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Teaching and Learning Methods in the Context of Industrial Logistics Engineering Education

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Abstract

Industry 4.0 approaches have gained increasing relevance to ensure sustainable growth and long-term competitiveness. Thereby, both logistics research and practical applications often neglect the importance of human skills development by primarily focusing on emerging technologies. Nevertheless, the structured development of employees' competences is one of the most important requirements for a successful implementation of Industry 4.0 strategies. This paper systematically evaluates a variety of conventional as well as modern teaching and learning methods for industrial logistics engineering education in the context of Industry 4.0. As such, a comparison of methods is presented and validated by using a systematic literature review as a research methodology. The identified methods are used to guarantee and/or extend quality assurance and, individual as well as collective, professional development in industrial logistics engineering education. Moreover, the authors have conducted a laboratory experiment for industrial logistics engineering education to evaluate the learning outcomes of lectures and a form of group work as two exemplary teaching and learning methods.

Keywords: Industrial Logistics Engineering Education; Industry 4.0; Teaching and Learning Methods; Professionalisation; Smart Logistics

1. Introduction

In recent years, industrial enterprises are constantly challenged by increasing competitive pressure. They need to produce faster, cheaper, with higher quality and increased flexibility. Moreover, the industry needs to introduce strategies for production and logistics to maintain the current competitive advantage in the long term [1]. In this context, Industry 4.0 provides a multitude of concepts and technologies to implement highly efficient and automated manufacturing and logistics processes, usually known from the mass production environment to an industrial environment [2] to increase the ability to respond to customer requirements quickly and flexibly [3]. However, Industry 4.0 approaches are determined by a multitude of economic/financial, cultural, competence- and/or resource-based, legal, technical, and implementation-process-related barriers [4]. Up to now, only a few studies have dealt with crucial requirements for the successful implementation of Industry 4.0 initiatives within industrial enterprises [5,6], small and medium-sized companies [7,8,9], and from an educational point of view [10]. Thereby, the training and further qualification of employees is one of the main requirements [11]. However, little to almost no profound studies are available that deal with the specific requirements of employees` professionalization and competence development from a logistics point of view [7,8]. Therefore, the authors aim to systematically evaluate a set of conventional and modern teaching and learning methods for industrial logistics engineering education. In the context of industrial logistics, Zsifkovits and Woschank introduce a conceptual framework of

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Smart Logistics which includes the research areas: 1) Intelligent and Smart Supply Chains, 2) Intelligent Logistics through ICT and Intelligent Logistics Systems and Transport Vehicles [12]. Therefore, industrial logistics engineering education must use a set of teaching and learning methods to provide tools for a lean and agile cooperation in interlinked networks and the digital interconnectivity of organizations. Employees must understand the state of the art information and communication technologies that allow the digital interconnectivity through data networks, sensors and actors, and intelligent technologies for the identification and tracking of materials, components, and products. Moreover, logistics engineering education must raise awareness for man-machine interaction within logistics systems. Autonomous transport vehicles, in combination with automated warehouses as well as automated storage and handling infrastructure, will change requirements in the education of the industrial workforce for efficient and collaborative internal and external material flow processes [12].

2. Theoretical framework of teaching and learning methods

In this section, the author will briefly outline the theoretical framework of teaching and learning methods. Because of the lacking, respectively partially missing, theoretical framework regarding teaching and learning approaches in the context of industrial logistics engineering education (ILEE), the authors transfer basic theories and recent theoretical approaches from pedagogical sciences to the area of industrial logistics in manufacturing enterprises. Therefore, Figure 1 summarizes teaching and learning as a complex process that is dependent from a multitude of exogenous and endogenous factors.

