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Total Immersion: Hands and Heads-On Training in a Learning Factory for Comprehensive Industrial Engineering Education*

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The 'Learning and Innovation Factory for Integrative Production Education (LF)' at the Vienna University of Technology (VUT) is the basis of the case study presented in this paper. One of the key objectives of the Learning Factory was to develop an immersive learning environment resulting in an integrated hands-on and 'heads-on' educational laboratory. One key-challenge was the utilization of the potential of problem-based and action-oriented learning and its transfer to higher education in industrial engineering. The teaching methodology harnesses the advantages of an interdisciplinary, experience-based and applied approach to learning and knowledge transfer, in order to build and hone the key competences of future industrial engineers. This is done in the context of a comprehensive approach to the Product Development Process, spanning the entire genesis of a product from product conception to serial production. Therefore, the pilot course was dubbed the 'integrative Product Emergence Process' (i-PEP). The presented case study shows the first results with respect to competence development for industrial engineers and presents the current approach of the VUT-LF and intended future developments.

Keywords: hands-on training; industrial engineering education; learning by doing; immersive learning environment; problem-based learning; action-oriented learning

1. The need for new forms of sustainably learning

In order to keep up with the requirements of today's workplace, individuals are faced with changing and often escalating demands for advanced skills, new competences and broadened expertise. Constant advances in technology and accelerating innovation cycles combined with shorter periods of employment and heightened economic competition put ever increasing challenges on future employee's basic academic foundations. However, in order to also meet the demands of the future labour markets, besides a solid academic foundation there is a strong need for solid application-oriented skills and competences. Traditional education always faced the problem of bridging the gap between what is taught in the classroom and what is needed in real-life. In particular, the discrepancies between professional education and competences needed in the workplace are widely known, but less frequently addressed in academic curricula. In order to succeed in tomorrow's working environment, students have to test their skills in real-life settings that foster the transfer of their skills into the working world. Hence, the traditional approach to professional classroom education has to be changed or at least supplemented by innovative teaching approaches. In particular, the broadly application-oriented and interdisciplinary subject of industrial engineering lends itself to such a practice- and application-oriented teaching and learning approach [1, 2].

In the context of the problems described above and with a vision of problem-based education, in the academic year 2011/ 2012 the Vienna University of Technology realized a learning factory. One of the key objectives was the testing and implementation of alternative education and training methods. One of the main reasons for the development of the VUT-LF was the realization and subsequent validation of an interdisciplinary and practice-oriented approach to education via an interactive learning environment. The goal of the developed programme is to teach the entire genesis of a product from product conception to serial production. Hence, the pilot course was titled 'Integrative Product Emergence Process' (i-PEP). The pilot run of the 'i-PEP' course represents the Product Development Process [3] or, more comprehensively, the Product Emergence Process (PEP) [4]. It was used as a test-bed for the enhancement of higher education for prospective industrial engineers through interdisciplinary and application-oriented competence development by means of an immersive learning environment. The educational project described above is accompanied by a research project about the educational efficacy of such environments in general and, more specifically, aims to verify the

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chosen approach and continuously improve the methods employed. To distinguish the discussion from the usual argument about 'effectiveness and efficiency' the authors will subsequently use the term educational-*efficacy*, as a term that sums up notions that are usually conveyed by the phrases efficiency, effectiveness, sustainability, profundity, etc.

In Section 2 of this paper the broader relevance and the inherent challenges and prospects of learning factories are discussed. Section 3 illustrates the didactical approach that has been applied by means of the case study that is at the core of this paper. It represents a novel approach that uses immersive learning environments for comprehensive and lasting education in industrial engineering. Section 4 reflects the results of the case study, especially with respect to the first findings of the research project and the future direction of VUT's Learning Factory.

It is necessary to emphasize that the following statements in Section 2 are generally applicable but Section 3 and 4 refer to the case study, the individual designed learning factory, implemented at the Vienna University of Technology. In this context, the results and conclusions can depend on local circumstances. The teaching approach in an interactive learning environment can be transferred to other educational facilities, taking into account that specific aspects (e.g. procedural method or course structure) have to be adapted individually.

