Editing and Visualization of NC-Code in an E-Learning Project

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ABSTRACT

At the ifab–Institute of Human and Industrial Engineering at University of Karlsruhe (TH) we are developing **LIVE-Fab** (<u>L</u>ernen <u>i</u>n der <u>v</u>irtu<u>e</u>llen <u>Fab</u>rik) in cooperation with the University of Applied Sciences Landshut.

The goal of the project is to give students an illustrative learning model of a production factory in the full range from incoming goods, manufacturing, assembly and quality control. Students should learn and recognize the complexity of production processes. Thus they shall learn the wide range of production processes and the application of information technologies in one tool.

LIVE-Fab is implemented on top of the DotNet-Framework using Web Controls, Web Services, and XML etc. Web Controls are implemented as an editor for NC-Code (DIN 66 025) to represent students a web based and state of the art learning tool. After NC-Code development the students can simulate their program and get immediate response through a graphical representation of the work done by the program in the browser. The graphical representation is rendered by a Web Service which receives model data and execution codes by SOAP.

Keywords

DotNet-Framework, ASP.Net, Web service, XML, ADO.Net, XDR, SCORM, ADL

1. INTRODUCTION

At the ifab - Institute of Human and Industrial Engineering at the University of Karlsruhe we have been developing the project LIVE-Fab (Lernen in der virtuellen Fabrik) since August of 2001 in cooperation with the University for Applied Sciences in Landshut. This project is sponsored by the "Bundesministerium für Bildung und Forschung" (BMBF) (ministry for education and research) within the context of the research program "Neue Medien in der Bildung" (new media in education). The goal of the project is to illustrate a comprehensive, working plant in a teaching and learning model. For this purpose a model plant with the areas of purchasing, parts manufacturing, assembly and quality assurance should be represented. The plant, along with its resources (machines, transportation systems etc.) and flow of materials should be visually ascertainable in a 3D-model.

The foundations for the creation of a functional production, including plant planning, and work preparation, the mechanism of customer orders and quality management should be imparted to the students in individual case studies (cf. Figure 1).

The students from the faculties of mechanical engineering, economic sciences, electronic engineering and business management with technical orientation should be given a learning aid, namely the virtual factory, with which they can learn to better understand the complex, inter-twining procedures of a production process. This means that the virtual factory combines the aspects of several preliminary lectures, thus creating a basis for the understanding of production processes.

2. Objectives

Modern production enterprises are marked by a multifaceted application of computer supported organization and manufacturing technologies. It was once so that computers were incorporated in the production for the numerical control of machine tools (NC programming); however, it is now almost unimaginable that a product development be carried out without computer supported procedures for the construction and work planning (CAD- and CAP-support).

Meanwhile, even order processing is carried out in many area exclusively with computer support. Production planning and control procedures (PPC) were the forerunner for the processing of customer orders and were soon followed by control stations for the controlling of work-shops. In combination with systems for Direct Numerical Control (DNC) and enterprise data registration (BDE) PPS merges process-orientated customer and product data together into computer supported manufacturing (CAM).

Figure 1.   LIVE-Fab web interface for students

This is currently being supplemented by the exchange of data beyond the borders of individual enterprises. The internet thereby plays an ever larger role in the co-operation of complex customer-supplier-networks, while the internal enterprise flow of information is being accelerated by intranet solutions in terms of a workflow management.

These technologies which have already found multiple applications in praxis should now also be brought across in post-secondary schools in an appropriate manner. In addition to the understanding of the functional connections and the models for the solution procedures for various problems, the students should also learn to deal with these new technologies. Therefore, it is necessary that on the one hand the methods in the computer supported procedures for various enterprise functions are understood, and on the other hand that the students learn to handle such tools.

Practically-orientated knowledge has always been imparted in industrial placement or in laboratory events in post-secondary schools, but new information and communication technologies now offer the possibility to learn, not only how to handle these technologies, rather also to acquire this experience-based knowledge. In addition to lectures, labs, seminars and industrial placements, these technologies also allow for a new type of learning: Internet or intranet supported learning modules in post-secondary institutions create the possibility for a temporally unbound, individual acquisition of business management knowledge.
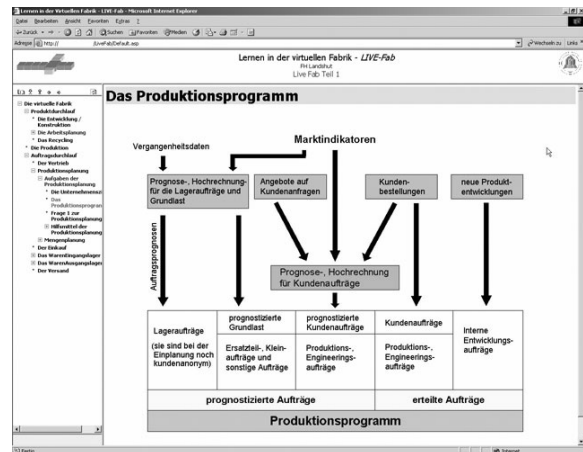