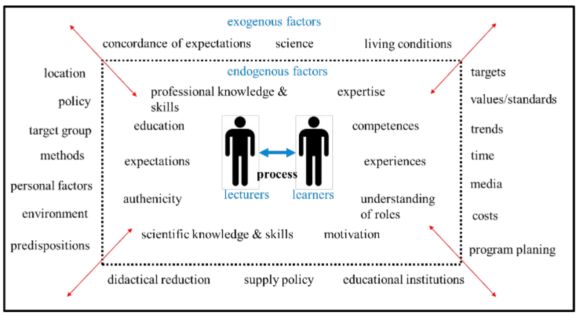

Fig. 1. Contextual framework of teaching and learning processes for industrial logistics engineering education

According to Ertel [13], learning is an individual, continuous procedure of information processing. Learning serves as an opportunity for self-development. First and foremost, it is a matter of acquiring certain qualifications to satisfy the curiosity for self-fulfillment and to be able to integrate into modern society. Human beings learn for many different reasons. Thereby, the requirements in terms of learning content are based on the current needs of the economy and society. Society strives to learn to increase its production capacity and competitiveness. Learning is seen as a long-term evolutionary process as it serves as a pure survival skill achieved through direct contact with the environment. People learn to ensure the manifold functions of subsystems by making the information required locally available by processing global and individual information and making individual-personal or electronic information processing possible [14].

Learning includes all areas that can be influenced by information processing and/or experience. Through a learning process, a lasting change can be generated; the already acquired experiences serve as a basis for further learning. In general, a learning process can be divided into three phases. During the first phase, also called ‘acquisition’, new knowledge is added. The acquisition of new knowledge is called ‘perception’. This knowledge is then acquired in the next phase. The second phase is called ‘retention’. In the course of this process, what has been learned is stored in memory. In the last learning phase, the ‘reproduction’, the stored knowledge, or the acquired competences are applied. This process involves the thinking function of memory in learning. Due to this fact, the process is also called ‘cognitive’ [15].

Human beings can acquire knowledge on different levels. There are three specific forms of learning, namely the informal, formal, and non-formal learning approaches. Informal learning takes place outside educational institutions. Thereby, learning is done through everyday experiences. Formal learning is carried out in educational institutions while non-formal learning is created through the distinction between informal and formal approaches. This type of learning is also called voluntary or unintentional learning. Moreover, successful learning processes are generally dependent on many factors and can further be divided into individual, collective and organizational processes. The concept of individual learning is neither fully defined nor is there a theory. In this context, information is acquired independently and self-controlled and then subsequently evaluated. This self-controlled learning process requires two basic prerequisites from the learner. Firstly, the learner must be capable of autonomous learning, and, secondly, the learner must have the necessary willingness to learn by himself [16]. Learning is defined as autonomous when the learner can decide independently on the subject areas and on the methods, as well. In order to highlight the different forms of autonomous learning, two important aspects must be addressed. On the one hand, the degree of autonomy of the learner, and on the other, the learning mediation within the educational institution are decisive factors. Within the educational institutions, certain paths of learning are prescribed according to the curricula. The offer of information available outside these institutions is also very broad. The free provision of information offers the possibility of both private and self-controlled access to information. The learner can freely decide which global information is relevant for subjective problem-solving. Autonomous learning takes place primarily in a private context, i.e., outside of educational institutions [14].

Individual or autonomous learning must be given more importance within the educational institutions and be guaranteed outside by an adequate offer of information. This restructuring can generate new problem-solving skills, which would allow an extension of existing information. This form of learning is becoming increasingly important today, as we live in a knowledge society. As the amount of information is constantly increasing, the individual must, therefore, orientate himself toward autonomous learning to increase his competitiveness. Educational institutions provide and teach the basic knowledge, but the information spectrum is too complex for these institutions. This individual process enables the independent acquisition of knowledge. Collective learning processes are understood to be a process through which several or all persons in a social group must pass. According to Miller, individuals can only learn something new if these learning processes can be integrated into an interaction. However, this can only succeed if all members of this group can do so. In general, it can be assumed that collective learning processes are the sum of various individual processes. Every human being reaches a certain state in which he is enabled to critically question moral judgments. Collective learning processes are generated by various information inputs within a group [17]. Individual learning processes are changed or modified among themselves; collective processes are the result of this exchange of information. As a result of collective learning processes, the values of a society are modified according to the state of the art. Furthermore, it is possible to achieve an adequate moral judgment of the individual members [17]. Within the framework of the organizational learning process, an attempt is made to transfer knowledge from individual learning processes to organizations [18]. This type of learning is a social system, which consists of individual persons. This learning process consists of two stages: 1) learning consists of elements that form the system and 2) subsequently collective processes take place which produce organizational learning [18]. Organizational learning is defined as the ability of an institution to find mistakes, to correct them, and to change the organizational value - and knowledge base - in a manner such that new problem-solving and action skills are generated [19]. Another important factor is the lecturers in general. The relationship between lecturers and learners, as well as the presentation of the learning content and the identification with the specific teaching content on the part of the teacher, are decisive. Learning combines the following dimensions: Content, form, time, objective, measurability, and complexity. The content of learning is largely measurable and verifiable; within the scope of learning processes, abilities, skills, attitudes, values, and knowledge are generated. Regarding different forms of learning, a distinction can be made between formal, non-formal, and informal processes, whereby these three dimensions are interrelated and cannot be explicitly separated. The learning period and point in time are determined by institutions and facilities and further determined, at least formally, by the beginning and the end of the learning process. Regarding learning goals, a distinction can be made between teaching goals and goals of learners, institutions, or even society. Teaching objectives are usually set by the instructor or institution and aim at the learning outcomes. Again, each learner has his/her own objectives, but of course society as well. To what extent learning is measurable depends on the practices used and the individual perception. In terms of measurability, the challenge is also to be able to represent all learning outcomes, since some of them can be also achieved unconsciously [20]. The complexity of learning is illustrated based on the above-mentioned characteristics, which also make it difficult to present, classify, measure, and compare learning processes. The determination of the time and period of learning can only be made to a limited extent and can only be controlled externally, since, especially, informal learning is usually also unconscious in time and space.

