribute to higher employability of engineering students and attractiveness of engineering curricula, and to greater competitiveness of Lean enterprises recruiting these students.

Throughout a detailed and comprehensive review of literature in the field of Lean education and engineering competencies for work in Lean enterprises, the authors will try to draw attention to complex relationship and interdependence between Lean philosophy and engineering education.

2. Education for Lean

The theme of employees' skills, knowledge and abilities has created a wide body of research over the last four decades. Nguyen (1998), Lang et al. (1999), Meier et al. (2000) were among the first authors whose research were focused on understanding the perceptions and expectations of graduate engineers from industry and academia. Nguyen (1998) has distributed a survey regarding the essential skills and attributes needed by engineers in academia and industry and engineering students, in order to compare specific attributes required for each of those three groups. Lang et al. (1999) conducted a survey regarding the necessary attributes for entry-level engineers and the summary of skills evaluated as the most important includes: ability to analyze data, teamwork and multidisciplinary communication, ability to identify problems and alternative solutions, professional and ethical issues, interpersonal skills (including written, oral and presentation skills and writing technical reports) and computer and information skills and technological literacy. Meier et al. (2000) have confirmed the results of Lang et al. (1999) regarding the interpersonal skills, and further stressed the importance of lifelong learning.

Baillie and Fitzgerald (2000) stated that employers need engineers with good critical, analytical and communication skills to implement innovative solutions in a team-based environment. Riemer (2002) pointed out that language and communications skills form an integral part of engineers' abilities. The list of important communication skills includes, but is not limited to, verbal, written, and presentation skills, and when communication takes place on a global scale engineers must be able to use new technologies. Besides, he insisted that excellent knowledge of English and knowledge of other foreign languages (multilingual skills) is an additional advantage for engineers. Lohmann et al. (2006) have formulated the conceptual model for engineers' success on a transnational basis, also claiming that ability to speak a second language is important component of an engineering skill set.

By Dudman and Wearne (2003) engineering career is not solely focused on technological expertise but also covers a variety of managerial skills such as leadership skills, teamwork and project management. Crebert et al. (2004) emphasized that Higher education programs must find different ways to integrate transferable skills that can be used in diverse workplace situations. Martin et al. (2005) explored issues such as technical competencies, communication skills, teamwork, management and business skills, interpersonal skills, lifelong learning. Interestingly, they decided to divide technical competencies on two different fields - the engineering science and engineering practice. The authors made an engineering competencies interaction model that shows how various features of graduate engineers fit together and make them successful in business. Shuman et al. (2005) in their review of modern engineers' skills noted while technical skills remain a prominent component of the engineers' set of skills, soft skills have become equally important.

Reio and Sutton (2006) have pointed out communication, teamwork and customer focus as the most important among generic competencies. According to Badawy (2006) managerial competency is composed of three interrelated components: knowledge, attitudes and professional skills (technical, administrative and interpersonal), so the engineer needs to be competent in all of these fields, although their relative importance varies during the professional career. Fuchs (2006) has recommended that educational institutions should re-focus on coursework required by engineering students to allow them to work more effectively within social and global contexts.

Engineers in modern workplace must be able to prove their skills are current and they are able to update these skills and knowledge to better suit the evolving working environment (Greenwood, 2007). Patil and Codner (2007) have developed a framework that, in addition to hard and soft competencies in engineering curricula, includes global competencies, because engineering graduates are expected to have all what it takes to work in a multicultural and multinational working environment. Also, company Siemens has launched a program, *Siemens Generation 21*, which was aimed to define the ten points that describe the main skills and competencies required for the new century. It was concluded that the structure of skills has to be T-shaped, where the horizontal line symbolizes the broad multidisciplinary knowledge, and the vertical line the depth of knowledge in chosen field (SEFI, 2007).

HEIs and professional engineering associations in many countries (National Academy of Engineering, 2004; National Association of Manufactures, 2005; Royal Academy of Engineering - RAE, 2007; International Engineering Alliance, 2009; Accreditation Board for Engineering and Technology - ABET, 2014; European Network for Accreditation of Engineering Education - EUR-ACE®, 2008) have studied for a long time approaches for teaching and learning the engineering subjects, including the necessary competencies in curricula. The selection and development of appropriate competencies is considered as fundamental dimension in engineering education. The following key attributes were identified as the ones graduates should have by all professional societies: ethics and professionalism, global perspective, the ability to work in a team, ability to apply knowledge, creative problem solving and critical thinking.

