D E R I V E

European IST Research and Development Project

Distributed Real and Virtual Learning Environment for Mechatronics and Tele-service

information society technologies

- Annual Report -

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Author(s)	Hauke Ernst, Prof. F.W. Bruns, Sven Grund, Hermann Gathmann, Dr. Ulrich Karras, Dr. Ian Hadfield, Kai Schmudlach
Abstract	
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Signature of the Project Manager

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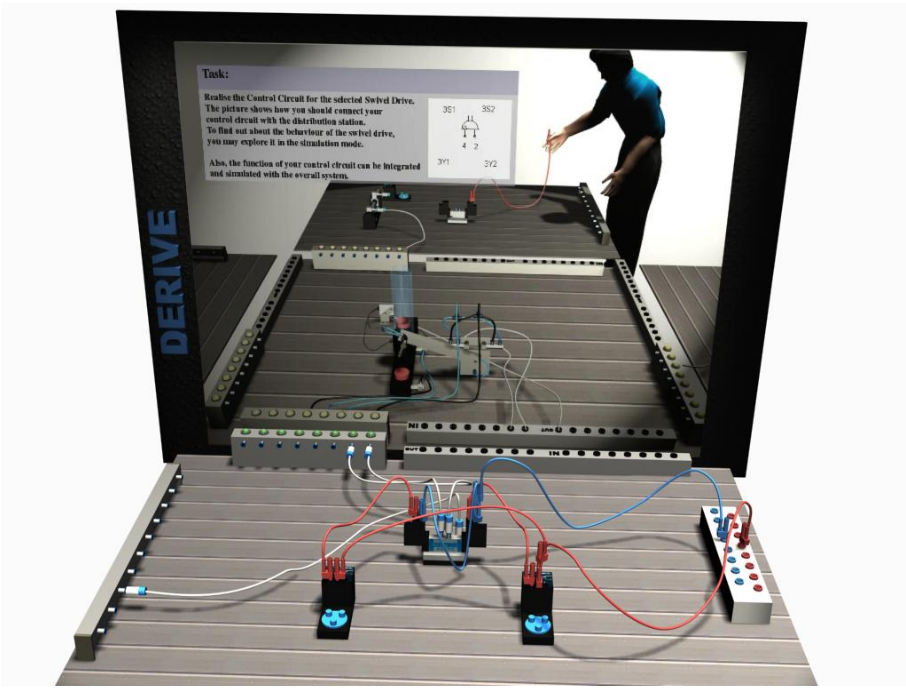


Project Co-ordiator
Research Center Work, Environment and Technology (ARTEC), University of Bremen
Prof. F.W. Bruns

Responsible Author:
Hauke Ernst (ARTEC)

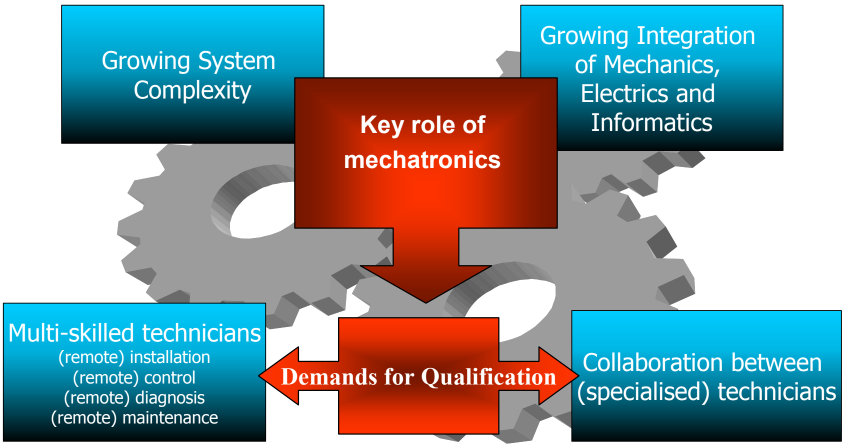
Co-Authors:
Prof. F.W. Bruns, Sven Grund, Hermann Gathmann, Dr. Ulrich Karras, Dr. Ian Hadfield, Kai Schmudlach

Content

1 SETTING THE SCENE

1.1 Project Background

Mechatronic systems play a key role in modern automation technology. It is obvious, that the dissemination of mechatronic systems simultaneously requires adequate service techniques. Mechatronic components can easily be integrated into telematic environments and corresponding work-concepts for tele-service such as remote diagnosis and maintenance of mechatronic systems. Mechatronics is therefore an enabling technology for tele-service. The emergence of remote diagnostic systems is very appealing to companies as it permits a more efficient maintenance and service of equipment. Problems can be diagnosed off site, and the appropriately qualified staff and equipment can be dispatched to solve problems.



The increasing dissemination of mechatronic systems in combination with tele-service implies new demands on the skilled worker in this field. Work in mechatronics requires knowledge of structure, behaviour and function of mechatronic systems. It also requires cognitive and operational knowledge about building systems, diagnosis and maintenance. A significant innovation is, however, the fact that working processes now are essentially characterised by the use of telemedial systems. In the professional field users need the ability to achieve their aims in (tele) co-operation with others, and they should be able to co-operate in virtual and supranational forms of organisation. Both, the professional and the social-communicative part of the working tasks are concerned.

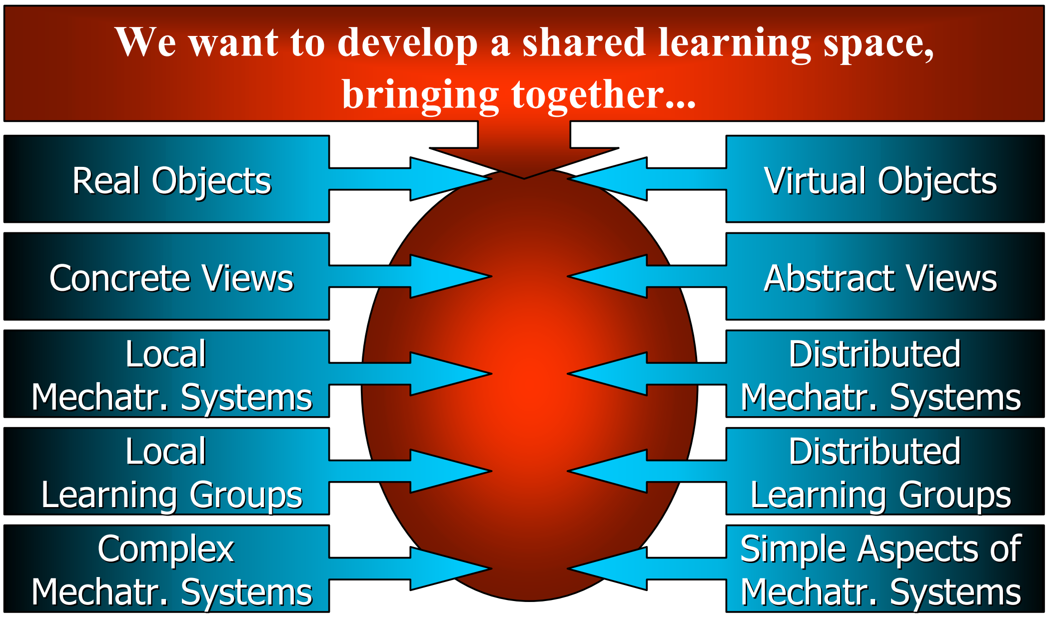
Schools are required to expose students to the types of equipment and situations they may experience at the workplace. With the increasing complexity of production systems it is unrealistic for schools to be able to simulate adequately the full range of systems operated in the industrial sector. Therefore, a co-operation with other industrial partners is required.

It is evident that many industries using vocational schools are pan-European or international. This situation requires the staff to^ meet at central locations to take part in common courses. This is very costly and the key staff is off the company for several days. On the one hand there is a move in many countries towards an emphasis on multi-skilling and a European harmonisation of training courses.

On the other hand, there are no elaborated concepts concerning pedagogical, technical and organisational aspects, particularly in the emerging field of mechatronics. Cultural differences and similarities concerning learning and collaboration styles can be noticed but have not been integrated into curricula, courseware and teaching methods.