2. Increasing efficacy in industrial engineering education

As shown in several studies concerning problem-based and action-oriented learning, a substantial increase in educational-efficacy compared with traditional classroom formats can be achieved [5–9]. The two teaching characteristics that determine the didactic approach of the presented case study are, on the one hand, multidisciplinarity and on the other practice-orientated.

2.1 Fostering knowledge transfer and innovation

Departing from classical economic theory, one could complement the production factors, 'land/natural resources', 'labor' and 'capital stock', with the factor 'knowledge' and some authors also argue for an 'innovation' factor. As knowledge is often becoming the factor limiting economic progress, companies invest to ensure, to protect and to gain knowledge through active knowledge development and management. Hence, vocational and continuing education is thriving and managers increasingly have problems in finding personnel with comprehensive know-how and interdisciplinary skills. In the engineering disciplines in particular, there is a great demand for university graduates who show high potential. However, often a lack of practical experience and an inability to cope with the increased complexity and dynamism that are present in today's workplace create major problems for novice employees. This is not surprising, since their abilities were formed during several years of university education characterized by mainly theoretical education in a frontal teaching setting.

The gulf between learning and work is large. Learning is often seen as abstract, classroom-based and academic. The world of work is seen as concrete, with bosses and customers, profits and machinery [10].

Certain contents and specific subject areas in higher education do not lend themselves to the commonly used classroom settings. Lectures are geared toward the verbal learner and do not take into account the varied learning styles of students. Many engineers are 'visual learners' in reality, much better served by active, visual and tactile teaching methods. Many students find little fulfillment or stimulation in the confines of the lecture hall and drop out of formal engineering programmes as a result [11]. Higher education often produces inert knowledge that does not enable graduates to solve complex and realistic problems in their working life. Transforming theory into practice is a significant challenge for them. Lectures, supplemented by examples from experience, cannot completely replace application-orientated knowledge transfer.

The current state of research assumes that a combination of cognitive (acquisition of knowledge, forming of practical knowledge) and constructivist (individual experience, know-how, testing) learning theories is best for the thematic complex 'Learning in Production' [12].

To extend the statement that is attributed to Confucius: 'I hear and I forget; I see and I remember; I do and I understand', from a scientific point of view the learning pyramid sustains the constructivist premise that instruction is more meaningful when it is realistic, engaged and reflective. Figure 1 depicts the effectiveness of learning methods involving different levels of auditory, visual, kinesthetic and interpersonal activity, suggesting that the more involved and communicative the instructional task, the more individuals remember as a result [13]. The *learning pyramid* was a departure point for the LF, where courses are based on direct linkage of theoretical studies with practice-based project for students.

2.2 Interdisciplinary teaching for sustainable knowledge acquisition

A key element in the education of future industrial engineers is the provision of a broad overview, to

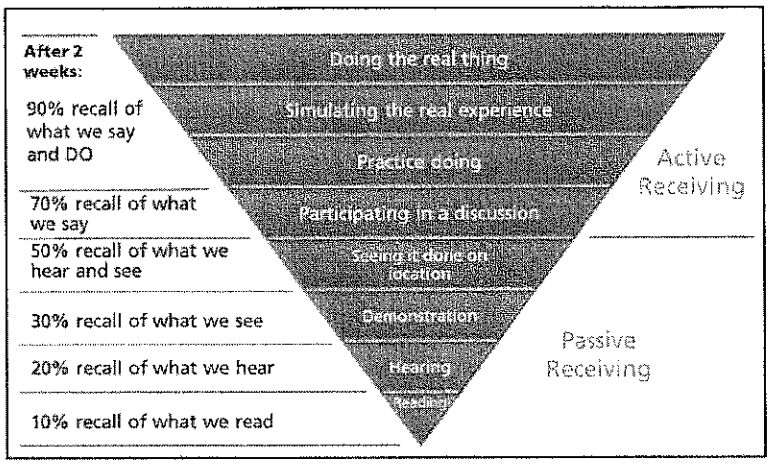

Fig. 1. Recall levels of the learning pyramid, reproduced according to [13].

enable interdisciplinary problem analysis and the development of comprehensive solutions. This integral approach should enable students to explore the interrelationships of knowledge, action and problem solving. Such an interdisciplinary approach has to be founded in education, requiring the substitution of a subject-specific instruction to a problem and experience-oriented teaching.