Galloway (2008) argues for the need to broaden current and future set of engineers' skills to become not only technically competent but also competent in communication and management practices. She lays out non-technical areas in which engineers have to become experts, such as globalization, communication, ethics and professionalism, diversity, and leadership. Duderstadt (2008) states that new generation of engineers must be especially skilled in three areas: the ability to innovate, the integration of knowledge and the global competency. He also highlights the skills of creating values in entrepreneurship, leadership, innovation and global engineering practice, capability to work with and among different cultures and knowledge on global markets. For Furuya et al. (2008) requirements for global engineers are multiple and include the possession of basic and advanced engineering knowledge along with the international communication skills and experiences.

In the study of Irish engineers' skills, Wallen and Pandit (2009) found that engaging engineers in social activities is helping to develop various soft skills. Balaji and Somashekar (2009) underlined that soft skills are extra or additional skills required by engineers of the 21st century and that employers are more likely to recruit applicants who show higher level of soft skills as opposed to those who demonstrate only high level of technical abilities (hard skills). Mentioned authors have identified 14 core dimensions of soft skills. Similarly, Male et al. (2009) have perceived communication, teamwork, professional attitudes, engineering business skills, problem solving, critical thinking, creativity, and practical engineering skills as highly important for engineering work. Nair et al. (2009) have elaborated the missing links between engineering graduates' attributes and employers’ expectations and found that the most important characteristics for employers are the following: communication, decision-making, problem-solving, leadership, emotional intelligence and social ethics. Farr and Brazil (2009) came to the conclusion that team skills and leadership skills play an important role in career of American engineers. Leadership skills and teamwork are related directly to individual's ability to deal with the other people.

Sharma and Sharma (2010) in their research on Indian engineers revealed that soft skills have become an increasingly important part of success, especially in the engineering field, and that these skills can be successfully incorporated to students during the educational process. Laker and Powell (2011) are among the authors who promoted the idea of acquiring soft skills and defined them as intrapersonal skills (ability for self management) and interpersonal skills (ability to manage interaction with others). Bol (2010) dealt with the gap in knowledge and skills observed at newly employed workers in production companies and pointed out that employees need additional training in mathematics and computer skills (within the hard skills) and communication, teamwork and decision-making (within the soft skills). Toner (2011) added that in interconnected world of today, engineers next to the above must possess skills for solving various local or global problems.

Male (2010) have stressed the importance of generic engineering competencies related to the attributes, jurisdiction or abilities important for graduate students in all disciplines, including engineering. Hellriegel and Slocum (2011) have described seven key competencies affecting the behaviour of an individual, team and organizational effectiveness, while Jones et al. (2010) have analyzed the data from multiple studies on skills needed by production engineers to meet the requirements in manufacturing. They found that knowledge of Lean processes, quality management, Six Sigma and CAD/CAM are the skills that both education and industry rank among the most important. Flumerfelt and Banachowski (2011) cited 20 leading paradigms chosen by university staff in the field of Lean training.

The skills and expertise of engineers in providing engineering services are unique. Kaspura (2013) declares there are no substitutes for engineers because their training is highly specialized, the necessary period of training is long and intense, and academic training only precedes to the development of practical knowledge and skills necessary to become competent practicing engineer Alves et al. (2013) have concluded that cooperation with industry is helping to define desired profile of graduates by clearly identifying competencies they have to possess in order to be successful in the professional practice. Rajaee et al. (2013) are advocates of education based on results aimed at higher presence of soft skills in engineering curricula. Soft skills, such as lifelong learning, project management, awareness of sustainability issues and social responsibility of engineers, and engineering ethics are embedded in assignments, case studies and projects. Berdanier et al. (2014) have revealed there was a difference in observations related to necessary knowledge and skills among students who seek academic and those who seek industrial career, so this aspect should be observed in future research.

