Research of the Effectiveness of Various Strategies for the Formation of Lean Competencies of Students

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The paper examines the efficiency of various strategies for students' lean competencies formation in the educational process of the university. The relevance of the issue is justified by the fact that university graduates with developed lean competencies are in high demand in the job market. The paper formally describes lean competencies, requirements for students' personal, professional, and other skills and qualities, action plans, methods, and algorithms of actions related to lean production in a particular field. The author solves the indicated issue by analyzing the pedagogical experiment results. During the experiment, the author tested the effectiveness of four students' lean competencies formation strategies – formal education, practical training, hidden curriculum, and mixed strategy. Two hundred and eight 3rd and 4th year students mastering undergraduate programs in "Economics (Accounting, analysis, and audit)," "Economics (Finance and business analytics)," "Management (Production management)," "State and municipal administration (Regional and municipal administration)" were surveyed during the experiment.

Keywords: educational process, case method, hidden curriculum

INTRODUCTION

Lean production technologies, or lean technologies, are an integral part of modern production or organization management system. According to many modern researchers and advocates of these technologies (Krafcik, 1988; Sekine, 1992; Womack & Jones, 2003), the center of management that implements lean production principles becomes the human and the community. In this respect, the issue of strategies for training staff based on lean production proves to be relevant. G. Hutchins has justified the dilemma in solving the issue of determining the effectiveness of on-the-job training or higher education (Gayneev, 2019; Hutchins, 2001). It is challenging to get an unambiguous solution to this issue since the effectiveness of the two training strategies depends on many factors. Nevertheless, the need to develop lean competencies of future professionals on the level of higher education is justified by employers' demand for a competitive workforce with the required competencies.

The concept of lean competence is the primary term in the paper. When determining the volume and content of this concept, the author focuses on GOST P 57523-2017 "Lean production (Federal Agency for Technical Regulation and Metrology, 2018). Guide for personnel training system." Lean competencies are

formally described requirements for students' personal, professional, and other skills and qualities, action plans, methods, and algorithms of actions related to lean production in a specific area. The Lean Enterprise Research Centre has developed a Lean Production Competency System (LCS) on the international level. According to the basic guidelines of this organization, individual acquisition of lean competencies with subsequent certification can be carried out in various ways. They include formal training in an educational institution or directly by a company and practical training that involves independent training. They also include on-the-job training.

The research examines the effectiveness of various strategies of students' lean competencies development in the educational process of the university.

MATERIALS AND METHODS

Studying various strategies of the students' lean competencies efficiency in the educational process of the university has been carried out through the method of pedagogical experiment. The research bases in the Institute of Law and Economics of Yelets State University, named after I. A. Bunin. Respondents are 3rd and 4th year students mastering 38.03.01 "Economics (Accounting, analysis and audit)," 38.03.01 "Economics (Finance and business analytics)," 38.03.02 "Management (Production management)," and 38.03.04 "State and municipal administration (Regional and municipal administration)" undergraduate programs. During the pedagogical experiment, the author tested the effectiveness of four strategies of students' lean competencies formation: formal education, practical training, the hidden curriculum, and mixed strategy. The authors consider these strategies in more detail.

The formal training strategy has been implemented in the form of a "Lean production" elective course. The scope of the discipline is 144 contact hours and four credit units. The author has developed the course content, taking into consideration GOST P 57523-2017 "Lean production. Guide for personnel training system" and based on A. V. Vyalov's training manual (Vyalov, 2014). The content of the course includes eight modules: "Lean production: Philosophy and basic concepts," "Value," "Value stream," "Losses in the value stream," "Improvement of the value stream," "System of lean production management," "Methods and tools of lean production: Standardized work (POC); Workspace organization (5S); Visualization, "Suggestions for improvement."

In the process of elective course teaching, the authors have applied both active and interactive methods and forms of training – problem method, business games, decision-making games, discussion methods, workshops. A special role in implementing the elective course content is a processing factory and case method.

A processing factory is an interactive learning method specific to lean learning. Methodologically, it is close to such methods as business games and training. The essence of the processing factory is that participants are immersed in any production process with specified roles. According to the presented algorithm, they perform a system of operations to obtain a specific result quickly. Then the participants analyze the process, determine losses, improve the process, and act it out according to the new model. The result of the experiment convinces the participants of the effectiveness of the improvements made. As a part of the elective course, the author implements two process factories. At the beginning of training, the author has carried out a processing factory without considering subject specifics; it has acted as motivation. At the end of the training, the author has carried out the processing factory considering bachelors' majors.

