Digital Learning Factory at FESB – University of Split

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Abstract-In this paper we present development of digital Learning Factory at FESB, developed by Very Small Enterprise (VSE) VENIO indicium Ltd, which was started in cooperation between food processing partner PIVAC Group and FESB. In parallel with the development and implementation at user sites VENIO ERP/PLM was used as Digital Learning Factory in two course in the fifth year of studies at FESB. In virtualized environment of the Digital Learning Factory the students (organized in small teams) have their own test companies for exercises. The PLM students have to design their own enterprises and prepare fully functional ERP/PLM for final exam. In the paper we discuss an impact of such digital learning tool based on student's self-assessment. This Digital Learning Factory is a candidate for a software part of Lean Learning Factory in the project Innovative Smart Enterprise in Croatia (INSENT) and as a learning tool for involved industry partners.

Index Terms-digital learning factory, computer science, Product Lifecycle Management (PLM), Bloom's taxonomy, Industry 4.0

I. INTRODUCTION

The world we live in today largely depends on technology that is constantly changing and progressing rapidly. So rapid changes represent a substantial challenge in educating new generations of students at the universities, especially in the field of Science, Technology, Engineering and Mathematics (STEM) [1].

Today's students are from an early age actively using new digital technologies (Internet, communications, multimedia ...) and are more adapted to them than their educators who teach them basic knowledge in STEM or business areas. For a couple of years, today's students will leave the university and go into the business world and for 10 to 20 years they will be leaders, managers, professionals. How is it possible still at the university to give to these 'digital' young people an important knowledge that they need for the near and

further future career? One of possible ways is an integration of faculty's three core activities:

- education at all levels,
- professional technological projects and
- scientific-research projects.

In these two project areas professors (that are at the same time scientists and practitioners) apply existing methods and technologies to solve problems in practice. It helps them in seeking new solutions, methods and technologies for these problems. These two project areas are helpful for the professors in third field, in education. This way the professors will be able to present and teach the students knowledge that has scientific relevance and is applicable in specific business domain and business community.

Further important approach in students education is an inclusion of highly motivated undergraduate and graduate students in research and professional projects [2]. Drawback of this valuable initiative is that only minority of students meets high demands of professional and research projects and the university has to take care of all students. More benefit the majority of students at STEM faculties would have if they had the opportunity during their studies to work in the laboratory and do something more than ordinary student exercises, e.g. if they could work student projects in real environments and under the supervision of experts. Such an environment would be like a factory and could be called a 'Learning Factory' [3] -[5] . The Learning Factory's mission is to integrate design, manufacturing and business realities into the engineering curriculum. This is accomplished by providing balance between engineering science and engineering practice [3] [6] [7].

In the September 2014 INSENT project started with the main objective of developing Croatian model of Innovative Smart Enterprise (HR-ISE model). One of the goals of the INSENT project is Learning Factory at FESB that will be used as "living lab" for HR-ISE model implementation and a

place for knowledge transfer from University to economy [3].

The process of establishing such Learning Factory (LF) can be difficult and expensive [3] [4] but in some areas like Computer Science (CS) it can be relatively easy. Such LF could be called a 'Digital' Learning Factory (DLF). In this paper we present the Digital Project Factory at FESB that is used in the classroom and that will be used for the purposes of scientific research project INSENT.

In the next chapter we briefly describe characteristics of INSENT and PIVIS projects. The chapter III shortly describes VENIO indicium Ltd's history and main functionality of VENIO ERP/PLM software developed by VENIO indicium Ltd and used in Digital Learning Factory. Virtualised Digital Learning Factory at FESB is described in the chapter IV. Experience of using DLF as a digital learning tool and its validation in teaching based on the students' self-assessment are described in the chapter V.