In one of the recent papers, Mohd-Yusof et al. (2015) have summarized the most significant challenges and desirable attributes of the 21st century engineer, as well as required characteristics of engineering education. In the same year (2015), Employment and Training Administration United States Department of Labor have made a draft model of engineering competencies, displayed as several layers pyramid, which identifies the knowledge, skills and abilities needed by engineers. At the same time, Rufai et al. (2015) claim that empirical studies on employment skills have shown that skills like problem solving, communication, teamwork, critical thinking and interpersonal skills have become critical for workers' employment at key positions, and therefore the skills that employers desire the most. According to CBI (2016) survey, enterprises insist on higher level of employees' skills and demand for leadership and management skills will increase in particular. Mohanty and Dash (2016) conclude that engineers are expected not only to be a technical expert in their field, but also to know how to behave and work within the company. Hence, engineers are required to learn/develop technical skills, management skills, problem-solving skills as well as the visionary leadership skills.

Based on the foregoing extensive literature review, it is evident that modern engineer needs a set of diverse skills (technical, communication, business, leadership, management) in order to achieve success. However, the system of engineering education is still focused on technical expertise resulting in graduated engineers who are not adequately prepared to work in Lean enterprises. In order to provide an effective solution to this urgent problem, industry and education should work together on building a coherent strategy and reducing the gap between supply and demand for certain profile of engineers. Cooperation between universities and Lean enterprises is a growing importance matter covering various fields of activities and forms of cooperation on both sides, with the aim of better interaction between participants, and timely and proper preparation of engineering graduates for the labour market.

In Lean terminology, any product not meeting customer expectations is considered defective and has to be re-worked to conform the requirements. Mapping this concept in education it seems that new workforce is being generated without the appropriate knowledge and skills, which does not meet industry (customer) requirements. Thus there is an urgent requirement to “re-work” them to become useful and contribute to national development (Sinha and Mishra, 2013). This is supported by the fact there are many inquiries from potential engineering students, wanting to enhance their Lean skills, or organizations, which have undergone or are currently undergoing a Lean transformation, seeking to employ engineers with Lean skills.

More than 20 years ago, Bishop (1995) has observed that a set of unique skills related to occupations that are highly paid and in demand, has obvious market advantage. According to his words, it is unwise to devote one’s entire education to learning things that everyone else already knows (such as basic skills), so one must select a vocation for which there is market demand and for which one has talent, and then pursue expertise and excellence within the niche. One of these promised niches for graduated engineers is certainly knowledge of Lean tools and principles.

As noted by Fliedner and Mathieson (2009), due to recent appearance of Lean initiatives in the industry skills, knowledge and expertise that can be offered to students prior to employment, have become important tool for distinguishing academic programs. Lean provides the ideal platform to educate engineers for future workplace, because it helps to bridge the gap between academia and industry, offering the engineering students competencies that industry needs. Unfortunately, Lean is not widespread in the curricula of HEIs and stand-alone Lean courses are rare. Students of production engineering study Lean concept in some extent, but for most other engineering fields, Lean remains just unexplored production tool. Therefore, vast majority of students leave faculties with poor knowledge of Lean and enterprises are forced to invest a large amount of time and money to further Lean training. To forestall this, universities must be aware of Lean knowledge level that industry expects from future engineers and adapt curricula accordingly.

Many organizations see Lean engineering education as a systematic, student-centred and value-enhanced approach to education that enables students to holistically meet, lead and form 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 (Flumerfelt et al., 2015). Fliedner and Mathieson (2009) have explored the importance of various Lean skills, knowledge areas, concepts and tools based on the opinion of industry and identified 10 critical Lean areas necessary to engineers in order to support establishing and spreading of Lean programs in companies. As the areas being quite extensive, it is not possible to study all within the Lean course, so their presence in curricula should be determined based on ranking. The most important Lean areas are system planning and thinking (meaning that successful implementation of Lean programs refers to entire company and all processes), interpersonal skills and Lean culture.

Educators in engineering should teach students about methods, rather than solutions, which is also in accordance with Lean philosophy. Besides, they have to underlain that Lean is not just a set of tools, and to emphasize the importance of people and building relationships for achieving goals such as cost reduction, waste elimination and quality improvement. Lean requires people to realize the complexity of their enterprises, therefore interdisciplinary Lean courses are recommended (at faculties of both fields business and engineering) to enable multiple viewpoints and better stress the system approach. Precisely the system approach to curriculum design and practical approach to learning can provide students Lean skills, knowledge and expertise that prospective employers are looking for. This can help companies to avoid the demanding employees' training and save time and costs, and simultaneously be an important item for differentiating the academic curricula.