1.2 DERIVE Objectives

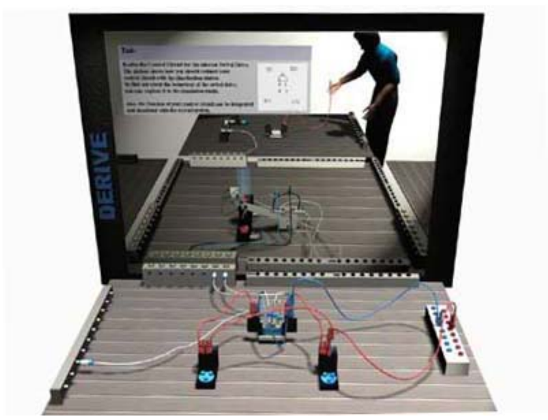
The DERIVE project brings together these demands with the development and evaluation of a new kind of multi-perspective learning environment. The learning environment will be used for vocational training in mechatronics, including first steps towards tele-service for production systems. It will consist of a combination of real and virtual, local and remote media.



A pedagogical concept which meets the requirements of learning and teaching mechatronics will be developed. In the mechatronics field the pedagogical and training concept will focus on providing the students in technical courses with experiences of the complexity of real production systems and to allow them to use resources which are normally only available at specialised sites.

The tele-cooperation functionality in the learning environment will allow companies to use the training facilities of vocational schools and/or other providers for training their own employees. The new environment will permit different groups of staff at remote locations to take part in training courses. Trainees will be able to work in a collaborative way to solve problems and to explore learning situations. This new kind of interaction will allow the systematic support of skilled workers and engineers by educators in vocational schools.

A learning environment which supports the achievement of the pedagogical objectives will be developed. The learning environment will support bridges between the real and virtual world with integrated simulations. We expect that the system will provide the function of freely replacing virtual parts by real ones and vice versa. With a special kind of electronic-electro-pneumatic coupling between the computer and a mechatronic hardware kit, it will be possible to build Hybrid-Hyper-Systems which can be considered as a mixture of real and virtual parts. The system may be distributed, having a set of real parts at one place and the virtual counterparts at remote places. This coupling will be realised by Internet links.



The envisioned learning environment of the DERIVE project

The suitability of the learning environment to achieve the pedagogical objectives will be evaluated. The effects of teaching and learning through the new technology will be analysed in different settings, including classroom only and various types of mixed classroom-workplace learning scenarios.

The market for innovative training systems for mechatronics will be initialised and extended. Numerous companies provide training materials for mechatronics. The project partner Festo Didactic is a worldwide trendsetter and market leader for training equipment in automation technology. Festo offers a broad spectrum of products related to the training for mechatronics with a worldwide market share of about 25 %. Through the development of the DERIVE system the position of partner Festo will be protected. However, the market potentials for innovative products must be developed before it can be exploited.

2 THEORETICAL FRAMEWORK

The theoretical roots of DERIVE are much influenced by the tradition of Shaping Technology by a Human-Centered Design Method instead of a socio-technological approach. This method, being in the tradition of Scandinavian action-research (J. Laesoe, 1993, Bedker, 1977) follows a shift compared to socio-technological approaches in that it is interested in the question "How do we enable people to design or change their own System?" instead of asking "How do we design systems to fit people?". L. B. Rasmussen and J. Laesoe propose four main principles of this approach:

1. Action research: Research and action, knowledge and utility are interwoven, not kept apart
2. User cooperation: Alternation between theory and practice is established as a dialogue between researchers and users.
3. Tool perspective: Users work methods and their tools "constitute a sensuously experienced knowledge, historically developed through practice, which we neither can nor should try to objectivize. Instead, we are to support the development of their work methods and use of tools by taking our point of departure in the tradition,…" (J. Laesoe, p.68)
4. Work culture: The design process is seen as an integrated part of the work culture.

If we try to apply this principle to the design of a learning environment, we have to take into account at least two types of users, the teacher and the learner, and the work situation is more a learning situation than a work situation. But it is interesting that we can transfer this approach also to school environments. Our project did not aim at a certain best practice or theory of learning, but asked for a close integration of teachers and students into the design process. Learning places, teachers and students were chosen to be very different, from a cultural, a technological, an education level and a teachers experience point of view. Experimental prototyping and visionary talks have proven to be a key element of our approach, as they have in the Scandinavian projects. Evaluation does on one side try to take a point of view of objectivity, but at the same time the designers always followed an approach where they tried to get insight and a feeling for the learning process based on individual experiences. The outcome of our project will be a learning environment, which takes into account different traditions of learning, different cultures of teaching and different connections to work. This spectrum covers pedagogical orientation from the German action orientation (H. Meyer, 1987), the Scandinavian and Russian activity theory (Engström) to American constructivist or even cognitivistic approaches.

We used formal development steps, but it would be misleading if we present them as a waterfall model or cycle model of sequential steps. The interaction between these steps is too much like a network of influences, even if the final documents have such a sequence. This is also the reason, why our project has so many difficulties with the expected sequence of deliverables even if we are good in time of the development process. The highly iterative incremental process of development is a key element of our work.

Laessoe, J. (1993): User-participation in the Shaping of New Technology. Cooperation between Researchers and Users in a Danish Project. In: W. Müller, E. Senghaas-Knobloch (Ed.): Arbeitsgerechte Softwaregestaltung.

Boedker, S. et al (1977): A UTOPIAN Experience: Design of Powerful Computerbased Tools for Skilled Graphic Workers, In: Bjerkens; Ehn; Kyng (ED.): Computers and Democracy

Engström, Y. (1999): Learning by Expanding: Ten Years After. Published as Lernen durch Expansion (Marburg: BdWi-Verlag; translated by Falk Seeger)

Meyer, H. (1987): Unterrichtsmethoden I: Theorieband. Frankfurt a. M.

3 PEDAGOGICAL CONSIDERATIONS

3.1 Looking Back

The analysis of future engineering workers has shown a significant change in the last 5 to 10 years. Traditionally engineers and technicians were classified into electrical engineering or mechanical engineering. These two distinct branches would work side by side but neither would encroach on the others area of expertise. However economic and technology changes particularly in the manufacturing industry has seen a new requirement from companies. With most manufacturing taking place in automated production lines, there is a need for technicians with a broad range of skills. Although the skills are not generally required to the same depth, the need for technicians to be able to perform mechanical and electrical operations is a clear requirement. The automation process also means that many manufacturing installations are now computer (PLC) controlled and thus a knowledge of information technology is also a requirement.

In response to these requirements from industry, governments and educational awarding bodies have developed new curricula and qualifications aimed at training technicians and engineers to meet these needs. In Germany the new profession of mechatronic worker has been introduced and in the U.K. vocational qualifications in Mechatronics have been developed. Also there has been a shift towards defining core aspects of vocation curricula to include elements of both electrical and mechanical engineering.

3.2 Relevant Learning Domains

Writers tend to separate learning into three domains[1]. These are psychomotor, cognitive and affective. The first is skills orientated and is associated with physical dexterity, in general the knowledge requirement is limited but there is a need for practice. In the cognitive domain we are concerned with knowledge. In particular the ‘how’ and ‘why’ and consequently more abstract thought processes are required. The third domain is often neglected and this is the affective domain. Here we are concerned with attitudes and beliefs. Generally these deal with feelings and emotions and are different from the other two domains.

If we consider the domains described above in the context of DERIVE we need to consider the needs of the learners and what are the curricula requirements of the technicians and engineers of the future.

Clearly these new qualifications require technicians to have practical skills and theoretical knowledge. Thus clearly hitting two of the domains described above. However, there are aspects of the third domain required in the training of these new technicians. The main area being in the cultural issues of manufacturing industry where there are still concerns about the value of multi-skilled technicians and engineers. The need to embrace and harness the value of new technology particularly in the areas of remote diagnostics and tele-service also impacts on the training of new technicians.

3.3 Adult Education

It has been argued by Knowles[2] that adults prefer to learn in different ways to that of children. He identified 6 assumptions[3] made about adult learning.

1. the need to know. Adults need to know why they need to learn something before starting to learn it.

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[1] Discussion from Chapter 2 I.Reece & S.Walker “Teaching Training and Learning a practical guide” BEP.