II. INSENT AND PIVIS PROJECTS

A. INSENT Project

In the September 2014 INSENT project started with the main objective of developing Croatian model of Innovative Smart Enterprise (HR-ISE model) [3] . Every global manufacturer has its unique manufacturing system (Toyota, Daimler, Bosch, etc), and some countries are developing their own unique enterprise model, like Germany - Industry 4.0. Model is aligned with their vision, strategy, values and culture. Republic of Croatia hasn't developed its own model of enterprise. The aim is to perform model's regional fit, i.e. to harmonize Innovative Smart Enterprise model with specific regional way of thinking, manufacturing and organizational tradition, and specific education. HR-ISE model could help Croatian enterprises to bridge the gap their competencies and between EU enterprises' competencies and capabilities.

The development of Croatian model of Innovative Smart Enterprise (HR-ISE model) and its transfer to economy could have a strong impact on recovery of Croatian industry. HR-ISE model could significantly improve competencies and capabilities of Croatian enterprises to make them more competitive on EU market. Additionally, Lea Learning Factory at FESB will be used as "living lab" for HR-ISE model implementation and a place for knowledge transfer from University to economy.

B. PIVIS Project

In 2010 the large food processing enterprise Pivac Group (which included Pivac Brothers Meat Industry, PPK Karlovac Meat Industry and Dalmesso with approximately thousand employees) decided to strengthen their information and communication infrastructure and launched a multi-year research and technological cooperation with FESB. Nowadays the Pivac Group includes several new companies and has a total of more than two thousand employees.

In collaboration with the Competence Centre for SW Engineering at FESB [8] [9] Pivac funded project called

'PIVIS' (s. Fig. 1) whose aim was the establishment of modern ICT company that will assume responsibility for the computerization of the Group to the highest professional standards and enable the realization of business plans of the Group. The core of the PIVIS project team consisted of Professor, one experienced developer and four students from the CS graduate study.



Figure 1. From PIVIS Project to VENIO Company and VENIO ERP/PLM

Detailed analysis of a large number of stakeholders which was made at the start of the project [10] [11] has significantly influenced the chosen project methodology and the positive course of the project. During the project some innovations regarding personal capability assessment are introduced [12] and regularly applied.

The whole system was divided into several subsystems according to the Group's main processes and therefore the phased development-based methodology [13] -[15] in conjunction with iterative agile methodologies and practices [16] -[20] was chosen. Already after 6 months PIVIS team has developed the first version of a distributed retail system which was implemented to more than 100 locations and integrated with a legacy system by the end of 2010. That was a confirmation of the maturity of the development team and the seriousness of the project approach.

The project parties have continued to build further on this basis in two directions:

- conversion of development team in a development company and
- development of integrated information system for the whole enterprise (ERP system).

III. VENIO INDICIUM AND VENIO ERP

A. From PIVIS Project to VENIO Indicium Ltd Company

VENIO indicium Ltd is a very small ICT enterprise (VSE) [21] developed from the PIVIS team. VENIO is developed evolutionary step by step and incubated in the Group while developing their core and supporting processes [21] -[23]. As an independent Group's spin off company VENIO has been operating since the summer of 2011 and has about 10 employees now.

Although it is a micro company [24] VENIO has high demands by the owner (PIVAC group) since its inception and is therefore organized and operates according to the highest professional standards [14] [21] -[23] [25]. All the time VENIO has had a balance between traditional, well defined processes and practices [15] [26] -[28] (because it works on a long-term project) and well established agile methodologies and practices [18] -[20].

B. VENIO ERP/PLM Software

The best validation of VENIO indicium's processes is main software product of PIVIS project is a distributed VENIO ERP system. It is n-tier application developed in Visual Studio Integrated Development Environment, MS SQL Relational Database and C# programming language with extended DevExpress controls for user interface. VENIO ERP is intended for Windows operating system at PCs and tablet devices in Local Area Network (LAN) and Virtual Private Networks (VPN) environment.

The main process oriented modules of VENIO ERP are:

- Master Data
- Supply Chain Management (SCM) and Warehousing
- Production
- Human Resource Management
- Financial Management (with Protocol)
- Distribution and Transport Management
- Asset Management.