Figure 2.   LIVE-Fab content (example)

In the context of the LIVE-Fab project, several learning modules (cf. Figure 2), each designed to transfer different aspects of business management problems to the students within a virtual factory, will be created. These learning modules supplement the corresponding courses and illustrate individual functions and their complex interplay in an industrial enterprise using, among others, simulation and animation. For this purpose the virtual factory will be represented in a computer, along with its most important enterprise areas. Aside from a 3D-model of the virtual factory, a computer model with its own database will also be deposited. All data relevant for the production are stored in this database and can be used or even changed for the case studies.

In the virtual factory the students can trace the processing of a production order, for which not only textual explanation, rather also charts, diagrams, video sequences and even 3D-animation is offered.

Furthermore, the students are called upon to solve tasks, such as in the areas of e.g. programming of CNC-machines, the controlling of workshop orders, the planning of parts manufacturing workshops, the configuration of assembly systems etc. These tasks serve on the one hand to arrange the students' knowledge base within the virtual factory training units,

and on the other hand to adapt training content or simulations to the corresponding knowledge level or learning progress of the students.

3. Didactic Concept and Models

In order to improve professional competence the virtual factory tries to combine curriculum which has, up until now, been handled individually. The holistic nature of the production process and the interconnection of its individual sections should thereby be made apparent.

In addition to the central question of how knowledge should be imparted, the question as to the means to be used, in particular regarding the media for the transportation of knowledge, is also affiliated. Independent planning, execution and controlling of an operation are decisive for the training. Operation-orientated methods are well suited to bringing this aspect across to the students. They differ from traditional instruction forms through a combination of target, content, methods and media areas, which is why one refers to multi-dimensional teaching-learning-arrangements or complex methods.
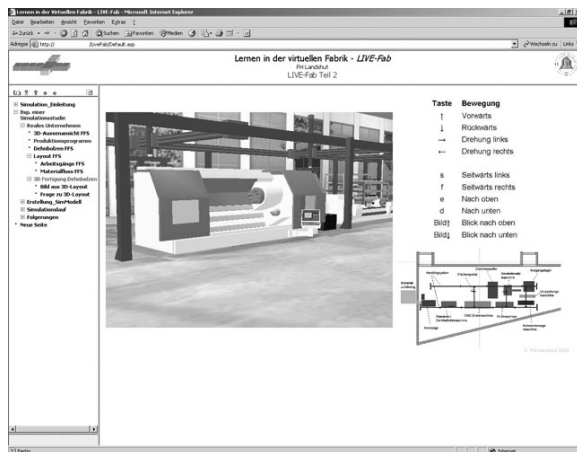

Figure 3.   LIVE-Fab virtual reality

4. Content

The ifab institute participated in the development of two LIVE-FAB modules. One deals with the area of CNC-programming and the other with the area of assembly workplace configuration. The curriculum was reduced didactically, prepared digitally and implemented within the project learning environment for both modules.

The represented virtual factory encompasses the areas of warehousing of goods received, work preparation, parts manufacturing, assembly and quality control. The entire production of the virtual factory takes place in the areas of parts manufacturing and assembly. The curriculum of the CNC-programming and assembly workplace configuration modules are ex-

plained in the chapters CNC and workplace design. A computer supported question system which has been integrated into LIVE-Fab was developed at ifab for the selection of the curriculum to be offered to the students. This question system determines, similar to a written test, the knowledge level of the user by using a question catalogue (cf. 4.3).
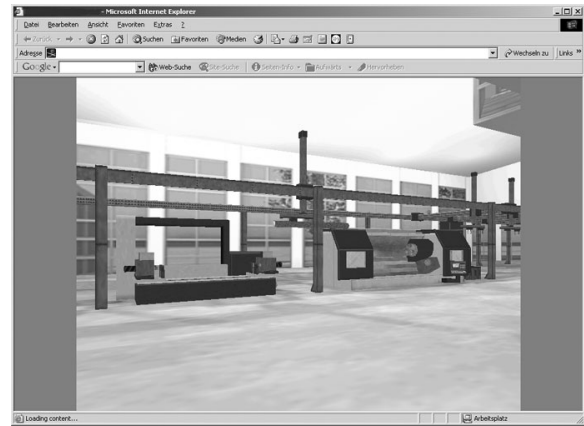