[2] Knowles M. “Andragogy: an emerging technology for Adult Learning (1970)

[3] Knowles M. “The Adult Learner: A Neglected Spieces” 1984

2. self-concept. The self-concept moves from teacher dependence to self-direction in the learning process. Adults have a self –concept of being responsible for their own lives. Once they have arrived at this self concept a need is developed to be seen by others and treated by others as being capable of self-direction.
3. experience. Adults have a reservoir of experience upon which to draw for their learning/
4. readiness to learn. Adults are motivated to learn those things they need to know and be able to do in order to cope with real life situations.
5. orientation to learning. Adults are motivated to learn when it will help them to perform tasks or deal with problems that the meet at work.
6. motivation. While adults are responsive to some external motivators the best motivators are internal pressures.

3.4 Conclusions

If we consider the theories and concepts set out in the above discussion and how they relate to DERIVE and the training of new mechatronic technicians, we come to some conclusions. Mechatronic technicians need to develop practical skills and have underpinning knowledge in their subject area. They will need to be able to develop logical thought processes for problem solving and most importantly be able to continually update their own knowledge.
The Andragogy discussion implies that adults would be motivated to learn new concepts and skills in relation to their work if it makes their work easier and they can see the reasons behind learning new skills and ideas.
In the work of BREVIE we discovered that the building of mental models can be improved by the use of symbiotic real and virtual worlds. In DERIVE this work is expanded by setting the real world situation into the context of a whole working machine.
From a practical point of view the concept of learning is complex and influenced by many different factors. No two individuals are alike and the skill of a teacher is in presenting learning situations that support each individual's style of learning. Motivation to learn is a critical factor and should not be underestimated in its affect on the learning outcome students.

The key element to the DERIVE learning environment is its flexibility. The methods employed by the teachers using the environment can range from free action orientated exploration, to tightly controlled planned activities.
The use of a central complex model develops a holistic approach and places the learning into the context of the real world. This develops relevance for the learning and gives it a practical application both of which are known to increase motivation.
The symbiotic link between the real and virtual world, helps to build on the cognitive theories that learners need to link their new experiences with existing perceptions. The use of symbolic and real world representations is known, from BREVIE, to aid in the development of mental models, thus in theory leading to deeper understanding.
In a practical teaching workshop (see *4.2 Getting Involved*) it became clear that learners, given, the freedom prefer to select their own learning style. With sufficient motivation and goal orientated approach it is clear that all methods lead to the same conclusion. In DERIVE the learning environment provides for practical, theoretical and hypothetical approached to learning. Development of communication tools within the environment can only help to encourage the sharing of information between protagonists of these different learning styles.

4 METHODOLOGY

4.1 Dual Approach

The profession of Mechatronics is a new and far-reaching occupation, therefore any user-requirements and acquisition for appropriate learning environments remain somehow speculative. To broaden the input for the DERIVE system, we use two different methods of user-participation:

- one by explicit questionnaires and interviews of representatives of stakeholder-Classes,
- the other as hermeneutic action oriented acquisition or "by getting involved" (known in the Scandinavian Work-Technology Science-Community as "Action Research").

The aim is to get an implicit and explicit knowledge and insight into the field of application. Especially for areas of uncertain development, innovative concepts or large differences in culture and experience, a method of subjectivist participation and observation in a common work oriented learning process seams to be promising.

In a Guide to Curriculum Revision and Development (CURRENT), Gronwald et al (1999) introduced a concept of curriculum development, differing from the traditional syllabus: "learning objectives and contents are included or excluded from the curriculum on the basis of their relevance for future situations in which the learner will find him/herself, rather than merely as dictated by the systematic of the subject in question." (p. 2) The decision-making criterion - "relevance for the future situation of the learner" however cannot be derived in a static analysis of the work performed at an existing work place or an existing learning situation.

"The formulation of learning objectives has in some places become an academic and semantic exercise. The original intention of making the situation in the working world in which knowledge and skills will later be applied as the criterion for deciding whether to include or exclude subject matter was never translated into practice. Now, at least in Germany, excessive formulation of learning objectives is at last seen with more scepticism.

In an effort to avoid the further formulation of unrealistic learning objectives, and to bring together, more closely, the learners with the work environment in which they will later apply their skills and knowledge, we will in general use the term "competencies", i.e. the goals of the learning process are defined in terms of the competencies to be acquired. *Competencies* embrace abilities, skills, knowledge and patterns of behaviour which are necessary in order to perform an activity. Traditionally a distinction is made between specialised, methodical and social competencies. The distinction between the major vocational competencies, as required for training, then results in the categories *technical/craft, business/entrepreneurial and environmental competencies* which translate the three traditional factors (specialised, methodical and social competencies) appropriately."(p 3)

We agree with the position, that an excessive detailed description of learning objectives is misleading, even if they are derived from a prospect of competencies. Instead, the aim of these learning objectives is to "strengthen the employment orientation, the relevance of the labour, goods and services markets in the competencies to be acquired in training. The curriculum should include *learn&work tasks* which combine congruent contents and methodical components that are tailored to the labour and/or goods market"(p.3). The term "Learn&work task" describes a concept of work-process oriented learning, where a learning task is derived by didactical and by/through social reduction and enrichment from a working task. "Learn&work tasks tell teachers, instructors and learners in concrete terms *what* should be done during training and *how* this should be organised. They thus encourage a practice orientation which is not achieved merely by listing learning objectives or competencies. Learn&work tasks, which for example include the production of simple products, can be presented in the form of sketches or drawings. They do not require long-winded written presentation. They thus take into account the disinclination of some teaching staff and learners to read long texts.

The term "curriculum" as we understand it thus includes exemplary learn&work tasks, as well as methodological pointers alongside the description of the competencies to be acquired and the subject matter to be covered, which should be laid out as briefly as possible. The learn&work tasks can, for example, be disseminated with the curricula in the form of flexible components.
A distinction is generally made between open and closed curricula; the former do not specify everything, but leave some leeway for teachers and learners to decide on contents and methods. Not infrequently, closed curricula are called for on the grounds of the lack of competence of teaching staff. It is however impossible to "cover" a closed curriculum with learn&work tasks. The learn&work tasks should rather be used as examples, to give teachers and learners ideas on the basis of which they can develop their own tasks in line with local conditions and possibilities.
We do not see curricula as a static diktat, but rather as a process-type development in which teaching staff, learners, employed individuals and "users of manpower" (employers and self-employed small and micro entrepreneurs) should be involved on an ongoing basis. This is the only way of ensuring genuinely employment-oriented training, that not only takes into account the dynamics of the working world, but actually helps to shape this.

We try to reflect this position in our focus on learn&work tasks. On the other hand, we have to fulfil traditional requirements of curricula based on systematic objectives and competences. We therefore also derive a framework for desirable and supportable competences as a complementary perspective. These two views on vocational education (learn&work tasks and competence orientation) will be supported by a dual mixture of user-requirements acquisition: by interviews and by case studies.

Our search for adequate learn&work tasks is an iterative process of action research taking place on different levels of application and different levels of cultural background. One characteristic of these activities is, that they are not always deliberately organised for the aim of user requirement specification (for DERIVE) but may have their primary reason in some other contexts. Some of them are