The author has utilized the case method in the form of distance learning. Cases are devoted to such issues as determining losses in the value stream, finding errors in the compilation of standard operational maps, compiling standards and algorithms.

The author employs the strategy of practical training during the on-the-job training of students. In implementing this strategy, the author has used methods such as workplace training, mentoring, and an individual educational route. Students are placed in enterprises and organizations which use lean production technologies. Among the organization or enterprise employees, students have been assigned to mentors (usually members of the change teams) who have immersed themselves in lean production during the internship. Obtaining practical experience has been planned and recorded in the individual educational routs

of students, which have been developed before the placement together with students, mentors, and curators of the job placement from the university staff. Each placement stage has been subjected to professional reflection with the placement supervisor.

Of particular interest is the strategy of the hidden curriculum. The hidden curriculum is a channel for transmitting educational effects beyond educational standards and curricula. The transmission subject is values, social attitudes, traditions, and certain innovations, etc., which determine primarily personal development, the specifics of the socialization processes and professional identification of students.

The hidden curriculum is marked with a negative semantic load since it acts as a mechanism for influencing the nature of personal development without "notifying" students, thereby violating individual freedoms (Apple, 1990; Bernstein, 2000; Bourdieu, 1984).

Additionally, scholars interpret the hidden curriculum as a technological and methodological solution to issues that go beyond the framework of formal state standards, plans, programs, representing a curriculum that contains specific aspects of the newly formed structure of subjects, the content of which is determined by the traditional curriculum (Jelich & Zorich, 2017; Nechitaylo, 2015; Polonnikov, 2011).

In the current research, the hidden curriculum refers to a contextual educational technology, functioning of which is based on the immersion of students in an active social context through the systematic introduction of lean production components into the teaching content, as well as through the forced use of active methods and means of organizing the learning process (Mishina & Shcherbatykh, 2019).

In the context of the current research, the author uses the following resources of students' learning activity: academic courses "Management," "Finance," "Econometrics," "Marketing," "Labor economics," "Money, credit, banks," "Economy of firm," "Accounting, financial accounting," "Macroeconomic planning and forecasting," "Taxes and taxation," "The complex analysis of economic activity" (bachelor degree 38.03.01 – "Economy" [specialization] "Accounting, analysis and audit"); "Finance," "Management," "Econometrics," "Marketing," "Labor economics," "Money, credit, banks," "Federal taxes and collecting," "Accounting," "Tax accounting and reporting," "Regional taxes and fees," "Accounting financial statements," "The economic analysis" (bachelor degree 38.03.01 - "Economy" [specialization] "Taxes and taxation").

The mixed strategy involves the organic use of formal, hands-on learning, and hidden curriculum strategies.

To study the effectiveness of each of the strategies for forming lean competencies of students, the author has identified four experimental groups. In the process of implementing the pedagogical experiment in pilot group No. 1 (58 students), the strategy of formal education has been implemented, in pilot group No. 2 (51 students) – the strategy of practical training, in pilot group No. 3 (49 students) – the strategy of the hidden curriculum, in pilot group No. 4 (47 students) – the mixed strategy has been employed.

When developing the criterion of the study, the author has applied lean practice competence assessment criteria prescribed by GOST P 57523-2017 "Lean production. Guide for personnel training system." They include the following: (1) advantages of lean production (applying knowledge and practices); (2) principles of lean production (value loss), stream (value stream), pulling, desire for excellence (improvements, standardization, opportunities for improvements); (3) management of stakeholders (communication skills, changes at the individual level, changes at the organizational level); (4) measurement of improvement process (indicators of improvements); (5) creative thinking; (6) visual management; (7) workplace optimization; (8) process improvements based on teamwork; (9) implementation of lean production (implementation planning); (10) data analysis; (11) risk analysis; (12) stability; (13) motivation of employees.

The author has identified the following as components of lean competencies: (1) knowledge and understanding; (2) skill; (3) implementation. These components correspond to the first three levels according to the international classification of lean competencies, namely, fundamental lean competencies: knowledge and understanding – level of awareness (1A); skill – level of diagnostics and analysis (1B); implementation – level of improvement and implementation (1C) (Lean Competency System, n.d.).

Diagnostic tools include testing, expert evaluation of case solutions, and development of lean projects. The author has carried out statistical data processing based on a Fisher F-test variance analysis for three or more independent groups using Statistica 10 and SPSS 20 software.

RESULTS

The results of the pedagogical experiment have confirmed the hypothesis on the heterogeneous influence of learning strategies on forming lean competencies of students (Table 1).