2.1 Professionalization in the context of ILEE

Professionalization, quality, and development of professionalism of teachers are only a few keywords that accompany us in the current discussion in the context of modern industrial logistics engineering education. These sub-segments are a central challenge for both practice and research. In the following, we will take a closer look at the current developments in professional adult education.

In this context, Gruber and Wiesner [21] refer to a paradigm shift regarding tasks, activities, and expectations in adult education. In this sense, the authors understand 'professionalism' as the demarcation to amateurish activity. However, this adult educational competence must be permanently developed and adapted to current trends and conceptualizations using practical experience and an immanent ability of reflection. The demand for specific competence transfer should be generated within the framework of a professionalization process. Already in the discourses of 1975, a distinction was made between 'planning' and 'teaching' activities. According to the subsequent enlargement, the activities refer to a total of five levels of professional adult didactic action. These include the following: 1) the context of social conditions, 2) the horizon of institution-specific requirements, 3) task and learning areas, 4) educational responsibilities and 5) teaching/learning processes. These levels of action influence each other. Therefore, it is a matter of education management as a permanent, optimizing institution [22]. This understanding of education postulates that lecturers should act as mediator, supporter, and advisor for the learners. In this context, Schiersmann [23] states that new requirements are needed for professionalization. Regarding the pedagogical tasks (micro-didactic level), this concerns the required diversified methodological competence and the ability to shape the learning situation in a way appropriate to the situation; it further concerns the already characterized advisory competence regarding different groups and levels as well as the operational and organizational competences for the integration of further training into personnel and organizational development.

For Nittel, professional didactic action by adult educators is only successful if they contribute to adult learning, combining individual and societal educational interests in a meaningful way and being able to relate partial, general, scientific, and professional knowledge and skills [24]. According to Peters [25], adult education professionalism can only be generated within this interrelated framework through this ability to relate. Gieseke sees integrity and trust as essential maxims for the success of professional action [26]. Thus, the areas of responsibility of adult education lecturers include the ability to relate and to act in a situation-specific manner, the transformation and interpretation of (expert) knowledge and skills as well as the reflection of the teaching and learning process. In accordance with the conditions described above, they not only ensure truth, correctness, and completeness, but also the relevance and usefulness of the learning and educational content in terms of their interests, thus taking into account not only the interests of individuals and society, but also those of their respective employers, clients, and sponsors. Regarding adult learning professionalism, the involvement and attendance of participants is also needed to ensure that learning and educational progress can be achieved. The adult educators act as learning companions, supporters and advisors, the actual learning and education process is carried out by the participants [25].