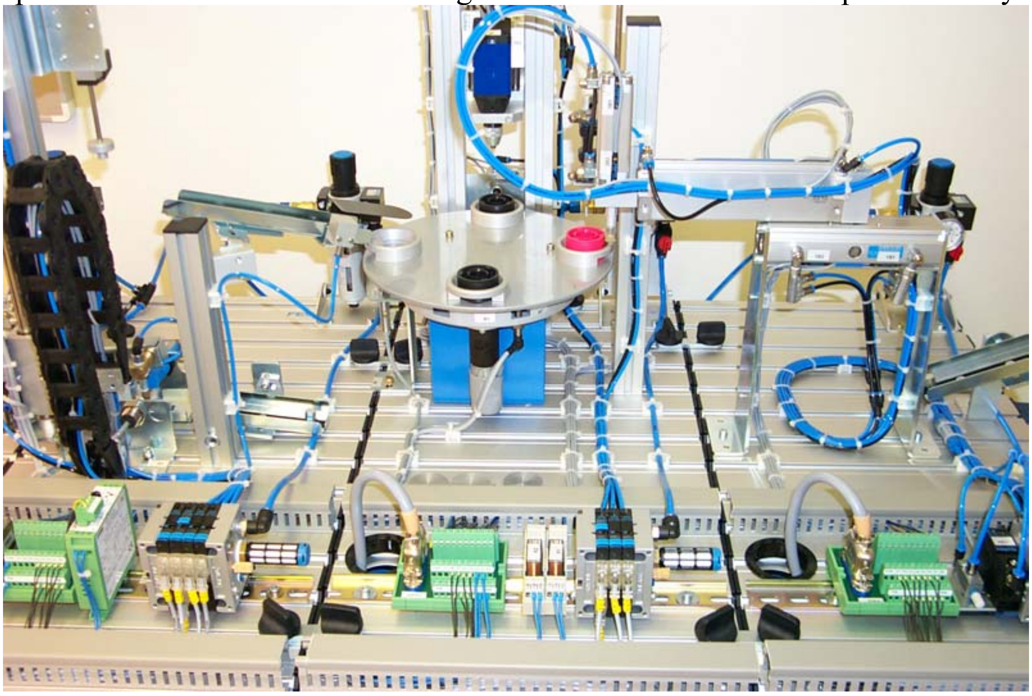
- laboratory work with a Modular Production System for teacher-students
- laboratory LEGO work for teacher -students
- experiences of classroom teaching done by teacher-students
- theoretical framework of experienced based simulation
- self experience of the DERIVE project team
- further education of polytechnic teachers and chamber of commerce experts
- further education of vocational, high school and college teachers
- in depth study of maintenance and repair work at an airplane service SME
- installation of PLC-programmes at an automotive producer by a service provider
- installation and optimisation of control programmes for a unique CNC-milling machine
- installation and adaptation of operating systems and control programmes for material testing machines
- maintenance of a laboratory equipment for a Flexible Manufacturing System (FMS) with non-frequent use for education
- remote installation of a learning environment supported by desktop-sharing
- understanding and presentation of the DERIVE concept from some popular point of view

From these case studies and interviews our assumption that the work-situation of mechatronic and tele-service workers and their competences and qualifications are far from being clear, is well supported. Nevertheless, the sum of interviews and case studies experienced so far, provides a good basis for a rough picture of needs.

If we want to support all these different needs with one learning environment worldwide, we have to be very modular, very scalable (up-gradable), very visionary. With Festo’s Modular Production System (MPS), we have chosen a good starting point. Further requirements should improve this product to suit new learning tasks.

4.2 Getting Involved

In order to explore the pedagogical concepts and teaching methodologies of action orientated learning and constructivism, members of the DERIVE consortium and students from ARTEC embarked on a workshop exercise in November 2000.
The aim of the exercise was to explore the experiences of students placed in an action orientated learning situation and to look at the management of these experiences from a teaching perspective. The participants at the workshop were 3 teachers of Mechatronics and Electronics and 3 Engineers with experience of Mechanical, Electronics and Infomatics. The group contained a mixture of novices and experts but had no concrete knowledge about the FESTO modular production system.



Distribution and testing stations of MPS

The participants were given the task of exploring an automated production line consisting 4 stages. The scenario set was that the machine was not working and that there was no person available to operate the machine. The documentation for the machine was incomplete but there were available detailed component descriptions. A further though unplanned complication was that the machine had a real fault not known to the facilitator at the start of the workshop.
In summary the participants moved through a number of phases. Initially sub-groups formed with the idea of looking at individual stages of the production line. This approach quickly failed due to the complexity of the machine and the interrelationship between the stages. After a period of time there was a realignment of the groups with individuals working with partners with similar learning styles. Three groups emerged a practical group, a theoretical group and an activist group. The practical group continued to look at the real hardware. The theoretical group concentrated on the documentation and the activist group look at a software simulator to hypothesis about the actions of the machine.
During the first group review it became clear that this approach to learning required the group to self-organise and also to have good lines of communication. As the group was highly motivated there was a clear drive towards achieving the goal from all members. However, it was recognised by the group the facilitator was required to ensure that good levels of communication existed in the group and that when the group realigned, that the talents and merits of the individuals be recognised. The group would also have benefited from a more formal team building approach with the identification of leaders/coordinators.
The group reached a number of brick walls and it was only the motivation of the participants that allowed them to pursue the solution to the unknown fault. The group discussed at great length the motivation factors for students in mechatronics. This now raises a question in terms of the teaching

approach. In the previous section it was suggested that adults are motivated in different ways to children. In the case of this workshop this proved to be the case, in that the participants were all adults and all highly motivated being in the upper stages of Maslow's hierarchy of basic needs. But were do students in tertiary education sit? Before this stage of their education they are considered to be children and then they are suddenly exposed to the adult world. This transition is clearly not a step change and for some students the transition time takes a number of years. In terms of Maslow, these students are generally only in the middle stages of basic needs and are still seeking acceptance in the real world. At this level they cannot be considered to have the mature motivating factors associated with adults and this means that teachers need to consider how many degrees of freedom are afforded to students in vocational studies.
The workshop undertaken in November 2000 was extremely useful in highlighting the approach to be used in DERIVE and how it may need to be adapted for the situations experienced by teachers in the classroom.

4.3 User Participation

There were several user participation activities. Links to industry, to institutes as well as to teachers and students in other schools were established and interviews were made.
A special workshop for user participation issues took place in Denkendorf with all project partners (17. and 19.5.2000). We had a brainstorming session concerning user requirements as well as training scenarios. We defined user participation mechanisms, coordinated the forthcoming tasks for each partner and prepared material for the interviews with potential users. Furthermore, all partners have now installed contacts to local industry and involved external experts in mechatronics training.

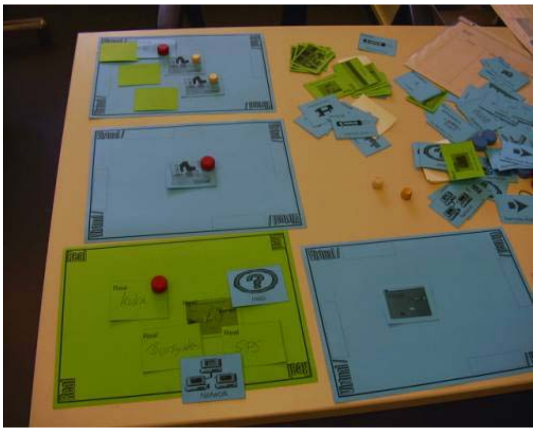
During the interviews it turned out that the new learning environment might be successful if it can be used as a universal tool supporting multiple and manifold training scenarios for mechatronics. Therefore an adequate level of system complexity is important. The necessity of integrating PLC was stressed out in several interviews.

Despite demanding a lot of effort, these interviews and contacts will be continued. Demonstrations of DERIVE prototypes will give the companies, schools and other institutes the opportunity of observation and further influence on the design of the new learning environment.

Participation Tool
The participation process itself required new tools and methodological means, therefore we developed a participation tool, based on a concrete open mock-up toolbox (J. Huyer 2000) and guidelines for user inspiration
For each partner, we put together a box of materials, which we call 'DERIVE Participation Tool'. The material is designed to beversatile enough to discuss different scenarios.
It consists of:

- Brainstorming material in terms of cards with images
- Information flyer as a handout for external users/experts