TABLE 1
FORMATION OF STUDENTS' LEAN COMPETENCIES BY LEVELS

Pilot group	Awareness level (1A)	Diagnosis and analysis level (1B)	Improvement and implementation level (1C)
Pilot group No. 1	79.31%	20.69%	0.00%
Pilot group No. 2	11.77%	84.31%	3.92%
Pilot group No. 3	48.98%	44.90%	6.12%
Pilot group No. 4	29.79%	44.68%	25.53%

The formal education strategy allows one to firmly develop the level of awareness of lean competencies among students (79.31%). Some students have demonstrated higher results corresponding to the level of diagnosis and analysis (20.69%) when mastering the elective course. However, the level of improvement and implementation has not been achievable for anybody in pilot group No. 1. The practical training strategy has demonstrated effectiveness in forming the level of 1B (84.31% of students of pilot group No. 2), a small part of students have mastered lean competencies in practical training at the level of 1C (3.92%). A more balanced distribution of results is observed using the hidden curriculum strategy: approximately equal groups of students have mastered lean competencies at the 1A (48.98%) and 1B (44.90%) levels. The group of students who have a level of 1C appear to be more numerous in the strategy of the hidden curriculum than in the use of strategies of formal and practical training (6.12%). The mixed strategy has provided the best results. The level of 1A is shown by 29.79% of students of pilot group No. 4, the level of 1B – 33.68%, the level of 1C – 25.53%.

Table 2 represents the results, evaluating the effect of each of the strategies tested in the experimental groups on the lean competence components derived from the Fisher F-test dispersion analysis.

TABLE 2
STATISTICAL SIGNIFICANCE OF THE COMPONENTS OF STUDENT'S LEAN COMPETENCIES FORMATION (VARIANCE ANALYSIS ACCORDING TO THE FISHER F-CRITERION)

Components	F_{emp}; F_{cr}=265 at $p \leq 0.05$; F_{cr}=388 at $p \leq 0.01$			
	Pilot group No. 1	Pilot group No. 2	Pilot group No. 3	Pilot group No. 4
Knowledge and understanding	561	214	496	534
Skills	315	428	398	628
Implementation	122	299	276	312

In pilot group No. 1, formal learning strategy has had a statistically significant impact on forming knowledge and understanding components of lean competencies. The inefficiency of this strategy to form the implementation component has also been confirmed. The practical training strategy has demonstrated statistically significant efficiency in forming the component of skill and inefficiency in forming the component of knowledge and understanding of lean competencies of pilot group No. 2. The most effective for forming knowledge and understanding skills of students' lean competencies have been demonstrated by the strategy of the hidden curriculum and the mixed strategy, with slightly higher values of the latter strategy. When determining the effectiveness of strategies applied in pilot groups No. 3 and No. 4 to form the implementation component of lean competencies of Femp students, it has been recorded in the ambiguity zone.

DISCUSSION

If the technology of lean production has been introduced into the activities of Russian enterprises and organizations for more than 10 years in the field of vocational education, this technology is being mastered less intensively. Nonetheless, there are many studies devoted to this topic in the Russian segment of pedagogical science. Most of them describe the experience of lean university management.

S. A. Gaivoronskaya analyzes in detail the SQDCM management system implemented at the Belgorod State National Research University (Gaivoronskaya, 2019). The scholar also describes the experience of applying the Six Sigma method in university management through the DMAIC algorithm: define, measure, analyze, improve, and control. S. A. Gaivoronskaya notes that the complexity of universities, the difficulties of interpreting some specific production concepts, the relationship between teaching and research make it difficult to implement known approaches and require the development and implementation of their models and management systems in new conditions, taking into consideration lean transformations (Gaivoronskaya, 2019).

O. V. Vaganova and A. S. Kumargei present the experience of implementing the concept of "Lean University" in this institution. They focus on the effectiveness of the following tools: Lean process factories; 5S method; transforming the university intranet in accordance with the principle of "one window." Scholars present a portfolio of lean projects implemented at the Belgorod State National Research University: the creation and organization of the Lean process factories; organization of workplaces according to the principle of the "5S" system; creation of personal accounts of students and teachers on the intranet with an improved interface; implementation of the one-stop-shop principle for fast processing and receipt of documents by employees and students; creation of a mobile application "My BelSU"; creation of the information and communication portal "Exchange of Ideas" (Vaganova & Kumargei, 2019). Nonetheless, the given examples of lean manufacturing implementation in university management do not have empirical confirmation of efficiency.