2.2 Conventional teaching and learning methods in the context of ILEE

In this section, the authors review a set of conventional teaching and learning methods for logistics engineering education. Essential for the success of a seminar is a good balance between rest and movement, i.e. listening, absorbing, discussing, and becoming active. In terms of detailed planning, this means: 1) an appropriate change between theory input, individual work or group work, 2) the usage of experimental learning and learning by doing, 3) an appropriate change between, respectively, listening and sitting quietly self-initiated movements. In this context, we refer to the SAVI model as a suitable method for 'accelerated learning'. According to Meier [32], the model is particularly suitable for the active involvement of participants. This method involves the coupling of active movements, cognitive effort, experiential learning, and the experiencing of feelings. Thereby, Meier recommends the following approach: 1) Somatic - in the seminar, movement while learning (doing actively) should be possible, 2) Auditive = Listening and speaking should be possible, 3) Visual - observation learning and imagination should be possible, 4) intellectual problem-solving and reflection should be possible[27]. This approach can serve as a self-examination of the lecturers´ practice. Additionally, according to Weidenmann, the following questions can be asked: 1) how much exercise do I allow in my lectures?, 2) is listening dominant or do my participants have enough opportunity to speak for themselves and talk to each other?, 3) how often do the participants have to do something independently?, 4) do I work with visualizations often enough?, 5) how often do I encourage the participants to imagine something with their 'inner eye'?, 6) are there enough problems in my seminars for which my participants can search for solutions, plan, cooperate and try out? and 7) how much space do I give to reflect on the experiences from the activities, i.e. on solutions, mistakes, differences between participants? [28,29]. By using a permanent reflection, weaknesses in the seminar design can be identified and corrected. For this reflection, every lecturer can ask himself or herself the question on whether they would like to be a participant in this seminar or whether they would like to learn in this way. Within this approach, Meier [27] suggests a 70% active participation of participants during the seminar. Accordingly, about two-thirds of the seminar should take place through the active engagement of the participants with topics and contents. According to this approach, for the teaching and learning culture, the following learning settings can be applied: 1) flexible, 2) joyful, 3) multi-channel, 4) benefit- and results-orientated and 5) multisensory. The focus is on cooperation and on individual activities as well [28,29].

The choice of method strongly depends on the previously outlined teaching and learning principles and on the content after didactic reduction [30]. In the following, the authors will briefly outline a selection of the most suitable conventional methods for industrial logistics engineering education. Of course, this selection does not represent the entire spectrum of methods available.

Individual work: As described above, learning is an active and self-directed process. Individual work as a method is intended to promote this learning process and, thus, contribute to the inner differentiation of the topic or problem. Furthermore, this method contributes significantly to self-directed learning, a key competence of the 21st century. Learners can choose their subjective learning pace independently of others [28,29].

Group work: Group work involves the independent development of a subject or problem by one or more small groups. After this group phase, the respective groups usually present the previously discussed results, questions, or topics to the remaining groups. This method forms the annex to the teaching lecture. The group work requires the initiative and self-control of the participants in the group phase so that the interests, experiences and individual learning styles of each participant can be brought in. For the lecturers, the planning, organization, and evaluation of the group work are time-consuming. In addition, the leaders give up control of the seminar, and the result depends largely on the group phases. Thereby, positive experiences in group work include learning in any case: From each other, together, about each other and by mutual agreement [28,29].

Lectures: In the context of information transfer, the teaching lecture is the most traditional and widespread method. In university education, it is used as a standard method for imparting specialist knowledge. From the participant's perspective, this form of teaching can be understood as a kind of assembly line. This conveyor belt transports knowledge and information like assembly parts past, if you miss a moment, the belt tears off and essential components are lost. The participants cannot influence this flow of information. After 20 minutes of teaching, the attention span drops below 70%. From the point of view of the seminar leaders, a teaching lecture can be planned and realized very well because the influence of the participants is much less than, for example, in group discussions [28,29]. Nevertheless, the frontal lecture is very popular, especially with conservative people, and is used very often. Interactive methods, such as role-playing games, are more preferred by experimentalists [30].