Figure 4.   LIVE-Fab factory building

4.1   CNC-Programming

In this module the students should learn about the topic CNC-techniques for the manufacturing technologies of milling and turning step by step: beginning with CNC-machine setup and the function of NC-controlling and ending with the simulation of the manufacturing of a component. The educational objective of this module is to enable the student to manufacture a component using a technical drawing.

The module presents the topic of CNC-technology within a theoretical and a practical block. In the theoretical block the students are offered information in the form of, for example texts, graphics, images, animation, and video sequences. It deals with factual knowledge which can not be transmitted in an application. In the practical block the students must manufacture a component (e.g. drive shaft) using a technical drawing. For this they must write a CNC-program which is simulated after its creation (cf. Figure 5, Figure 6).

In theory blocks the students should learn to recognize the major difference between the types of NC-controlling (point, distance and lane controlling) and the types of interpolation (linear, circle or circular interpolation). The various types of controlling and interpolation should be offered as video sequences or as textually represented information.

In practice the 3D-lane-controlling is of great importance since it is used in most modern CNC-machines. Furthermore, 3D-lane-controlling allows work pieces to be processed with linear, circular or spatial tool movements at several levels simultaneously.
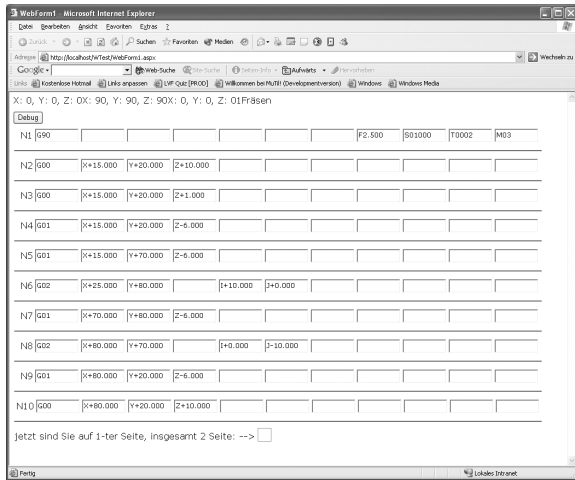
Figure 5. LIVE-Fab NC-Editor

3D-lane-controlling can create any spatial contours desired at a milling machine. Furthermore, the co-ordinate system is explained to the students, to supplement the NC-controlling, in order to determine the X, Y and Z axes on the main guide lanes of the tool machine with the right-hand-rule. The various zero points (work piece zero point W, machine zero point M) and reference points (reference point R, program zero point, tool transfer point) are explained in detail. In this context the tool system and the tool settings for the milling and drilling machined are represented. The procedural methods of the tool for the manufacturing procedures milling and drilling are thereby dealt with. The most important NC-commands (e.g. G00, G01, G02, G03, M30 etc.) and the construction of a program setting are explained in depth in DIN 66025.
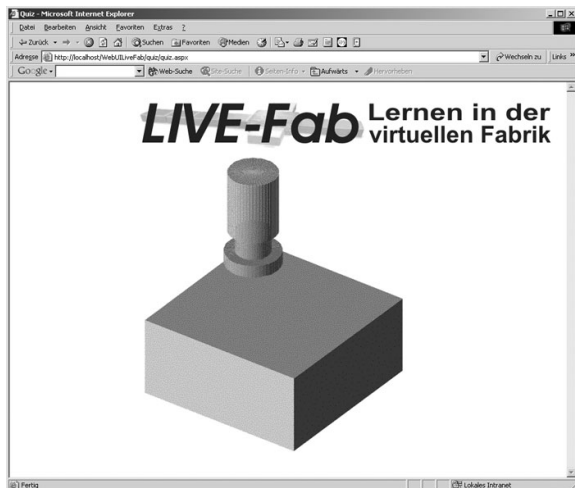