Carvalho et al. (2013) emphasized the importance of Lifelong Learning programs whose objectives were to provide training on Lean principles used in organizations and to improve the employability of engineering students in their professional life. Flumerfelt et al. (2016) believe that education for Lean should focus on critical issue of workforce development, mostly from initial up to managerial positions, present in the specialized professions. They claim that focus is on the new approach to Lean Education, which is education of Lean leaders, that is managing programs stretching from Lean education and turned into the implementation of mutual leadership in different sectors. Finally, Alves et al. (2017) conclude that Lean education has already incorporated into many universities around the globe and these programs have been developed as response to workplace gaps.

Overall, there is no doubt that Lean has an enormous wealth of knowledge to offer the engineering students and engineering professionals. Lean implies for continuous improvement, problem solving skills, teamwork, creativity, innovation and respect for individual, which are some of the characteristics that 21st century engineer needs in order to serve society in a global world.

3. Lean for education

Although its origins are in manufacturing, Lean has been increasingly applied to a wide variety of settings, including Higher education with excellent success (Balzer, 2010). Lean higher education is the adaptation of Lean thinking to higher education, both in administration (admissions, add/drop, purchasing, facilities, hiring, budgeting) and academic activities (course design and teaching, improving degree programs, student feedback, handling of assignments). Comm and Mathaisel (2003) were among the first authors who provide a framework for developing and implementing Lean initiative at universities and identifying the best Lean practice at the institutional level, which can contribute to the sustainability of universities (2005).

Emiliani (2004) described the application of Lean principles and practices improving consistency of business course on leadership and taken by part-time working professional students. He (2005) used Kaizen process for ten courses in a part-time executive degree program in management and concluded that Kaizen can be can be an effective way to improve business courses and values for students. Radnor et al. (2006) underlain that Lean is most suitable for organizations with large number of repetitive tasks and highly bureaucratic management structures, characteristic for health, education and other public services. Stratton et al. (2007) improved the medical education process by introducing hybrid curricular quality-assurance (centralized curricular oversight with individual creative control over the educational process).

Lean is gaining interest in the educational sector as useful organizational philosophy and administrative toolkit bundle. Maguad (2007) proposed using Lean techniques to eliminate wastes in educational sector, to cut costs and improve revenues, and to ultimately improve teaching and learning activities. Moore et al. (2007) have studied the application of Lean methodology in the administration area of university to overcome the significant financial issues. Hines and Lethbridge (2008) argued that academic environment is more difficult to change than many other conventional environments and have presented the steps necessary for the development of effective Lean enterprise in such environment. The authors proposed the Lean iceberg model in which Lean technology, tools and techniques that affect the processes are just a visible part of iceberg.

Flumerfelt and Banachowski (2011) have claimed that Lean provides the tenets and tools needed to operate and engage in continuous improvement in order to maintain and improve the quality from current state to future state. In later paper (2013), Flumerfelt and Green highlighted the contribution of some other authors (e.g. Stecher and Kirby, 2004; Barney and Kirby, 2004; McMahon, 2006; Zivkosky and Zivkosky, 2007; Balzer, 2010), according to which Lean awakens growing interest in the educational sector as useful organizational philosophy and administrative tool set.

Langer (2011) concluded that conditions for Lean implementation in Higher education are similar to those in a broader public sector, whereas the understanding of Lean principles and methods reflected in aforementioned projects is only partially, because most analyzed projects are concerned only with the support processes or the administrative parts of core processes. Furthermore, Langer criticizes the lack of integrated coordination of all activities and neglect of "human aspect" role in Lean implementation. Doman (2011) also puts accent on the administrative activities and uses Lean principles and practices to improve university administrative processes through an innovative and engaging learning experience. Snee (2010) was criticizing HEIs for paying more attention to the fact that Lean process is seen to be done correctly and is aesthetically correct, rather than doing the core work needed to drive change in to the organizations. Radnor and Bucci (2011) emphasized that practitioners and researchers are increasingly turning to Lean principles trying to address the economic and organizational pressures in the context of Higher education. They cited the lack of responsibility, change ownership, personnel dedication, inadequate resources and training, and resistance of academic managers as the main challenges faced by Higher education when implementing Lean.