The main Product Lifecycle Management (PLM) functions are seamlessly integrated through all VENIO subsystems. With different types of articles an advanced user is able to define his own types and groups of (raw)materials, products, their characteristics and lifecycle across the whole enterprise. He has similar freedom in defining the types and groups of partners and own organization and internal users (and levels of their rights).

Integration of CAD files and other types of documentation is enabled during the whole product life cycle. A communicatin with other specialized systems (d.e. Manufacturing Execution Systems or other ERP systems) is enabled through the XML or some specific EDI protocols.

Customer Relationship Management (CRM) and quality Management (QM) are integrated across all subsystem also. All documents in VENIO ERP can be signed digitally and sent to customers via e-mail directly from ERP. In 2015 einvoices were adopted adopted in Croatia and VENIO ERP has therefore fully integrated external automated module for receiving and sending digitally signed bills (e-bill).

Some metrics from the biggest customer, Pivac Brothers Meat Industry, describe the reliability and overall quality of VENIO ERP:

• 230 distributed retail and warehouse locations with own database that communicates with the central database

through the VENIO services and independent FTP server

- 6.000.000 retail bills pro year issued from distributed databases and synchronized with the central database
- 140.000 receipts of goods received into distributed databases and synchronized with the central database
- and 150.000 incoming invoices per year (for goods and services) received at the central location and connected automatically with distributed receipts of goods.

The market potential of the VENIO ERP is confirmed by its just finished implementations in one micro enterprise (ME), one large enterprise (LE) and five small-and-medium sized enterpsises (SME). Three of them are old customers and are implementing the newly created subsystem Financial Management while other four companies implement a complete ERP. All seven companies started with operational work on 4 January 2016. Three new projects of ERP implementation and customization in pharmacology and food processing enterprises are in preparation and will start on the spring of 2016. One of them is SME and two others are LE.

IV. 'DIGITAL' LEARNING FACTORY AT FESB

The continuous collaboration with the University is a strategic priority of VENIO indicium expressed through the following forms:

- Professor is actively involved in the development
- developers are actively involved in teaching at the University (lab work with students, mentoring of student seminars and theses)
- collaborations on research projects
- doing of post-graduate studies
- lecturing in Learning Factory at FESB.

All VENIO's employees were student at University of Split and know how valuable is 'learning by doing'. This is the reason that students of the fifth year of studies in Computing and Industrial Engineering – PLM (Graduate level) have licenses of VENIO ERP/PLM for the practical part of the courses Business Information Systems (for CS students) and PLM Information Systems (for PLM students). Software is installed at virtual machine with Windows server 2008R in FESB' virtualized data center and managed with WMware tools (s. Fig. 4).

These two groups of students differ significantly in acquired and targeted knowledge that are defined by their study programs when they come in the Learning Factory. Those in the group CS have more knowledge in computing and those from the group of PLM have more knowledge about the processes and management. The objectives of Learning Factory for these two groups are similar but different – each group has to (s. Fig. 3):

- improve the level of knowledge in their domain and
- aquire certain level of knowledge from the second domain.



Figure 2. Virtualised Environment of Digital Learning Factory at FESB

CS students must be able to understand knowledge from the right side of the Fig. 3 in order to be able to design new software (or ICT general) solution for enterprise. And vice versa, PLM students must be able to understand knowledge from the left side of the Fig. 3 in order to be able to design new enterprise. To accomplish these goals, each group requires somewhat different approach and different lectures.

Both groups (each of 30-70 students) have their own terms and are divided into small teams of 2-4 people. Each team has its own test company with the test data on which it will conduct practical exercises and study the concepts learned on the course (s. Fig. 3). The both groups have adequate written instructions for exercises and they listen to lectures adapted to them. The lectures are held by the Profesor and Assistant, authors of the VENIO ERP/PLM, and the students have the opportunity to ask and discuss with them all important and relevant topics from both fields.

In addition to the practical excercices based on written materials, the most active students have the opportunity to cooperate with the developers during the making of their master thesis. Right now (*in winter semester 2015-16*) a few CS students are writing their Android applications that should communicate with the VENIO ERP.