Interview guide including a template for interview protocols



Interview with User Participation Tool

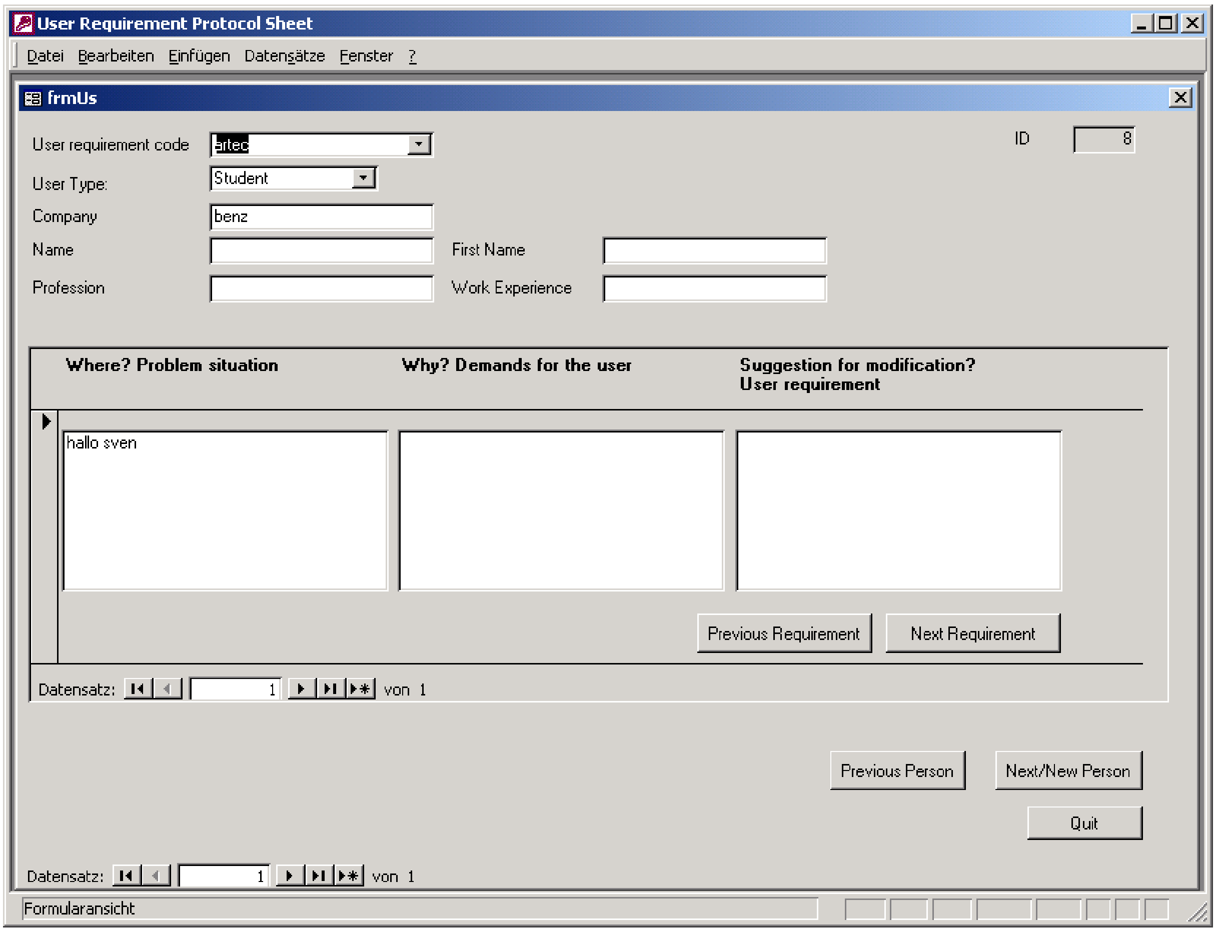
DERIVE Information Event in Zurich
Partner IfAP (Institute for Work Psychology) ETH Zurich invited 52 companies, 16 vocational training schools, and 8 ETH Institutes all over Switzerland, to take part at a DERIVE information event by an invitation letter including research and project information. The companies and schools were selected by their vocational training proposal for students to study polytechnician, the mechatronic expert in Switzerland. The event took place at the 8th of December, 2000 at the ETH Zurich. Three vocational training schools (Bern, Solothurn, Winterthur), three companies (Gretag Imaging AG, Alstom and Rockwell, Zellweger Luwa AG) and two ETH Zurich Institutes (Architecture, IHA) participated in this event. The following topics were presented:

- Presentation of the BREVIE and DERIVE concept and further developments
- BREVIE research results: Is real experiences still necessary in vocational training?
- Live on-line demonstration of the virtual DERIVE system with artec performed by Kai Schmudlach in Zurich and Juergen Huyer at artec
- Discussion about open questions and further co-operation

The event started at two o´clock and ended at half past five in the afternoon. The participants were interested in the research results as well as in the DERIVE system. In discussions we talked about their personal experience in training with new technologies, options of co-operation in usability tests and system use at their schools and companies. The minutes were send to each participant at the end of the meeting.
Two schools are taking part at the first usability test of an early DERIVE prototype and afterwards each school will get a full DERIVE system to be used and tested as a concrete result of this event. One school will perform a project week with the DERIVE system.

4.4 Selection Process

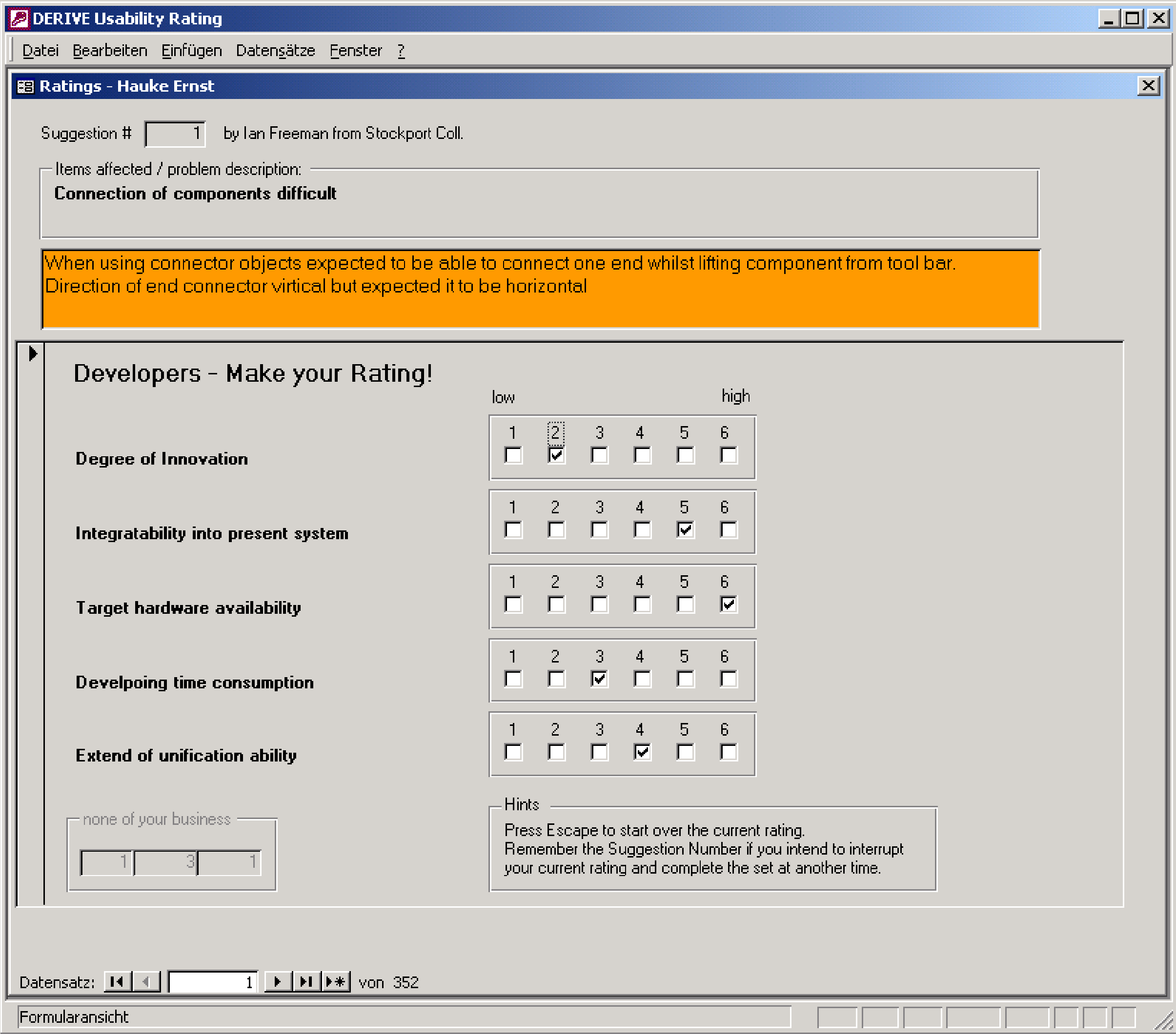
User requirements are collected during interviews with the participation tool (see chapter above) or by observations during trials with prototypes. To maintain and filter the resulting user requirements, ideas and hints, we developed a database tool. With the following form the interviewers can type his session protocol as a structured list of personalised user problems together with hints to solve the mentioned problems.



