Conceptual and Experimentational Approaches as Learning Styles for IT-Supported Educational Environments

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Abstract— As computer-based visualizations like those in VR (Virtual Reality) and modeling for design and idea generation becomes more common, the research interest may shift forward into a new and highly intriguing field. It is the question how to promote a new type of visualization that is based upon human conceptual imagination rather than the conventional perception of the 3D world around us. It is not an essentially new step since we extended our naturalistic way of displaying what we saw into the more or less abstracted indication of what we take as crucial behind the meaning and impact of the issue; Quantitative graphs, schematic displays of complex functioning and not to forget the topographical map itself. Maps may suggest that you see a landscape from a bird's perspective. However we soon perceive that without filtering and articulation there is no conveyance of thought and navigation. As visualization techniques develop we attempt to display conceptual entities rather than reminiscences to objects and physical space. Concept mapping is the more salient exemplar in this new line. The paradigm is that any mental entity or process may appear in a spatial configuration of both concrete and abstract ideas. The further formalisms how to control expressiveness and topology by pruning and zooming is a matter of conventions that should fit in the contract between a task, its user and the concrete representational device like a white board or a computer screen. Some tasks inherently aim at configurational awareness like planning, decisions making, etc. Some tasks address the more intuitional stages of human thinking like learning, persuasion or worshipping. Concerning learning and teaching, the so-called instructional approach has almost become synonymous with effective cognitive growth. The more recent years we see however that the cybernetic aspiration of the 60-70ties has mainly led to an over-organization of study programs and students complaining that the school is like a factory and at the same time like a hospital. The term 'existential learning' attempts to indicate its complement: The student being the main character of his longer-term development. We again start to accept that learning has a lot to do with mental and emotional growth in which information access plays only a subordinate role.

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1. From an Informational to a Conceptual Approach

Before further highlighting the need for conceptual rather than instructional representations it is useful to stress that already in pre-instructional learning theories the notion of meta-cognition has played a dominant role. Ann Brown has systematically brought forward the dominance of cognitive development, intentional learning, transfer of learning, meta-cognition and self-regulation.

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> … Learners came to be viewed as active constructors, rather than passive recipients of knowledge. Learners were imbued with powers of introspection, once verboten. One of the most interesting things about human learning is that we have knowledge and feeling about it, sometimes even control of it, meta-cognition if you will. We know that small children understand a great deal about basic principles of biological and physical causality. They learn rapidly about number, narrative, and personal intent. They entertain theories of mind. All are relevant to concepts of readiness for school, and for early school practices. Those interested in older learners began to study the acquisition of disciplined bodies of knowledge characteristic of academic subject areas (e.g. mathematics, science, computer programming, social studies, and history). Higher order thinking returned as a subject of inquiry. Mind was rehabilitated….
>
> Ann Brown, The Advancement of Learning. Educational Researcher, November 1994

> The cognitive apprenticeship model (Collins, Brown & Newman, 1989) is another illustration of the shift from guidance to self-control; it claims that effective teachers involve students in learning by problem confrontation even before fully understanding them.

Essentially you may say that learning is in fact the recreation of earlier cultural processes and evidences. Though this is an expensive phenomenon, it has the power of revalidation, as learners will also check the presented expertise against their own experiences. Also the regeneration facilitates the knowledge activeness during life. Simply storing and remembering transmitted ideas is less adequate to pop-up in new problem settings. The intriguing question for this position paper is how we rely on pictorial, schematic and iconic images during this process of intellectual "reverse engineering". Is there any pre-arranged repertoire of visual grammar or should we stimulate learners to re-invent one's personal semiotics for conveying the learning process.