A major problem is the weak connection of teaching contents that is often caused by an institution-specific adherence to the table of contents of textbooks or curricula. Instructors select the content based on their specific personal knowledge and according to how much importance they put on a specific subject. The basic situation before the LF was that many lectures followed strict subject-specific topics without promoting any cross-over issues between subject matters. In consequence, instead of subject-specific goals and contents, key competencies to be gained should be defined for a results-based instruction. Hence, subjects are not treated separately but tied in with each other.

Bringing real experience into classroom settings means avoiding traditional teaching in the form of teacher-fronted explanatory instruction and aspiring a teaching culture that fosters interactive participation. According to this approach, which is also known as 'learning by doing', the combination of real-life involvement and experience-based learning is the key factor for success in higher education. Applying this basic didactic approach to industrial engineering means that an immediate transferability to real-life situations is desirable.

2.3 Developing key competences and skills of industrial engineers

According to the Institute of Industrial Engineers 'industrial engineering is concerned with the design, improvement and installation of integrated systems of people, materials, information, equipment and energy. It draws upon specialized knowledge and skill in the mathematical, physical, and social sciences, together with the principles and methods of engineering analysis and design, to specify, predict, and evaluate the results to be obtained from such systems' [14].

Manufacturing companies are increasingly confronted with a rising complexity, both in their inside and outside operations and, on top of that, with increasing domestic and international competition. As a consequence, the demands with respect to work effort and the qualification of employees and managers are permanently increasing. Nowadays, it is not enough for an employee to have mastered a specialized subject, but professionals are required to oversee and understand the organization in its entirety, identify cause–effect relationships of various processes along the value chain and make them understandable to a broader audience and, if necessary, reengineer them. Hence, the qualifications and competencies of an industrial engineer change. In particular, competencies in mechanical engineering, mathematics, physics, electronics, information and communication technology and economics, as well as social competencies, are relevant for industrial engineering students [15, 16] and are part of the curricula in the faculty of mechanical and industrial engineering at VUT. Traditional curricula for industrial engineers stress methods competence, but only methodological knowledge might prepare students to take a technologically lead and organizationally implement industrial value streams. In order to prevail in tomorrow's workplace, students need a profound knowledge of systemic interrelationships in complex production processes [17].

Industrial engineering in organizations (especially in manufacturing companies) deals with the planning, design, implementation and continuous

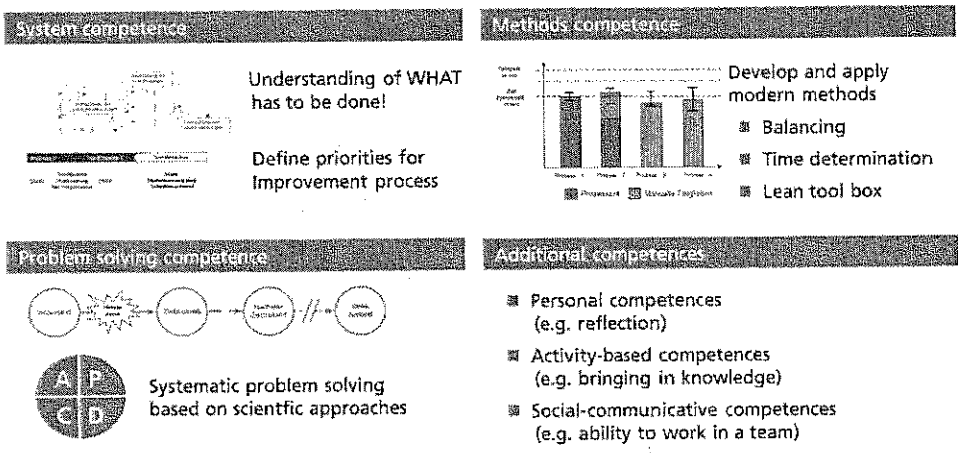

Fig. 2. Industrial Engineering key competences, composed of [18, 19].

improvement of socio-technical work systems in order to establish and operate economic value streams and production processes. Thereby industrial engineering technically leads the continuous improvement process and contributes methodological and problem solving competences, as well as additionally required competences, to the system (see Fig. 2).