The user requirements database is maintained at the ETH Zurich. Regularly, the project enters a requirement scoring phase, where new requirements are scored by the pedagogical and technical experts in the project. Two scoring forms with pedagogical – or respectively technical - scoring categories are used:

Pedagogical Categories	Technical Categories
Support Pedagogical Subjectives	Degree of Innovation
Support Different Learning Styles	Integratability into Present System
Motivation	Target Hardware Availability
Independent Learning	Developing Time Consumption
Knowledge Transfer	Extend of Unification Ability

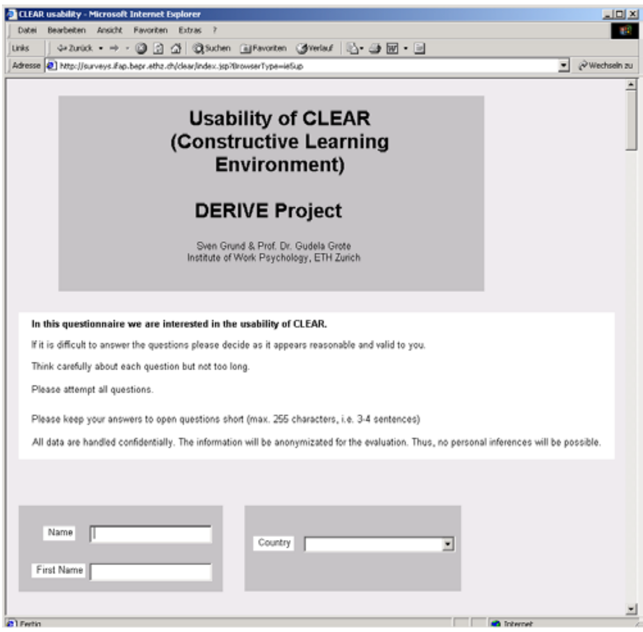
Scoring Form for Technical experts:



The result of the scoring is a sorted list of requirements which is an appropriate basis to discuss and decide which requirements should be implemented within the project.

4.5 Online Questionairs

We performed an **intensive market analysis** for online questionnaires and tested some systems for their applicability (http://rogator.de, http://internet-rogator.de, http://www.siriusteam.ch/english/default.htm, http://www.surveyormanager.com/default.htm , http://nettz.de/Formular-Chef/, http://www.spss.com)
After the test we decided to use the SPSS software package, because of the stability on different browsers and server accesses.
An online questionnaire for the 1st evaluation phase (focussing on usability) was developed and published on a web server.



4.6 Interview Guide

In the area of **evaluation design specification** we develop an usability interview guide including a protocol sheet and an usability video (30 minutes) as an example on how to perform the DERIVE usability test.

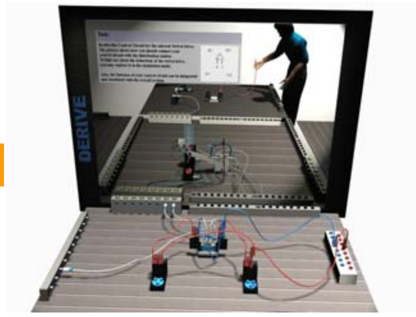
^

CLEAR[tm]

Constructive Learning Environment

for Mechatronis

Clear[tm] for Mechatronics is a dedicated learning environment for mechatronic training. It provides you with a suitable set of tools and equipment for your laboratory and covers a wide spectrum of your curriculum. With **Clear**[tm] for Mechatronics you can run real pneumatic or electro-pneumatic components on a baseboard. Your real circuit can run together in connection with a complex, simulated factory context. The real subsystem can be handled as a separated aspect of the virtual system, integrated with a special sensor/actor interface. The system works both in a local classroom setting as well as in a network of distributed learning groups, using **Clear**[tm] as a platform for communication and collaboration. This provides the possibility to work with remote schools or companies together on complex tasks or projects.
Clear[tm] for Mechatronics is not just a loose collection of standalone tools. Instead, it is an integrated learning environment providing diverse interfaces between software components and even hardware equipment.



Distributed Constructive Learning Space

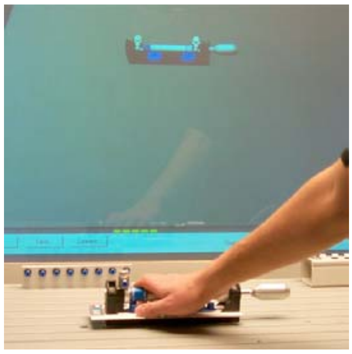
A 3D environment with avatars provides a consistent and intuitive user interface. Virtual mechatronic systems can be visualised, safely simulated or even constructed. Also, the environment includes communication functionality.

Mechatronic Construction Kit

With the reliable hardware toolkits of FESTO Didactic students can construct authentic pneumatic or electro-pneumatic circuits.

Simulation

Simulation has proven to be a valuable tool for planning, programming and optimisation of robot work cells and control circuits. It is cost efficient, safe and supports explorative learning without any risks. Complex system behaviour can be easily understood.



Hyperbonds

Mechatronic hardware equipment can be connected to a virtual environment with a special sensor-actor coupling. This virtual environment gives you i.e. the impression of tubes and wires as if they were reality.

Optical Circuit Recognition

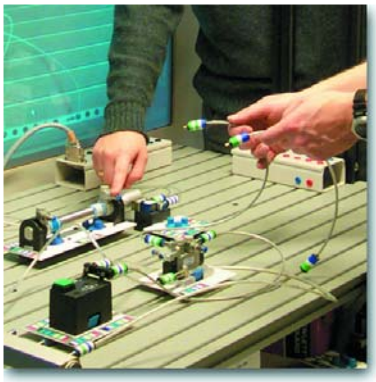
Real electro-pneumatic circuits can be directly imported into the virtual world. A system with camera and image recognition software captures the components as well as tubes and wires with barcodes. 3D representations and circuit diagrams are automatically generated.

Hypermedia Assistant

Easily accessible web-based learning material contains theoretical background information, online exercises and component libraries.

ROMAN[tm] Technology

The RealObjectManager (**ROMAN**[tm]) platform coordinates the interoperability of the software tools and hardware equipment. It synchronises model data in the system components and handles network access.

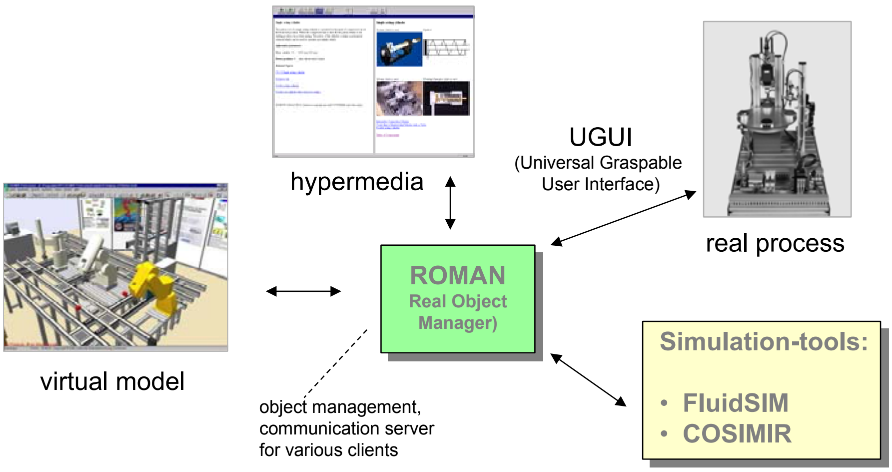


6 TECHNICAL DEVELOPMENT

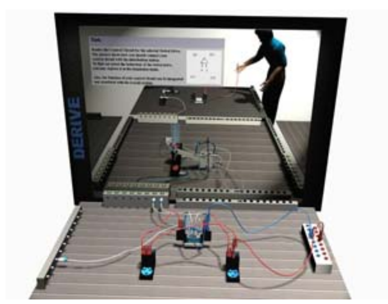
6.1 Architecture

The DERIVE system architecture and its central components where already realised in prior projects, especially in BREVIE. It was shown that this architecture is suitable to form a coherent application.