2.3 Modern teaching and learning methods in the context of ILEE

In this section, the authors investigate a set of modern teaching and learning methods for logistics engineering education. Therefore, we performed a systematic literature review in Scopus supplemented by a forward and backward research strategy. The search string included literature that represents learning, teaching and education methods in the context of industrial logistics and Industry 4.0. We consider only articles and conference papers in the English language in the areas of engineering and business, management and accounting. Therefore, the research string was formulated as follows: TITLE-ABS-KEY (logistics) AND TITLE-ABS-KEY (industry 4.0) AND TITLE-ABS-KEY (teaching AND methods) OR TITLE-ABS-KEY (learning AND methods) OR TITLE-ABS-KEY (education) AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "cp")) AND (LIMIT-TO (SUBJAREA , "ENGI") OR LIMIT-TO (SUBJAREA , "BUSI")) AND (LIMIT-TO (LANGUAGE , "English")).

Based on the psychometric criteria for empirical research (validity, reliability, objectivity, etc.) [54], the authors emphasize that the identification process is very crucial for the outcomes of a systematic literature review. Therefore, we used an independent research team consisting of three Postdoc-researchers for the screening process. The first step of the screening included the title and abstract screening. We used a scoring method with inclusion and exclusion criteria to evaluate the appropriateness of the identified studies for our research [31]. Papers without significant differences in the scoring were included in, respectively, excluded from, the literature review, while papers with significant differences were reevaluated by the research team.

In general, we have identified only a handful of relevant but increasing number of studies which consider teaching and learning methods for industrial logistics engineering education in the context of Industry 4.0. From the resulting 15 papers (latest update on 02 January, 2020) nine have been identified as relevant for this research study. The results of the analysis are displayed in Figure 2.

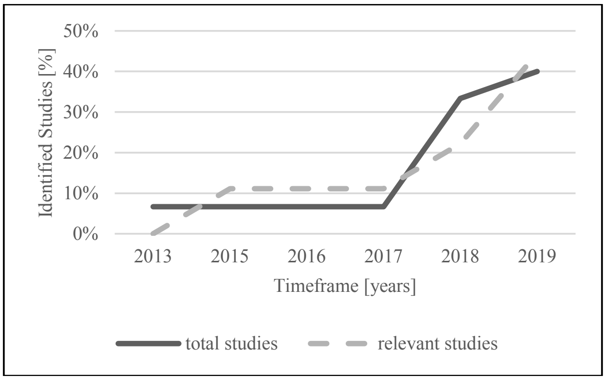

Fig. 2. Systematic literature review

Most of the resulting papers were assigned to the category ‘learning factories’. Thereby, various researchers introduce different types of learning factories as an important toolset of human skills development in industrial engineering education. In this context, Pfeiffer and Uckelmann describe a virtual laboratory as a tool for the integration of the Internet of Things (IoT) as an integral part of teaching in universities to meet the requirement of Industry 4.0 [10]. Mortensen et al. discuss an Industry 4.0 awareness game at the Aalborg University which is based on a learning factory within a smart production lab. By using Industry 4.0 approaches, the participants will have to efficiently produce products to gain an interdisciplinary understanding of Industry 4.0 approaches [32]. Hoffman et al. recommend the usage of material flow simulations within the Industry 4.0 learning factory of the Otto-von-Guericke-University for the enhancement of human skills to cope with the challenges of future logistics complexity [33]. Moreover, Karre et al. describe a learning lab factory (Lean Lab) at the Technical University of Graz for a practice-orientated learning in an environment close to industrial reality [34]. Blöchl and Schneider introduce the PuLL Competence Centre as a learning factory for lean production and lean logistics, where they developed a simulation game for the adequate integration of Industry 4.0 technologies in production logistics [35]. Seitz and Nyhuis describe the IFA’s learning factory for the training of employees’ competences in applying logistics models to improve order processing [36]. Moreover, we have identified two additional papers that describe modern teaching and learning approaches in the context of industrial logistics engineering education. Thereby, skill development is achieved by using collaborative and gaming-based approaches. In detail, Wermann et al. describe an interdisciplinary demonstration platform where various institutions and departments can work and learn together how to implement Industry 4.0 concepts [37] and Duin et al. introduce serious gaming as a method to develop the necessary skills for industrial logistics applications [38].

Summarized, most of the identified papers used learning factories as a teaching and learning method for ILEE. These smart laboratories allow a game- and/or simulation-based transfer of process-relevant knowledge, e.g., the optimization of material flows, by operating in an environment that is close to the industrial reality. However, the current approaches still represent an isomorphic projection of the industrial environment and, therefore, lack of a high degree of external validity. Future laboratories must incorporate more realistic industrial settings, aligned to the real needs of businesses. In addition, practice-oriented teaching and learning materials, as well as expertise and practical professional experience of teachers, are needed to enable problem-based learning and, thus, train the students' problem-solving skills.