In this terminology competence implies that individuals are able to successfully apply their traits, skills and knowledge in combination with experience, values and norms in a self-organized fashion to novel situations [19]. To enable an industrial engineer to act proficiently requires the necessary competences in engineering and economics as well as additional social key competences, critical introspection and self-reflection as well as active communication skills in order to work effectively, and independently in teams and task forces. This is especially important for industrial engineers who are organized in a staff unit and work temporary as consultants with line-managers [20].

The term *system competence* in the context of industrial engineering depicts the trait of comprehension of overall flow and individual performance on a systems level, in order to guarantee a goal-oriented alignment and prioritization of activities. In other words, industrial engineering connects the close to reality depiction of integral processes in production with the capturing and evaluation of dispersions, i.e. in manufacturing or logistics processes, and derives conclusive fields of actions. Further, it sets goals and the states of process goals from the superordinate objectives (strategic objectives, customer goals, factory goals, etc.) of the enterprise.

Methods competence in industrial engineering spans from the ability to apply the methods of methods time measurement (or similar systems) and a production system for the definition of target states and standards, as well as for the deriving of ergonomically relevant data (i.e. stress data) and range, to the design of state of the art business processes and methods of operation (along the value stream).

Problem solving competence describes the proficiency for goal-oriented problem solving and hence the realization of a systematic and continuous improvement process on the basis of a PDCA-cycle. Industrial engineering creates the basis to move from an 'as-is state' to a 'to-be state' by means of a continuous process of improvement.

The *additional competences* of industrial engineering encompass personal, activity and action-related as well as social-communicative competences, which enable a professional appearance and operation.

In a nutshell, industrial engineers require a well founded methodical and substantiated education in the different areas of industrial engineering. The breath of the discipline necessitates a focusing on experience-based and practically-oriented educational offerings.

2.4 Learning factories as immersive learning environments

To effectively develop competences in students, an activating teaching and learning environment that makes learners the protagonists is required. As a theoretical basis for such learning environments, the model of experience-based learning by Kolb [21] can serve as a good starting point. Such a problem-oriented approach to learning can be paraphrased as 'learning by doing' and encompasses four phases:

1. Starting with a specific experience with appropriate consequences an observation and respective reflection upon it is made.

2. Subsequent contemplation of the experience leads to an investigation into possible causes of the consequences that occur.
3. Reflection finally leads to an abstraction and generalization that allows the transfer of the experience to different situations.
4. In the fourth step, active experimentation with the new insights influences the behaviour in real situations.
5. Subsequently, the learning cycle starts anew.

The presented approach to teaching and learning is intended to create awareness of the problems that arise in professional practice and to lay the groundwork for alternative actions. By allowing room for experimentation without risk and creating an atmosphere that encourages constructive failure, learning on a meta-level will be enabled. The objective of an experiment is to find out which parameter has what influence on a dependant variable of a defined process [22]. The systematic hypothesis testing in experiments is the classic procedure employed by scientists to derive new knowledge [23].

The learning factory at VUT provides a testbed to inspire self-directed student experimentation and exploration with the following procedural objectives [24]:

- Apply theoretical knowledge to solve real-world problems.
- Develop common sense and judgment.
- Learn to work with individuals of all motivational levels.
- Develop an appreciation for other disciplines.
- Learn from your own errors and failures.
- Discover that usually everything takes longer and costs more than planned.

The ideas and concepts taught in 'learning factories' vary widely. However, in the area of industrial engineering education the term 'learning factory' is an established term and synonyms such as 'teaching factory' or 'method laboratory' are also commonly used, but might imply a different focus with respect to content or methodical approach.

A learning factory is not only an exercise room or a training workshop for industrial engineering activities to practice certain methods employed in manufacturing and logistics. It is much more than an accumulation of production machines and workbenches, where students learn how to manufacture a product. It is a learning environment, a place where learners may work together and support each other as they use a variety of tools and information resources in their guided pursuit of learning goals and problem-solving activities [25]. In the field of competence-based education in industrial engineering, a learning factory is a replication of a realistic factory, especially for mediating skills in production process optimization. It provides an immersive, realistic experimental environment that allows differentiated teaching and learning methods with an unconventional didactic and methodological approach.