One important component is the Real Object Manager (**ROMAN**), a central module which controls the communication and data flow between the subsystems. The **ROMAN** maintains a model data base where the virtual circuits are stored. It is also the task to provide access to learning material, interface the off-the-shelf simulator **COSIMIR** and integrate the overall system under a coherent graphical user interface. Via the *Universal Graspable User Interface* ***(UGUI)*** the virtual model is interfaced to the real hardware process, utilising diverse innovative devices such as the hyperbond, an image recognition system etc. All software components are realised as specialised software agents that connect to the central *ROMAN*, register their services and communicate with each other via **ROMAN**. The network of communicating ROMAN clients forms the overall (software) system. Additional to the **ROMAN** a **DirectPlayerLobby** handle's the audio, video and chat communication.



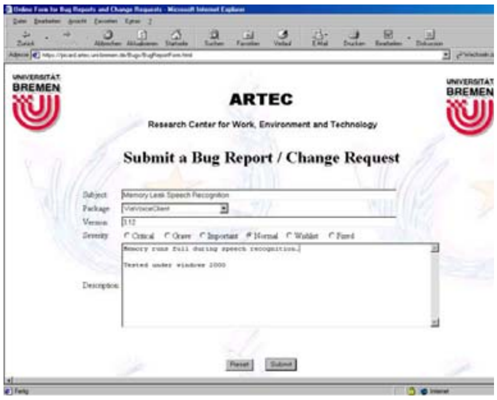
6.2 Progress



Several technical meetings (FESTO, ARTEC) took place in Bremen and Denkendorf, where hardware development issues were coordinated and tasks were scheduled.
Technical requirements were derived from user requirements and a common view among the project partners on the envisaged system was achieved. A technical design was developed, taking into account the technical basis which comes from the BREVIE project. Hard- and software units were identified and defined as task descriptions for developers.

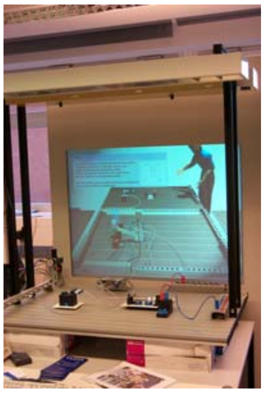
We set up configuration management mechanisms and de-

fined a structure for the software repository.
We improved the quality of existing software components which will be used in DERIVE.

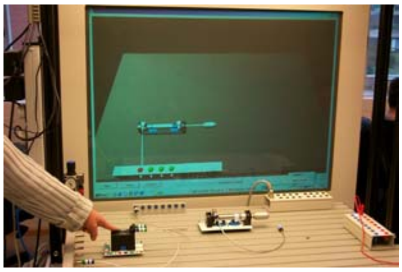


The central software components of the planned DERIVE system were tested concerning their stability and labelled as a release version. This version will be used as a frozen platform for DERIVE and will be modified only after an explicit decision in the weekly developer meeting.

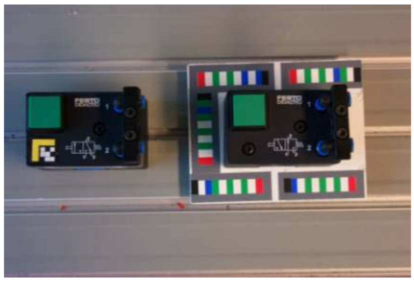
A video projection screen that fits the modeling tables in size and height was manufactured by Larivière Digital Presentation Systems. It can also be laid on the back to become a modeling table with a projection from underneath. The projection screen was refined by manufacturing a cloak-cover for the back of the screen to become more independent from the environmental lighting.



FESTO's IO-device easyport has been integrated into the DERIVE system as a UGUI plugin-device to become part of the hyper- connector. It can be switched remotely by our software and the sensory results are connected to the scene-graph maintained by the ROMAN server. We can demonstrate the first real-virtual hyperactions with this interface.
The circuitry of the real side of the hyper-connector interface ^has been designed and tested. The development of the hyper-connector is now finished, integrating the real circuitry with the virtual one.
The circuitry of the real side of the hyper-connector interface has been miniaturised and manufactured by FESTO.

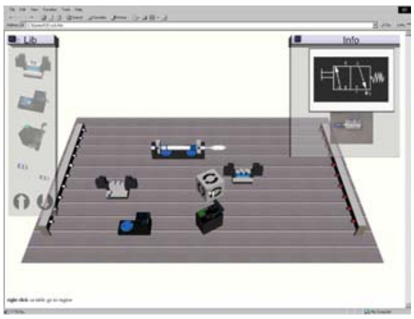


A first prototype of the new image recognition system that allows dynamical calibration, high precision recognition and permanent table synchronization has been completed.
The new mini-colour-barmatrices are recognised by the image recognition system as well as the large old-style barcodes.



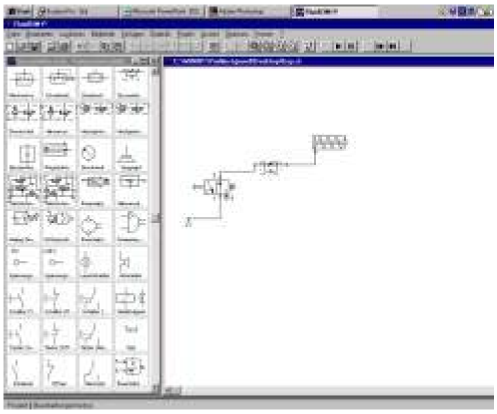
A first prototype of an optical pointing device as well as a radio-based button signalling has been completed. Trials will take place if this new device is useful to select real world objects.

A 3D scene editor, running on a web site, was produced and the connectivity to the ROMAN server was partially implemented.



The required electro-pneumatic 3D models for the 1st evaluation trials have been created. A number of pneumatic VRML models from BREVIE have been remodelled to decrease bandwidth and computational requirements of the 3D viewer. The geometry is defined as VRML97: functional properties using VRML-script. A template library to reuse

parts from was created.
FluidSim is connected to the ROMAN system, allowing simulation of pneumatic as well as electro-pneumatic circuits.
Via ROMAN, the 3D scene editor on a web site is connected to FluidSim and circuit modifications are synchronised. It is planned to deliver this configuration to the partners for the 1st evaluation in May 2001, but there are still some stability problems. The interface to FluidSim, provided by FESTO's partner *ArtSystems*, is based on DDE and seems to be technically inadequate for a stable real-time interface.



First experiments with the robotics simulator Cosimir have been conducted to demonstrate the capability of the networking interface.

A market watch was undertaken to determine an adequate third-party system to supply audio/video communication support that can be incorporated into the DERIVE system. It was decided to use the *ActiveX 8 SDK* for integrated many-to-many conferencing support.

7 COURSES

In DERIVE, five teaching units are planned to be delivered in three phases and the titles of these are shown in the table below.

unit	*Title*	*phase*	*duration*
1	Usability	1	2 hrs
2	Collaboration and Communication	2	3 x 2 hrs
3	Advanced Mechatronic Systems	2	20 hrs

The three evaluation phases have been dedicated to evaluation of different aspects of the project.

7.1 Phase 1 - Usability

This phase of the evaluation is dedicated to usability testing of DERIVE system components. In particular evaluation of the software ergonomics and general bug hunting will be investigated. The evaluation will produce a list of requirements that can then be tested against criteria for inclusion in the final development of DERIVE.

The original teaching unit proposed to use a typical fault finding scenario. Students would be presented with a circuit containing simple and complex faults and use the tools available in the DERIVE system to find the faults. During the teachers meeting in Zurich (January 2000) it was felt that these tasks would not allow the consortium to explore fully the features of the DERIVE software. It was also evident that the hardware development would not be sufficiently complete for the evaluation to encompass the hardware aspects at all the delivery sites.

Under these circumstances it was decided to focus the teaching unit on the design, construction (virtual) and simulation of circuits, rather than fault finding existing hardware circuits. In terms of the evaluation these changes would allow the consortium to explore more aspects of the DERIVE environment whilst still providing typical learning scenarios.

An important feature of these teaching units is the limited involvement of the teacher in the learning. This aspect is necessary to evaluate the usability of the system and to explore the intuitive look and feel of the software interface.

7.2 Phase 2 – Communication and Collaboration

This phase of the evaluation is dedicated to communication and collaboration. The three areas to be considered are tele-service, collaborative design and distance teaching. In this phase of the evaluation the team will explore the tool requirements for these tasks and to test existing and tools built into the DERIVE system.

It is planned to deliver this part of the evaluation in three stages.

- Teleservice – remote service of a system.
- Collaborative design – between students on the same problem.
- Distance Teaching – delivery of a lesson to students at different evaluation sites.