Figure 6. NC program simulation

At the end of the theoretical block the student is in a position to write a CNC-program and to correct it (cf. Figure 5). Should an error occur, a correction recommendation is made by the system and is carried out in the program. In the practical block the students must

first create a work plan for the manufacturing of a work piece (cf. Fig. 5). This work plan contains all steps from the creation of technical drawings, to the determination of technological and geometric data, to the actual manufacturing ("simulation of the manufacturing program").
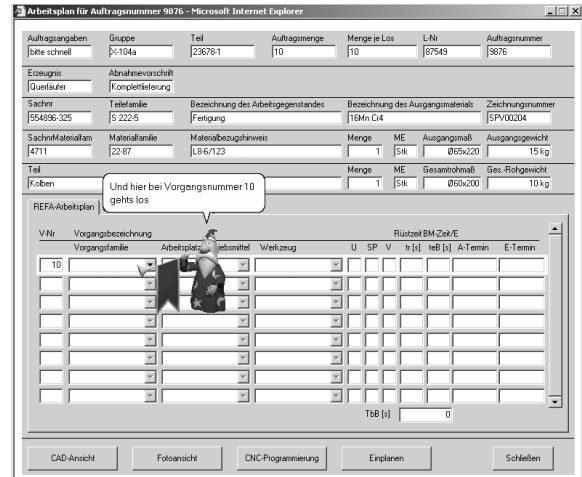

Figure 7. Agent technology

All activities undertaken by the student are supported by the "Context-Help-System" offered within LIVE-Fab. The learner can thus receive support in all phases of the processing of tasks. The configuration of the help system: when, how and where help can be provided is dynamically configured by LIVE-Fab through entries in the database. The help can then be carried out by implementing the Microsoft Agent Technology in the form of an animated assistant (cf. Figure 7).
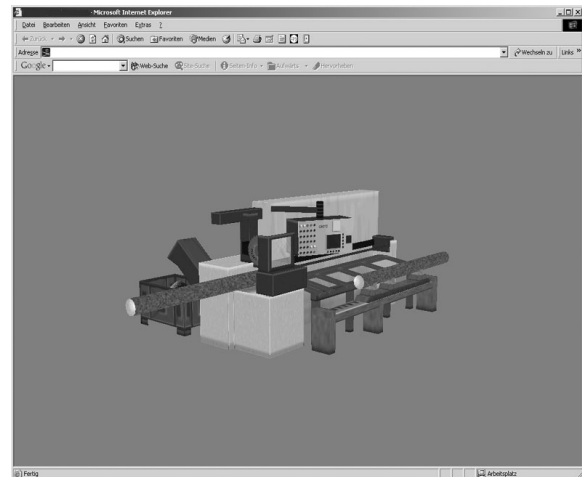

Figure 8. LIVE-Fab NC-machine simulation

4.2 Workplace Design

In this module information regarding fundamentals for the configuration of assembly workplaces is transmitted to the learner. The focus is thereby the configuration of the work sequence and the work-

place equipment. Questions relating to the configuration of the environment (lighting, noise, and climate) are also dealt with. The learner can consult important guidelines and threshold values in a glossary. Using the example of a part to be assembled, the learner passes through various phases of workplace configuration: analysis, configuration, assessment and realization. In the analysis phase the work operation sequence (precedence diagram) must be created. The learner has the possibility of being shown, with hypertext, the theoretical background and the procedural sequence or of having this demonstrated with a similar example (constructive learning). After that, he must create a precedence diagram for the assembly of an example product alone.

Figure 9.   LIVE-Fab "Quiz system" Web-view

This precedence diagram is then reviewed for errors by the program and possible mistakes are pointed out to the learner. In the second phase (ergonomic workplace configuration) the selection of equipment elements and the anthropometric and biomechanical configuration of the assembly workplace are focused upon. The importance of percentile values and those of the anatomical measurements as well as the inner and outer dimensions of the work-place should thereby be explained. Movement simplification and compression are also elucidated. Aside from the fundamental equipment elements (table, chair, footrest etc.) and their selection, the learner should be aquatinted with; in particular parts provision containers and assembly aids. The learner can select from a database of various aids and compare them with respect to time savings and costs before commencing with the configuration of the workplace. A focus is hereby placed on the arrangement of parts containers and assembly resources within the reach envelope as well as on the ergonomic sequence configuration. In addition to this temporal assessment, the assessment criteria for physical and psychological significance of the assembly activities should also be examined

through analyses of the assessment criteria in order to take the humans into account in the assessment. In the third phase the manufacturing costs are determined for the assessment of the assembly workplace, after the time allowances and the wage methods have been determined. Finally, the user configures an assembly workplace with the module, whereby learning and application phases are alternated.