Majority of HEIs believe that management commitment is the most important aspect of the successful Lean implementation. Higher education requires clear direction and guidance to ensure the job will be completed, as many projects demonstrated less than adequate level of progress, return on investment and invested capital (Thomas et al., 2015). According to Byrne (2013) the failure of leaders to embrace Lean Higher education is the most likely reason why Lean is not widely accepted within and across Higher Education. Emiliani (2015) shares this opinion and points out that words and actions of senior leaders, including their control over the resource allocation, strategy and organizational obligations (business commitments, reward system), will have powerful influence regardless whether the work environment supports or hinders the implementation of any Lean Higher education initiative.

Barling (2014) believes that greater leadership practices will be needed, particularly when the process slated for Lean Higher education is critically important to the institution, impacts a large number of individuals inside and outside the university, and when the climate is neutral or hostile to change. Byrne (2013) recommends that it would be wise to consider along the work climate and leadership practice, when reviewing the readiness of universities for Lean Higher education. Strong working climate and strong leadership practice may signal the willingness for Lean initiative throughout the university, whilst less supportive climate and limited leadership practice may restrict the scope for Lean initiative. Where working climate and leadership practice are very variable or constantly not supportive, it may be best to postpone the implementation of Lean Higher education or even to abandon it (Balzer et al., 2015).

As noted by Burke (2014), leadership commitment and external community support may not be enough to create a genuine Lean college or university, because institutions tend to resist change. Antony et al. (2012) have identified the critical success factors of Lean implementation in the Higher education sector, which include inter alia, strategic and visionary leadership and organizational culture. The same authors stated the lack of communication at various levels, along with the lack of resources (time, budget) and weak link between projects of continuous improvement and strategic goals of higher education, as main brakes in the Lean implementation. Byrne (2013) rightfully advises that Lean cannot be just one of the 10 elements of business strategy, but foundation for everything that needs to be done in order to become the part of organizational culture. He points out - Don’t just do Lean, be Lean.

For Flumerfelt and Green (2013) Lean is a valuable process improvement approach to be considered for the inequities in education that plague some of the students, and according to literature review (Tobias, 2011; Parasmal, 2009; Radnor and Bucci, 2011) carried out by Sinha and Mishra (2013), the impact of Lean in Higher education is found to be very encouraging. The benefits include cost reduction, lesser cycle time, increased satisfaction level for students and faculty, higher performances of employees, job satisfaction and overall process improvement of organization.

Simons (2013) and Antony (2014) reported increasing level of students' satisfaction, providing educational institutions with problem solving templates, changing the institution’s culture, identifying and reducing hidden costs, tackling the process efficiency problems, establishing measures and so on, as benefits gained in some HEIs.

The essence of Lean is to eliminate all types of wastes, losses and non-value adding activities and, as noted by Hines and Lethbridge (2008), there is a lot of potential to improve values for customers and eliminate waste at universities. Yorkstone (2013) shares the opinion of Comm and Mathaisel (2005) that it is difficult for Higher education to fully understand Lean concept and its key principles, because it does not have determined key customers. Yorkstone (2013) pointed out the fact there is an evident user conflict in the Higher education sector and that is impossible to identify only a single user group. El-Sayed et al. (2011) also agreed there seems to be multiple stakeholders within the educational process, but Stratton et al. (2007) previously stated while there is an obvious conflict of interest among the education stakeholders, this situation is similar to manufacturing stakeholders conflict of interests and Lean has provided a successful way-out.

On the other hand, Antony (2014) sees Lean as powerful methodology in reducing waste and non-value adding activities in business processes, which solves visible problems in an economical manner. In their study Jahan and Doggett (2015) were engaged in the applicability of Lean principles at universities, relying on the perception of students. The majority of monitored students have been focused on different categories of waste (muda) and unevenness (mura) in the university system, and some of the identified wastes included bad layout of faculty facilities, unequal teaching schedule, poor understanding of the curricula, inadequate communication between faculty and students, improper management of facilities, resources and inventory. In their paper Douglas et al. (2015) have presented eight wastes of Lean for Higher education institutions. Once those wastes have been identified, the facilitator knowledgeable in Lean principles, tools and techniques, will search for possible Lean solution that could eliminate the wastes.

Thomas et al. (2015) have stressed that literature on Lean application in Higher education institutions is still in its infancy, compared to the wealth of information on Lean in the production sector, but the extent of this literature is still increasing. The authors were particularly interested in adoption, integration and application of learning and knowledge in Lean implementation projects. Balzer et al. (2015) have also perceived the implementation of Lean principles and practices to improve the efficiency and effectiveness of university processes as a potential for the realization of dramatic improvements in a way which Higher education provides its services. They insisted on reviewing the best practices of organizational changes outside and within the Higher education.