Figure 3. Learning Outcomes Level in Relations to the Study Field

V. VALIDATION OF DLF BY PLM STUDENTS

A. Students' Projects and Exams

The group of PLM students is smaller than the CS group (cca 30 students and 10 teams pro year). From this reason these students have another important and valuable project in the course PLM Information Systems. During the semester each team must design their own enterprise with:

- main and supporting processes
- organisations, users and their rights
- (raw)materials, products and their lifecycle
- sevices and their lifecycle
- all other types of articles
- partners and their types
- production locations and all other locations (wholesale, retaile, warehouse,...) and their communication
- production process' documentation (material request/issue, work order, BOM,...)
- traceability system for (raw)materials and products through the enterprise.

Team's designed enterprise should be elaborated in a written project and implemented in the information system of their company (s. Fig. 5). All of the time the team has access to both databases/enterprises:

- test eneterprise with test data for exercices
- their own enterprise with their data (and minimum master data).

Based on their designed enterprise the students take the exam and explain how their enterprise operates (purchase, production, sales, SCM,...), what are the product's/material's lifecycle and similar scenarios.



Figure 4. Architecture of the Digital Learning Factory at FESB

B. Students' Self-Assessment as a Validation of DLF

Professor evaluates students' knowledge level but his assessment of the contributions of his methods and tools for students' knowledge level is largely subjective. Students can assess the contributions of professor's teaching methods for each of them better than professor. In fact, perhaps they will evaluate some methods as boring and worthless if the survey is anonymous and if it will not have any negative impact on the finale grade. In order to measure the advance of students' knowledge level in some areas during the course a special anonymous survey among PLM students was conducted in Februar 2016. An impact of DLF's on their advance in each knowledge area (KA) was investigated also.

The 17 students completed the questionnaires for 9 knowledge areas before the exam and handed them to Professor after the examination. They assessed for each area own knowledge level before course and before exam. They assessed also levels they would achieve with classic learning tools and exam methods. One questionnaire was rejected due to insufficient valid responses. Knowledge levels were measured according to Bloom's taxonomiji [29] and the students had a detailed description of it.

Students' improvement for each areas is shown in Fig. 5 while improvement of each student in all areas and impact of DLF are shown in Fig. 6. Measured average advance for 16 students in all areas is 1.76 of *Bloom's level's* across all KAs and direct impact of DLF on this avance is 1.03 of *Bloom's level's*. Such huge impact of DLF could be taken as validaton of DLF as a digital learning tool and Professor's exam method also.



Figure 5. Average Knowledge Level for all Students by Knowledge Areas (*levels 1-6*)



Figure 6. Personal Advance and DLF Impact for all Areas by Students (*levels 1-6*)

Assessed knowledge areas are: KA_1 Business Processes in general; KA_2 Business Process Management; KA_3 Financial Management; KA_4 Traceability; KA_5 Production Processes; KA_6 Logistics & Supply Chain Management; KA_7 PLM Processes; KA_8 Information Systems; KA_9 ERP/PLM Implementation.

VI. CONCLUSION

VENIO ERP/PLM which is the backbone of the digital Learning Factory will be further improved functionally (in terms of production scheduling and shop floor system) and technologically (in terms of broader integration with other mobile platforms). Since Split-Dalmatia County (local government) recognized a potential of VENIO indicium and funded in part development of VENIO ERP the triple helix model [3] [30] has been implemented.

VENIO ERP proved its potential at the market in Croatia while student's self-assessment proved its validity and value as a digital learning tool in the Digital Learning Factory at FESB (the advancement of knowledge was measured by Bloom's Taxonomy). It will be further improved based on project Innovative Smart Enterprise in Croatia (INSENT, financed by Croatian Science Foundation [3]) and on reuirements from industry partners. Therefore it will be candidate for a software part of a Lean Learning Factory used as a learning tool for companies involved in INSENT project.

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