In a study by A. N. Chelombitko, the influence of lean production methods on the KPI of universities that are members of the Association of Lean Universities has been established. The scholar determines that the lean management system primarily has a positive effect on indicators such as "Income from all sources per one scientific and pedagogical worker" and "Volume of research and development work." However, no statistically significant relationship has been found to improve the quality of applicants and graduates (Chelombitko, 2020).

Additionally, A. N. Chelombitko believes that the introduction of lean manufacturing has great potential for Russian universities. It is reasonably advisable to use it both in the organization of internal auxiliary, service processes, and in the management of research projects (Chelombitko, 2020). Simultaneously, the conclusions of the presented work are still preliminary due to the limitedness of quantitative data on the penetration of lean production and the timing of its use by Russian universities.

Undoubtedly, at this stage of development of vocational education, lean production technologies are being actively introduced into the university management system but not into educational activities. Nevertheless, specific aspects of forming lean thinking in students are presented in the research segment of Russian pedagogy.

A. E. Ugreninova analyzes the results of introducing the discipline “Fundamentals of lean production” into the educational process of the South Ural Multidisciplinary College (Ugreninova, 2018). The author has obtained results that coincide with the research results: the formal learning strategy has a statistically significant effect on forming the cognitive component of lean competencies. However, it is ineffective for forming practical skills and experience in lean production. Simultaneously, A. E. Ugreninova notes that the issue of introducing the “Fundamentals of lean production” discipline into the educational process requires implementation at the methodological and pedagogical level.

The experience of teaching lean manufacturing skills is presented in the studies of M. V. Dadonov, A. V. Kudrevatykh, A. S. Ashcheulov, and E. R. Gaineev (Dadonov, Kudrevatykh & Ashcheulov, 2020; Gaineev, 2020). However, M. V. Dadonov, A. V. Kudrevatykh, and A. S. Ashcheulov have not provided an experimental substantiation of the effectiveness of these practices. Nevertheless, the authors see the organization of interaction of students with real production in the process of passing educational and industrial practices, course design, carrying out scientific activities, and performing graduate qualification works as effective practices for the formation of lean thinking in students.

On the contrary, in the works of E. R. Gaineev, the effectiveness of forming lean skills through such practical forms of training as a production excursion (Gaineev, 2020), a training workshop, and competition classes of professional skills (Gaineev, 2020) is confirmed. E. R. Gaineev, at the level of the content of practical training, focuses on the development, together with students, of rationalization ideas, kaizen proposals in collective forms of rationalization (Gaineev, 2020).

Among the array of publications on this topic, only the works of S. A. Tomilin, E. S. Arsentieva, Y. A. Evdoshkina, A. G. Fedotov, and R. A. Olkhovskaya have expressed ideas that are close to the results of the current research on the need for systematic formation of lean competencies of students. Although, the author has not experimentally confirmed these ideas. The author adheres to the idea that lean competencies must form in students both in terms of technical disciplines and in some disciplines that ensure the solution of issues in economics, organization, and production planning. At the theoretical level, this approach is the closest to the concept stated in the current paper, according to which the hidden curriculum strategy has shown maximum efficiency. The author also focuses on the fact that lean manufacturing has become the object of research of papers and graduate qualification works of students (Tomilin, Arsentyeva & Evdoshkina, 2018).

CONCLUSION

The pedagogical experiment has demonstrated the high efficiency of the hidden curriculum and mixed strategies in the formation of students’ lean competencies in the educational process of the university, but the limited, isolated use of formal and practical learning strategies. Each of the proven strategies possesses several shortcomings.

A strong organizational resource is needed to implement the hidden curriculum strategy since this strategy requires coordination at planning and implementation levels in terms of the content and training technologies for many teachers. The mixed strategy has proven to be relatively resource intensive. Simultaneous application of other strategies within the framework of mixed strategy can harm other aspects of training activities in contrast to the formation of students’ lean competencies.

The research makes a significant contribution to developing the issue of forming lean competencies of students in the educational process of the university. In particular, the prospects of the hidden curriculum strategy have been experimentally confirmed. In the Russian segment of pedagogical science, this study is the first of its kind since most similar studies are limited to describing specific practices without experimental and statistical confirmation of their effectiveness.

From a research perspective, the authors consider replicating the hidden curriculum strategy for the formation of lean competencies of students by improving this strategy at the technological and methodological levels. In particular, the author touches upon developing a standard operating procedure for creating a hidden curriculum. This tool will make it possible to successfully replicate the practice of developing lean competencies of students at universities and colleges.

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