5.   Gathering Information about Students

A concept for the dynamic creation and evaluation of a questionnaire has been developed in order to determine the learner's knowledge level and to put together a teaching plan for LIVE-Fab.

Questions with "Single-Choice" selection (cf. Fig. 8) are well suited for this questionnaire. The types of questions are defined in such a way that varying content can be represented. The questions are stored in a question pool (relations in the database) and offered to the learners according to a random sampling principle.
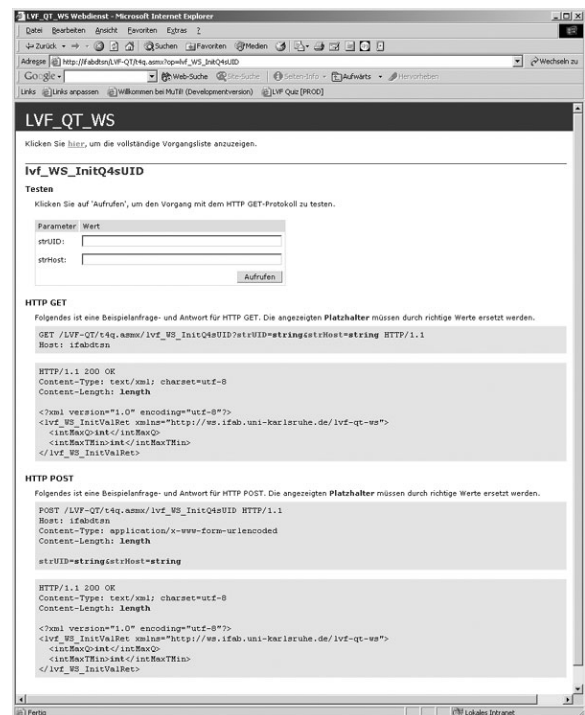

Figure 10. LIVE-Fab "Quiz system" Web service

The implementation of the questionnaire (Client/ Frontend) is done with the authoring system Macromedia Authorware 6.0 (cf. Figure 9).

The evaluation of the questionnaire is carried out with a classification system which delivers a qualification matrix as a result. This qualification matrix references the questionnaire results for the individual LIVE-Fab curriculum. The classification system divides the learner's knowledge into three groups: low,

middle and high level of knowledge per curriculum; other classifications can be implemented. Dependent upon the placement level the curriculum is adaptively compiled and offered to the learner within the virtual factory. The dynamic nature of the configuration of the curriculum is based on the analysis of the qualifications matrix by extracting the qualification vectors and their representation on the curriculum.

The questionnaire data is transferred between the server/SQL database through a Web service (cf. Figure 10) to the front-end with XML (cf. Figure 11) which uses SCORM DTD "QTIv1p1" (cf. SCORM). This format was chosen since it receives direct support within the authoring system and since a possibility for data exchange with other systems implemented according to this standard can take place and possibilities for transfer to other curriculum are provided within the question system itself. An interface which offers the possibility to exchange content with other systems which use this standard, since the storage of the questionnaire content does not take place according to SCORM DTD, has been defined .
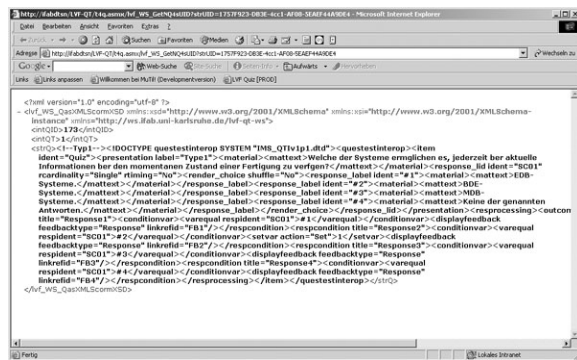

Figure 11. LIVE-Fab "Quiz system" question in XML (SCORM DTD)

6. Implementation

The Microsoft® Windows® (32-bit) platform was chosen in agreement with the other project partner for the implementation of LIVE-Fab. Preferably, Windows® 2000 or XP should be used. LIVE-Fab runs a client/server model, which is based on internet technology. Thus, the possibility for "absolute" media integration arises since no integrated development environment can work with types of media as well as a browser can.

The Microsoft® Internet Explorer (version 6.x or higher) was assumed in order to avoid the difficulty of different browsers with various programming models (Netscape® is also possible, but with a different "look and feel").