Learning factories have been created as pilot factories for competence-based education and training in production. Further, this learning environment is complemented by various information, demonstration and communication segments. As the combination of theory and practice can take place under real conditions, there is a significantly greater authenticity of results compared with traditional cognitive knowledge transfer, followed by a positive impact with regard to both expertise and motivation [26]. The active involvement of the students under real-life conditions is the central focus of the didactical approach of learning factories, which simplify models of real processes. They promote open minded learning and combine theoretical learning with practical application. Basic theoretical knowledge gets extended by understanding why actions and decisions have to be a certain way ('why' and 'how').

A learning factory allows a direct approach to (production) processes in changeable and very realistic conditions. Typically, the learning content is not exclusively delivered by means of presentation or role-play; in addition the trainees have the chance to experience the learning content within an authentic (true-to-life) simulation. Their own actions and the participant's active involvement are a genuine part of the overall concept [27]. By means of integrating the elements of practice close to real-life conditions a learning factory facilitates an experimental environment for multi-purpose training and education.

3. Case study

The 'Learning and Innovation Factory for integrative Industrial Engineering Education' is a case study of an innovative concept for the design of an efficient education environment for cross-disciplinary and practice-based learning for students in the production sector. One of the central question was: How can the learning factory and its correlating teaching course be implemented systematically by using adequate knowledge and technology in order to enable the best possible transferability in possible fields of application?

3.1 An interdisciplinary and practice-based approach for teaching the 'Integrative Product Emergence Process'

In 2011, a formal cooperation was formed by three institutes of the faculty of mechanical and industrial

engineering at the Vienna University of Technology, consisting of:

- Institute for Management Science/Industrial and Systems Engineering (IMW) in cooperation with Fraunhofer Austria Research GmbH
- Institute for Production Engineering and Laser Technology (IFT)
- Institute for Engineering Design and Logistics Engineering (MIVP).

The goal of the partnership was the development of cooperative activities with the vision of building up a learning factory for cross-disciplinary and real-life education in production. In comparison with other European learning factories it is outstanding and unique that the VUT-LF is operated by more than one institute. The cooperation of IMW, IFT and MIVP ensures an examination of the PEP from different points of views of what a comprehensive approach to teaching implies. Therefore, the three institutes set up a strategic plan with key objectives and goals (see Fig. 3).

The three institutes forming the consortium are involved in research in the field of manufacturing but in different specific subject areas (see Fig. 4).

The thematic spectrum of the consortium is represented in the 'Integrative Product Emergence Process (i-PEP)' course. Each of the institutes focuses on a specific part of the integrative product emergence process that is closely related to the other institutes' subject areas and expertise. The MIVP starts with product development, especially construction and design. IFT deals with production technology with two focal points: manufacturing technology and production systems. Last but not least, the IMW contributes logistics and assembly. Partial overlaps in their respective teaching fields promote a multi-disciplinary approach. Starting with the customer request and ending with the delivery of the developed and manufactured products, the students get real experiences and a broad understanding of the integrative product emergence process.

3.2 The 'Learning and Innovation Factory for Integrative Production Education' as experimental setting for the course 'Integrative Product Emergence Process'

The physical workspace layout (140 m^2) of the 'Learning and Innovation Factory for Integrative

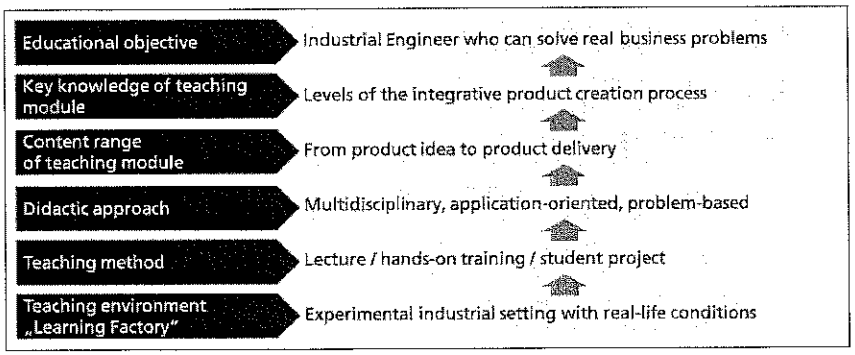

Fig. 3. Strategic plan for the 'Learning and Innovation Factory for Integrative Industrial Engineering Education'.