Waterbury (2015) have cited the key success factors (training, leader support, skilled executives, project selection, staff dedication, IT resources) and challenges (time limit, financial capabilities, different understandings) faced by HEIs during the application of Lean concept. Flumerfelt et al. (2015) concluded that Lean education provides the knowledge base and practice for students, using serious achievements in learning and required competencies in the workplace. In the same year Balzer et al. (2015) expressed the view on employees as the most valuable asset of organization and called for creating culture that challenges all the employees to continually improve university processes and empowers them to find and fix bad processes. They also made very useful proposal that faculties, and academic courses and programs studying

Lean should be listed, in order to contribute to increasing the number of Lean initiatives in Higher education.

Svensson et al. (2015) are among the authors of Lean education field engaged mainly in administrative activities and auxiliary processes, neglecting the core processes such as learning (teaching, evaluation), research, etc. They affirm that universities should develop their business strategy based on the progress of science and technology through research and development, and to make this role successfully played auxiliary processes at university (administration, finance, procurement and IT) need to be efficiently organized to provide students, researchers and faculty the necessary support to become outstanding. And at the end, in one of his latest papers Emiliani (2016) states that some leaders of Higher education institutions are seeking an educated response to basic cost, quality, and service delivery problems and have adopted Lean management in order to improve the administrative and academic educational processes.

After the application of Lean principles and tools has given good results in industry, further implementation was extended to other areas. Since the beginning of the 21st century, studies have shown an increase in the number of Higher education institutions attempting to apply Lean. Lean application in the education sector aims to overall waste elimination and Lean practices and principles have the potential to dramatically improve the effectiveness of educational processes. Numerous aforementioned authors have proven this statement in their research and pointed to the benefits that Lean implementation could bring to Higher education, but also certain obstacles and limiting factors.

4. Conclusions

This paper had purpose, throughout detailed and comprehensive review of the available literature on the Lean philosophy implementation in the field of education and education of engineers for work in Lean enterprises, to indicate all the complexity and interdependence of their relationship with numerous positive effects and mutual gains. The authors have tried to answer the question what benefits modern Lean enterprises may have of properly educated and qualified engineers and how application of Lean tools and principles can improve the educational system.

It is clear that further development of modern Lean enterprises is conditioned by the availability of qualified and educated human resources, primarily engineers. The growing expectations of employers from Lean enterprises regarding the necessary level of engineering knowledge and competencies have influenced on increased competitiveness and demand on the market of highly educated engineers. As presented in paper, besides the standard knowledge and skills, future engineers are expected to possess a whole range of additional, more sophisticated and complex skills, as opposed to the traditional engineers characterized by narrow technical specialization. Lean knowledge and skills provide an ideal platform for educating engineers for the workplace and preparing them for the multidisciplinary nature of problems and challenges they will face every day in modern industrial systems. So, the task of academic institutions is to educate better engineers, innovate and reform curricula and make them relevant to the industry practice, and define the profile of engineering graduates with the competencies demanded by Lean enterprises.

On the other hand, Lean manufacturing philosophy and experiences of Lean enterprises in managing human resources have provided methods, tools and approaches that could be used for improvement of educational process. The application of the principles and ideas of Lean philosophy is leading to the achievement of rational and optimal educational system which is free from all forms of wastes, losses, and uneconomical engagement of students and educators. Resources saved by eliminating wastes can be reinvested in other higher priority processes that create values for users, respect their time, minimize errors and are available exactly when needed. The paper presents the basic principles and possible ways to improve education through the implementation of Lean concept and defines potential positive impact of Lean on the educational processes. The benefits include reduction in cost, lesser cycle time, increased satisfaction level for student and faculty, cost saving, better employee performance, job satisfaction and overall organization's process improvement.

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Saveta Vukadinovic
Faculty of Business Economics and Entrepreneurship, Belgrade
Serbia
savetavukadinovic@yahoo.com

Marko Djapan
Faculty of Engineering, Kragujevac
Serbia
djapan@kg.ac.rs

Ivan Macuzic
Faculty of Engineering, Kragujevac
Serbia
ivanm@kg.ac.rs