3. Empirical Study

Up to now, in ILEE, little attention has been paid to the empirical evaluation of the learning outcomes of teaching and learning methods. Therefore, as a first systematic attempt, the authors conducted a business simulation study within a laboratory experiment to evaluate the learning outcomes of two different teaching and learning methods. In general, laboratory experiments are one of the most exact scientific tools which allow the control of a set of variables to explore isolated cause-effect relationships [39,40]. Laboratory experiments are still an extremely underrated research and teaching method. Therefore, recent literature also often suggests the usage of laboratory experiments, especially in the context of logistics research and logistics education [41]. In the present case, the authors have designed a laboratory experiment for industrial logistics engineering education based on a business simulation study, where the participants will have to develop strategies with a special focus on logistics and production decisions in an industrial enterprise based on the information of different stakeholders. They will be introduced to the specific problem situation whereby they will receive useful information from various managers within the industrial enterprise. In the end, the participants will have to deliver a transparent solution to the business simulation study by completing a post-experimental questionnaire. The reported solution will be compared to a standardized expert solution. Thereby, we will use a multidimensional measurement model to capture a set of indicators for the latent measurement of the learning outcomes. In order to evaluate the effects of the teaching and learning methods, we will compare learning outcomes by using lectures, as a form of an individual learning approach, versus the learning outcomes by using group work, as a form of collective learning, in the simulated environment of an industrial enterprise. Table 1 outlines the structure of the laboratory experiment, which was conducted as a modified and, therefore, more realistic version of the Pipers case study [42].

Table 1. Structure of the laboratory experiment

Standardized process steps	Timeframe
1. Introduction (lectures – individual)	5-10 min
2. Processing of the simulation (lectures – individual)	20-25 min
3. Reporting results (lectures – individual)	5 min
4. Break	60 min
5. Introduction (group work – collective)	5-10 min
6. Processing of the simulation (group work – collective)	20-25 min
7. Reporting results (group work – collective)	5 min

3.1. Measurement development

For the measurement of the latent construct 'learning outcomes', the authors will have to develop a set of manifest indicators. Therefore, the authors refer to the guidelines by Esser which contain the following process steps: Specification of the concept, specification of the variables, specification of the indicators and development of appropriate indicators based on indexation [43]. In this study, the measurement of the learning outcomes is based on a framework of the descriptive decision-making theory. In this context, we will use a holistic measurement model, which measures 1) the quality of the developed solution by comparing the degree of target achievement with a pre-defined expert solution [44,45,46] and process satisfaction by 2) measuring the satisfaction with the developed solution and 3) the satisfaction with the problem-solving approach [47,48,49,50]. Consequently, Figure 3 displays the holistic measurement concept.

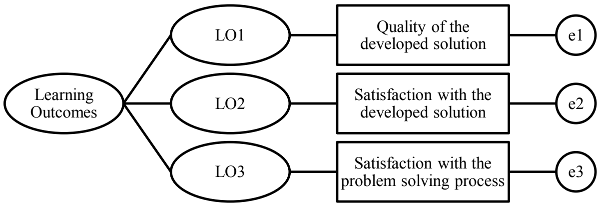

Fig. 3. Operationalization of the learning outcomes

All three indicators (LO1, LO2, LO3) of the learning outcomes were measured by a post-experimental questionnaire where we used a 5-point Likert scale from 1=worst solution to 5=best solution for LO1 and 1=completely unsatisfied to 5=completely satisfied for LO2 and LO3. We decided to use Likert scales, because of their easiness to use, the time-efficient conceptualization process, and their reliability [51,52, 53]. Consequently, the main hypothesis of this research study is formulated as H1: There is a significant difference in the learning performance between lectures (individual learning) and group work (collective learning).