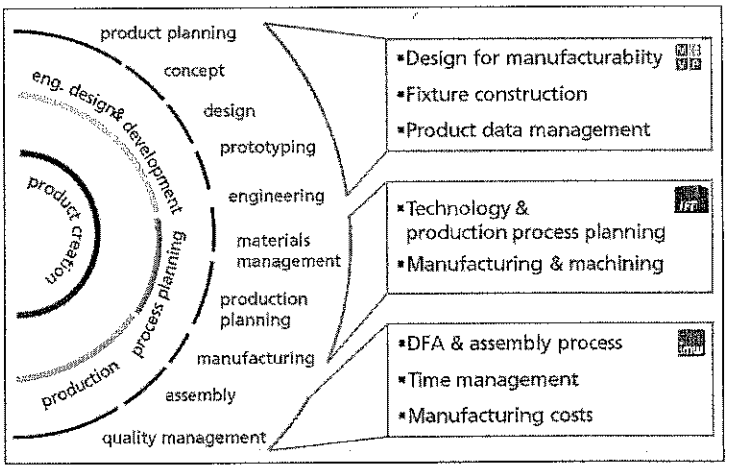

Fig. 4. Steps in the integrative PEP at the Vienna University of Technology.

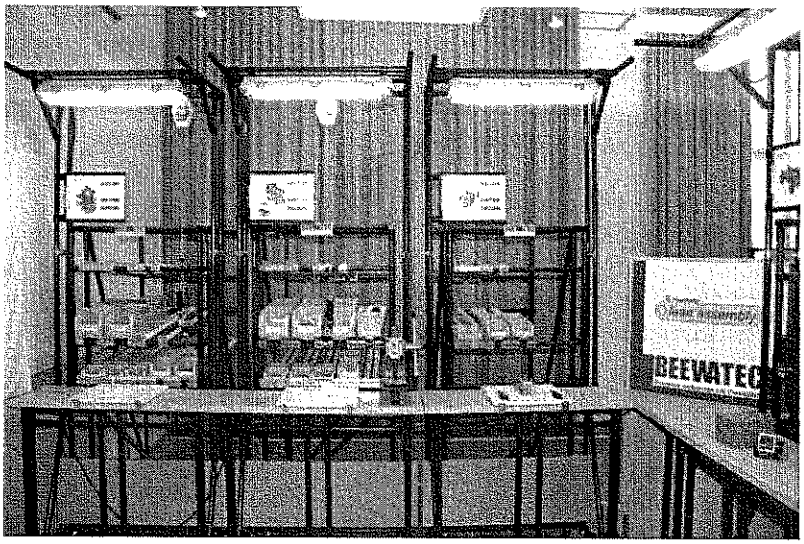

Fig. 5. Assembly line with flexible mounting stations and flow racks.

Production Education' is built up of real technological infrastructure with state-of-the-art equipment in order to simulate a real-life factory. It consists of a division for product and process planning with CAD workstations, a manufacturing plant (CNC-machinery, 3D and rapid prototyping printer, laser cutting machine, milling and turning centre, coordinate measurement machine, work benches with hand tools, etc.) and an assembly line with flexible mounting stations (see Fig. 5). The departments are physically connected via receiving and intermediate stores so that logistic aspects, especially the flow of materials, can be simulated. These practice-based facilities allow an improved knowledge delivery mechanism in engineering and production education that has a multi-disciplinary didactical character.

3.3 Course structure

The learning factory at the Vienna University of Technology (VUT) represents the physical educational platform for the learning course 'Integrative Product Emergence Process', which is part of the syllabus of the bachelor programme of mechanical engineering (see Fig. 6). The course addresses students who are on the verge of finishing their bachelor's degree. The participants have had five semesters of fundamental engineering and basic management education as part of the industrial engineering curriculum. The course was structured into three phases.