About the server, the Windows® 2000 server/ advanced server is used. This has the advantage that the necessary software products for video or sound

streaming are already included in the provided operating system. Thus, we had no extra costs for streaming media.

The database is implemented based on the Microsoft SQL Server 2000 and is available for the applications over ADO.Net. The data transfer between the database and the LIVE-Fab program modules occurs through XML. Dependent upon the user's content requirements a transformation of the XML data with XSLT takes place within the modules. Thus for future development the possibility also exists to not only support PC-systems, rather also tabloid-PC, PDA etc.
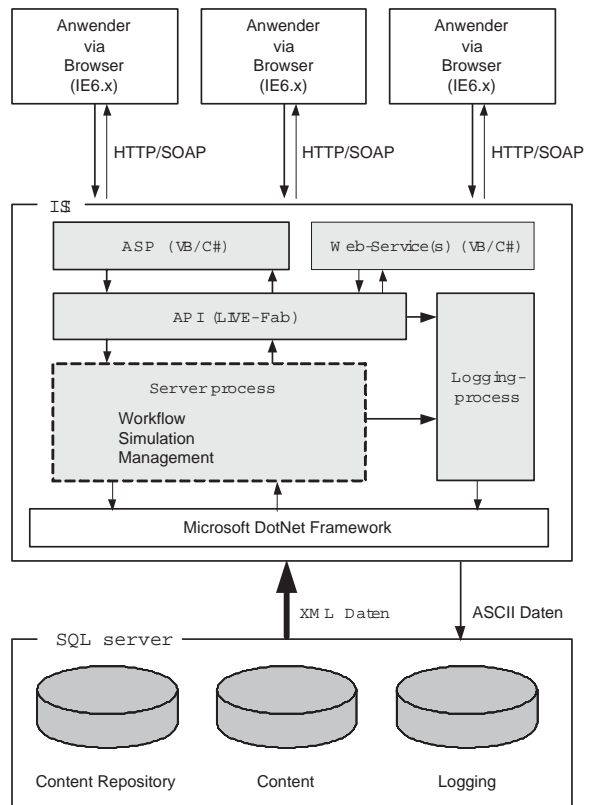

Figure 12. LIVE-FAB system design

7. Content

The software system consists of HTML (HTML 4, DHTML, and XML etc.), scripting (VBScript, JScript, JAVA applets etc.), embedded objects (Flash, Director, Authorware etc.) and video/audio. All curriculum items are stored as "objects" in the content database (SQL server). This server can be identical to the web server.

The use of a content management system is a possibility, but has thus far not been implemented. A content repository based upon the SQL database, which references the curriculum items, is also available. Thus, the possibility for changing the curriculum during a simulation arises since the referencing of

content repository does not need to be congruent with the content itself.

In order to record the system and user activities a logging-database shall be applied. This is however not currently being used (debugging exception only).

The creation of a certain curriculum is not integrated into an application and is carried out in individual steps in the various products. The created object is inserted, either integrated or separately, into the content database.

The student starts the system by activating the browser and connecting to the server (Fig. 10, Fig.12). After logon each user is referenced by a unique ID, which represents him during his entire use of LIVE-Fab. This unique ID keeps identical over time. The student addresses exclusively HTTP/SOAP request to the server and receives data exclusively through HTTP/SOAP in return. The uses of audio and video data, which are sent from the server with Microsoft Media Services (MMS) using streaming technology, are one exception.

The web sites are dynamic and based on Active Server Pages (ASPX) with VBScript or C# on the server's side. These web sites are connected to the server process for workflow, simulation and management with an Application Programmers Interface (API). One can use the logging process from all process levels. Also Web Services are implemented on the server, which act on SOAP requests, e.g. "Quiz system".

Server processes and ASPX web sites send request and receive answers from the content repository or rather content database with XML. Only the logging process runs, for reasons of simplicity, with pure ASCII data.

8. Outlook and further activities

The employment of new technologies may create ideal learning environments. Simulation is used to implement a real world scenario. Further development for collaborative working could be carried out by implementing a collaborative working environment for the virtual factory. One student drives only one part of LIVE-Fab and so on; so that e.g. five students build up the simulation of the factory.

The biggest step will be the transfer to real students (users). We must transfer LIVE-Fab from the developing lab to the "customer". This will show which of our assumptions are correct and which are faulty. Students will test the browser interface, the content, the simulation etc. Feedback will be given for further activities and other learning research projects.

9. Acknowledgement

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