3.2. Data collection

The experimental procedures were conducted at the Montanuniversitaet Leoben in Austria in the timeframe from September 2017 to September 2019. In sum, we collected a total of 192 questionnaires based on three experimental runs. We used a theoretical selected sample of advanced students in the study program Industrial Logistics with some practical experience in industrial enterprises. In this context, experimental research often uses advanced students as participants rather than members of the organizational population. In this context, several research studies have highlighted that, in laboratory experiments, experienced students and professionals produce almost similar results [54,55].

3.3. Research results

Table 2 shows the descriptive statistics of the empirical study.

Table 2. Descriptive statistics of the laboratory experiment

Indicator	N	Mean	Std. Error	Std. Deviation
LO1	192	2.5568	.07111	.98532
LO2	192	3.6299	.05622	.77899
LO3	192	3.6013	.05394	.74735

From a descriptive point of view, no values were missing in the final data set. A Kolmogorov-Smirnov test and a Shapiro-Wilk test showed that the data are not normally distributed. We have further investigated the homogeneity between the three test groups by using a non-parametric Kruskal-Wallis test.

The test showed no significant differences between the groups in 2017, 2018, and 2019. Out of the 192 participants, 72.72% were male and 27.27% were female with an average age of 23.05 years. We did not measure the processing time, as it was standardized by the experimental procedures. For the testing of the main hypothesis, we used a non-parametric Mann-Whitney U test. The results of the laboratory experiment are displayed in the Table 3.

Table 3. Group statistics of the laboratory experiment

Indicator	LO1	LO2	LO3
Mann-Whitney U	3655.500	2343.500	2395.500
Wilcoxon W	8311.500	6999.500	7051.500
Z	-2.556	-6.079	-6. 014
Asymp. Sig. (2-tailed)	.011	.000	.000

In sum, there is a highly significant difference (p-value<.01) in the learning performance between lectures (individual learning) and group work (collective learning). In detail, group work (collective learning) leads to higher indicator values than lectures (individual work) for LO1 (group: Mean 2.7223; SD .97211; SE .09922 versus individual: Mean 2.3913; SD .97548; SE .09956), LO2 (group: Mean 3.9476; SD .78364; SE .07998 versus individual: Mean 3.3122; SD .63398; SE .06471) and LO3 (group: Mean 3.9003; SD .59882; SE .06112 versus individual: Mean 3.3024; SD .76403; SE .07798). To summarize, in the laboratory experiment, collective learning leads to significantly higher learning outcomes, measured by the quality of the developed solution, the satisfaction with the developed solution, and the satisfaction with the problem-solving process, in comparison to individual learning approaches in the area of ILEE decision-making and problem-solving procedures. The systematic evaluation of learning outcomes is very important for the conceptualization, planning, and execution of educational programs and, therefore, should be extended to further teaching and learning methods within future experimental investigations.

4. Discussion, conclusion, and outlook

This paper adds a contribution to the body of scientific knowledge by systematically transferring recent educational theories to the specific area of industrial logistics engineering education. The developed contextual framework describes the teaching and learning processes for ILEE in the context of a multitude of exogenous and endogenous influencing factors based on the specific requirements for a successful implementation of Industry 4.0 strategies. The findings from the systematic literature review justify the need for structured development of employees' competences to contribute to the professionalization of ILEE. In general, little attention has been paid to the evaluation of teaching and learning methods in the context of ILEE. Therefore, we further suggest conventional (e.g., lectures and group discussions) and modern teaching and learning methods (e.g., learning factories, interactive demonstration platforms, business simulations, etc.) to guarantee and/or extend quality assurance and, individual as well as collective, professional development in ILEE.

The empirical study systematically investigated the learning performance by evaluating significant differences between lectures and group work as exemplary teaching and learning methods in the context of ILEE. Thereby, the research model measured the latent construct learning outcome by using a set of manifest indicators. In sum, there is a highly significant difference (p-value$<.01$) in the learning outcomes between lectures (individual learning) and group work (collective learning). In detail, group work (collective learning) leads to higher indicator regarding the quality of the developed solution, the satisfaction with the developed solution and the satisfaction with the problem-solving process. The research results are based on the computation of a non-parametric Mann-Whitney U test and limited to the sample of 192 participants. The investigated relationships should further be investigated as a moderating effect by using multivariate analysis, such as structural equation modeling procedures, in further research studies. Therefore, the sample size should be increased by adding participants from various manufacturing-related industries.

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