The *first phase* consists of a traditional lecture for theoretical preparation for the tasks to be completed in the following project. The participants receive basic knowledge that will be practically applied in the project. The theoretical introduction is intended to secure the necessary knowledge base for the subsequent project phase. The first phase is completed with an exam.

The *second phase* is a student project that lasts for ten full working days and takes place as a hands-on course in the learning factory. According to the

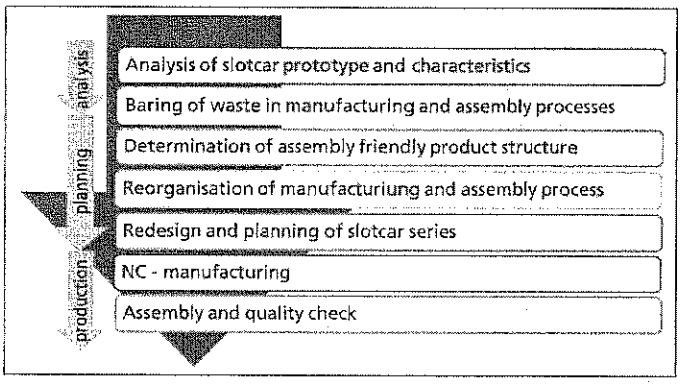

Fig. 6. Procedural method addressed in the 'Integrative Product Emergence Process'.

understanding of the teaching method, participants work independently and self-reliantly for a defined time on a given assignment. The project's aim is to optimize a real product, a prototype slotcar on the scale of 1:24, and its production process with regard to:

- lead time of manufacturing and assembly process,
- manufacturing costs and
- fault-free production (quality assurance).

Optimization of the production process in terms of driving characteristics takes a secondary role. The project incorporates an exercise to plan, build and optimize a real product and its production process, including product planning and design, engineering, manufacturing, assembly as well as quality assurance.

In the *third phase* students have to prepare a presentation with their project results. This step helps to reflect on the performed tasks and their influence on the outcome. Upon presenting their results, participants receive feedback concerning their performance, possible lessons learnt as well as their presentation skills.

The assignments given to the students improve their understanding of interrelationships and the influence of the coordinated operation of different parts of a company. The participant will be enabled beyond his or her curriculum to organize production technology in an optimal way. Further, the students experience a manufacturing and project-related design process and gain realistic business experience using the latest technologies and methods. In addition to the gained technical, analytic and professional skills, the students can hone their social competence and interpersonal abilities through collaborative problem solving, interdisciplinary team work, focused debate and rotating interim presentations. Further, the skills that are honed are analytical skills, excellence in project management, the ability for structured proceeding, leadership skills, independence, communication skills, flexibility and adaptability, as well as creativity. The students solve problems by identifying appropriate methods and learning how to implement them systematically. The participants develop the ability to make decisions on the basis of initial project and product information and experience the realistic results of those decisions. In particular, the impact of decisions made during the product design phase for the production process is experienced first-hand and illustrates to the students the challenges of manufacturing in an almost real-life setting.

The students' achievements are assessed by means of several criteria. Besides the three mentioned goals related to the product and its creation process, the lecturers evaluate the students' behavior, initiative and the development of the competences. Finally, the students also have to give a presentation with their project results.

4. Outcomes

The pilot course for 'i-PEP' took place in April 2012 with three teams and four students in each team. The student teams participated in a series of lectures and spent two weeks in the VUT-Learning Factory. With regards to the set operational objectives of the course, the students achieved excellent results. All teams realized a decrease in manufacturing costs of 20–25% and were able to reduce the lead time of manufacturing and assembly processes to about half of the initial time. The objective of guaranteeing a fault-free production could not be achieved by all the teams due to their lack of familiarity with the machinery and its characteristics. However, the operating performance of the participants is not the main key evaluation criteria of the course, since it is much more important to assess the approach that the participants took, to gain their results.

Students systematically applied methods they had learned in the previous lectures and investigated alternatives on their own. The product and its development process were analysed from different point of view, which included different interdisciplinary aspects during the planning phase. The decisions were taken as a team and the results were discussed in a final project presentation.