7.3 Phase 3 – Learning Benefit

This phase of the evaluation is dedicated to the learning benefit of the DERIVE system, compared to traditional and modern teaching methods. The benefits and experience of the BREVIE evaluation have significantly influenced the design of the DERIVE evaluation.

In the evaluation of BREVIE it was found that by careful control of the teaching scheme and lesson plans, it was possible for teachers at the different evaluation sites to deliver lessons in an identical way. This result has been significant in the design of the teaching units for phase 3 of the project.

Since the DERIVE project is linked to the more complex (and expensive) hardware of the FESTO MPS, it was considered difficult to ensure that there would be sufficient working prototypes of the fully working DERIVE system at each delivery site. In addition it was difficult in BREVIE to organise the teaching of different scenarios when the system set up was changed for each scenario. As such it was decided to deliver phase 3 of the project with one different teaching method at each delivery site.

The table below shows the allocation of the teaching methods

Teaching method	***Evaluation Site***
TRADITIONAL TEACHING	ESTG – Portugal
DERIVE LIGHT	Stockport
MPS	Festo Didactic
DERIVE	Bremen

As a development of BREVIE it was also decided to add a fourth teaching method. The DERIVE light model involves the use of software only. Students have all the features of CLEAR but do not have the hardware components. This scenario is of particular interest to schools as it may bridge the gap between using pure symbolic simulation tools and practical hands on experience. It is hoped that by using the 3D simulation students will be better able to transfer their knowledge to the real world.

In the design of this teaching unit it has also been necessary to increase the number of hours required to deliver the unit. It was felt that since the incorporation of programmable logic controllers was a definite requirement of mechatronic systems, the time of 16 hours for the delivery of the unit would not be sufficient to evaluate these aspects effectively.

7.4 Summary

Partner	Ph 1 (Usability)	Ph 2 (Collaboration)	Ph 3 (Learning Benefit)
Artec	Usability	-	-
Stockport	Usability	Collaboration	Simple Virtual / Complex Virtual
ESTG	Usability	Collaboration	„Traditional“ (Frontal, Real ...)
TBZ	Usability	Collaboration	Simple Real / Complex Virtual
Festo	Usability	-	MPS
ETHZ	Usability	-	-

8 DISSEMINATION AND EXPLOITATION

The Dissemination and exploitation of the DERIVE results is an essential part of the work in this project and contributes essentially to its success. With regard to dissemination the activities comprise the preparation of dissemination material as well as continuous dissemination activities.
The dissemination material that has been produced so far includes the creation of a common design, including logo, web page, flyer, poster and flash presentation. From a marketing perspective this unified design is important for a common identification of the project and later of the product.

The work done in the work packages *Dissmenination and Use Plan* and *Preliminary Product Specification* are fundamental for exploitation. In addition, the project investigated IPR issues at the IPR Helpdesk and signed a Consortium Agreement.

The deliverable D62 (the preliminary product specification) reflects a clear common understanding of the product concept which is very important for the objectives the DERIVE project wants to achieve. The task of workpackage 6100 (Dissemination and Use Plan) is to work out steps of how to disseminate the product idea and to create a use plan to identify the target market. In particular, the user participation activities of all project members to get into contact with external experts and potential users provided a successful way of dissemination. The work in WP 6200 was important for presenting a rather clear picture of the product concept.
We succeeded in winning a member of the Festo Training Department for the project. We are now able to use their marketing activities for the dissemination of DERIVE.

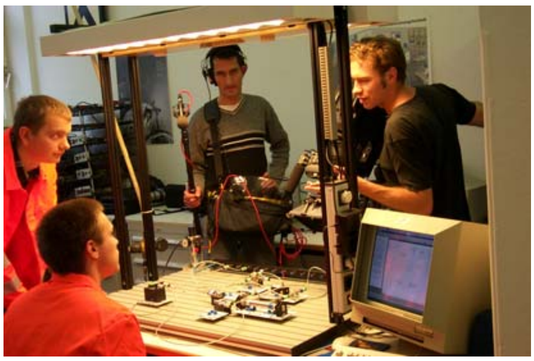
A homepage for DERIVE (http://www.derive.uni-bremen.de) was developed which will be continuously updated. Project flyers and posters as well as a flash presentation were created.

The exploitation strategy of project results was discussed (Karras, Ernst). Several meetings were organised at Festo in Denkendorf , artec in Bremen and IRF in Dortmund to make sure that all different aspects are taken into account for product development.

Exploitation of the DERIVE technology will be done by FESTO Didactic together with the new start-up company ***BendIt Innovative Interfaces***, which is a spin-off from partner Artec. There are very concrete plans and activities for exploitation, but – taking the exploitation issue seriously – the details about the strategy will not be published at this stage.

The DERIVE project idea was presented and discussed at several occations:

- Project presentation at the first meeting of the Virtual Learning Communities Cluster in Bremen
- Project presentation for a representative of Festo's training department
- Project presentation in a workshop session at CVE2000 (Third International Conference on Collaborative Virtual Environments ,sponsored by: ACM SIGCHI, SIGGROUP, and SIGGRAPH) in San Francisco
- Poster presenting the related FP4 project BREVIE at CHI2000 in Den Haag
- Project Presentation on the Conference "Network Event Lernnetzwerke und Wissensnetzwerke 2000" in St. Gallen/CH (09.08-31.08.2000)
- A lecture on a mechatronic workshop was held on 24th May at the Chamber of Handicrafts in Bremerhaven /DE
- Beyond Europe our project was introduced during a one week summer school seminar at the Korea University of Technology & Education in Chungnam (South Korea).
- In Bremen, an introduction of the BREVIE/DERIVE projects was produced for the German TV programme *"Nano"* on channel 3SAT.
- *BREVIE Evaluation: Lessons Learned* presentation at the Concertation Meeting 8 – 9 January 2001 in Luxembourg
- *BREVIE Research Result* presentation and a one day DERIVE exhibition at the 12-14 February Online Learning 2001 Europe in London
- *Multimediales Lernen: Wie wichtig ist die Gegenständlickeit?* including a publication and an four day DERIVE exhibition together with Kai Schmudlach, University Bremen artec on the Mensch & Computer 2001 5-8 March 2001.
- DERIVE information event on the 8th of December 2000 in Zurich with 52 companies, 16 vocational training schools and 8 ETH Institutes from all over Switzerland.



9 NEXT STEPS

The second year of the project will be characterised by evaluation phase I, II and III. Partner Artec and Festo will be busy to implement remaining system components and to deliver integrated prototypes to the other partners. Also, on-site organisation and preparation of evaluation material need to be done.

Concerning exploitation, the next reporting period will concentrate to a greater extent on the task of describing the discussed exploitation plans as a deliverable. Also, the marketing strategy has to be defined.

10 Contact Details

Willi Bruns *Projectcoordinator*	artec	bruns@artec.uni-bremen.de
Hauke Ernst *Projectmanager*	artec	ernst@artec.uni-bremen.de
Jürgen Huyer	artec	huyer@artec.uni-bremen.de
Kai Schmudlach	artec	sks@artec.uni-bremen.de
Martina Braun	artec	braun@artec.uni-bremen.de
Mladen Ilic	artec	myx@artec.uni-bremen.de
Rainer Pundt	artec	pundt@artec.uni-bremen.de
Ian Hadfield	Stockport	ian.hadfield@cs.stockport.ac.uk
Barry Boardman	Stockport	barry.boardman@stockport.ac.u
Paulo Gatha Amaral	ESTG-IPL	pgata@estg.iplei.pt
Nuno Gil	ESTG-IPL	ngil@estg.iplei.pt
Hermann Gathmann	SZ Holter Feld	gathmann@uni-bremen.de
Ulrich Karras	FESTO	dka@festo.de
Dieter Waller	FESTO	wll@festo.de
Helmut Meixner	FESTO	mx@festo.de
Sven Grund	ETH Zürich	grund@ifap.bepr.ethz.ch
Gudela Grote	ETH Zürich	grote@ifap.bepr.ethz.ch

Coordinator Contact Details

Prof. Dr.F.W.Bruns
Univsersity of Bremen/artec
Research Center Work, Environment and Technology
Enrique Schmidt-.Str.7 (SFG) D-28359 Bremen