The manufacturing and assembly processes were impacted by reviews to the upstream project steps, including process re-optimizations and the discoveries of new potentials for product enhancements. Thus, participants experienced in a practice-oriented way that different steps of the PEP are not to be treated separately but are tied in with each other.

The lecturers were supported by teaching assistants who acted as facilitators. Overall, the teaching staff could perceive that highly motivated students with above-average involvement gained best results. This enthusiasm was fostered by the additional challenge of a slotcar race at the end of the project. The teams competed against each other with their self-designed, -planned and -produced slotcars.

After the first pilot run, facilitators and students evaluated the course in a final open discussion. Students reported in agreement, that they had a great learning experience, which was characterized by an interdependent social interaction in a engineering environment. The VUT-Learning Factory was generally seen as a highly innovative learning environment. A participating student announced

his elation with the following comment: 'Performing in the learning factory helped me not only to understand methods; hands-on experience gave me tangible access applying methods as in real-life business!' All teams appreciated spending their time actively in the learning factory by self-directed working, instead of listening passively in a classroom to a lecture. All the teams said that they would recommend the 'i-PEP' course to their colleagues.

The expenditure of time in writing the program script for the CNC-machinery was perceived as a burden by some of the participants. They would appreciate a reduction of the components to be produced by themselves, in order to leave more time for process optimization.

Finally, the three cooperating institutes conducted an internal analysis of the 'i-PEP'course. In retrospect, building up the VUT-Learning Factory was the first step to foster action-oriented learning and it significantly increases the quality of education and training at the Vienna University of Technology. On the basis of the observation of the participants during the course, facilitators observed a strong increase in the students' system, methods, problem solving and additional key competences as mentioned in Section 2. The chairmen of the institutes agreed that this innovative method of experience based hands-on education enables and ensures the sustainability of the knowledge acquisition and provides an enduring learning success.

The main challenge that occurred during the development of the learning factory and the 'i-PEP' course was the enormous need for planning by the research and project staff. Based on the encouraging feedback, all three institutes decided to establish a second course addressing the master programme in mechanical engineering. That course will continue the learning objectives of 'i-PEP' that inspired the VUT-Learning Factory team to promote interdisciplinary and experience-based education.

5. Conclusions

The 'Learning and Innovation Factory for Integrative Production Education' provides a simulative learning environment to intensify student's professional and social competences. Further, it provides an innovative platform for creating a mutual understanding between higher education and real businesses. By means of innovative teaching methods future industrial engineers are able to practise traits and reflect knowledge in a real-life setting.

The interactive nature of the teaching methods employed, the goal-orientated learning approach and the compact format allow an intuitive development of skills and competencies resulting in lasting and sustainable knowledge. Hence, the quality of education is increased significantly. Furthermore, learning factories help to enhance teaching methods as well as to elicit tacit knowledge and innovation in education and higher learning organizations.

With regard to the positive student feedback and the tutors' observation and evaluation it can be asserted that the educational-*efficacy* in terms of teaching the product emergence process has increased significantly. This improvement in educational quality will be measured in a quantitative and qualitative analysis during the next run of the 'i-PEP' course. Therefore, a student group, educated in a traditional classroom format, will be compared with another student group that had experienced the PEP in the VUT-LF. Suitable methods for identifying, measuring and valuing the learning process and its linked gained knowledge are observation, interviews, questionnaires, sampling, exams and assessments.

This paper elaborates the potential of an action-orientated and experience-based course 'Integrative Product Emergence Process', using the example of an interactive 'hands-on' learning factory at the Vienna University of Technology. The learning factory system can be transferred to other industrial engineering programmes or training courses for production and logistics management. Other academic institutions could benefit by adapting the concept of a learning factory according to their field of research and its related vocational training. The resulting insights are not only relevant for the academic environment, but are also applicable to vocational training and human resources development in industry. Furthermore, the 'Learning and Innovation Factory for Integrative Production Education' is used as a research- and method-testing facility to develop appropriate services for industrial companies and, moreover, functions as a laboratory for process evaluation and optimization.

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