2. Concept-Orientation for Problem Solving

More and more we see the element of learning shifting towards real-life problem situations. An example of such a development is in the project "SMILE Maker" by Svetoslav Stoyanov. SMILE Maker is a web-based performance support system facilitating managers in solving ill-structured problems. It could be considered as a substantial part of HRD agenda (Human Resource Development) responding to the increasing needs nowadays to deal comfortably with complex, vague, and messy, information in order to survive in a very competitive unpredictable business environment. Ill-structured or open-ended problem situations might be for example making a new strategic plan, promoting a new marketing strategy, developing a new training program, inventing a new product, making decision on new organizational design, etc. One of the most reported issue of HRD paradigm is that managers, otherwise very good subject matter experts, struggle to shape their problem solving activities in the effective and efficient way (De Bono, 1990; Wagner 1991).

SMILE provides managers with a systematic rational approach to problem solving. Problem solving is being considered as a general process encompassing the activities such as collection and analysis of the available information; generation of alternative solutions, while breaking the established patterns and escaping from the traditional way of looking at the problem; selection the most appropriate solution candidate; and planning necessary steps to implement it into practice. SMILE could prevent managers from some individual problem solving style syndromes like 'analysis paralysis', 'functional fixedness', 'lack of insight', 'one idea', 'too many ideas', and 'premature judgment', (Wodtke, 1993) and from some negative effects such as perceptual defense, stereotyping, and expectancy, as well. SMILE capitalize on the strong points of the rational approaches to problem solving such as explicitness, generality and scientific soundness (Wagner, 1991), but also takes into account the intuitive, non-linear and thinking-while-doing ways managers solve the problems (Mintzberg, 1992). SMILE provokes the elicitation of managers' tacit knowledge.

Primarily SMILE is targeted to the group of senior managers, but put the matter in more long-term business agenda all people in company might benefit from SMILE. Systematic problem solving is one of the substantial building blocks of learning organization, along with experimentation, learning from past experience, learning from others, and transferring knowledge (Garvin, 1998). SMILE proposes good opportunities for all those activities. SMILE stands for Solution, Mapping, Intelligent Learning Environment. At first and very rough approximation, it is both a problem solving and a learning tool. As a problem-solving tool it provides a user with opportunity to apply a particular concept mapping method when ill-structured problem occurs. As a learning tool it builds up an intelligent user-centered learning environment for studying what the SMILE concept mapping technique is about and how to be applied when it is needed. SMILE tries to combine the advantages of some of the dominant educational doctrines. It attempts to set up an adequate balance between Instructivism and Constructivism educational philosophies, Content

Treatment Interaction and Aptitude Treatment Interaction instructional design paradigms, and System Locus of Control and User Locus of Control in human computer interaction. The four theoretical models behind the SMILE reflect this challenge. It consists of four sub-models: Content or SMILE Concept Mapping Method, User’s Profile, Learning Events, and Facilitator. The SMILE concept mapping method is a member of the concept mapping family approaches some of them, but not limited to are mind mapping (Buzan, 1996), cognitive mapping (Eden, et.al., 1995), process mapping (Hunt, 1998) and "flowscaping" (De Bono, 1994). All of them have been recognized as useful business problem solving techniques. Mapping approaches can be defined as kinds of soft models in management science. Soft Operational Research/Management Science is a relatively new theoretical perspective in the domain of management science (Pidd, 1998). Since recently managers have been recommending to use formal models based on hard data and visually represented mainly by matrices or charts (market segments/market power, Boston Consulting Group's market share/market growth, General Electric's business screen, competitive advantage/competitive scope, Arthur Little's life cycle portfolio, Gantt diagram, Pareto analysis, etc.). Mapping approach has some obvious advantages to matrix and chart:

- It models the way the human mind organizes information;
- It reflects a close correspondence between psychological constructs and their external mode of representations;
- It integrates two kinds of coding - verbal and visual;
- It externalizes cognitive and affective processes;
- It stimulates self-appraisal and self-reflection;
- It provides a whole picture of problem situation;
- It presents the relationships between components of the situation;
- It uses a simple formal convention - nodes, links and labels on the links;
- It supports mental imagery (Stoyanov, 1999);
- Some of the representatives of the mapping approach in the management soft methodology are cognitive mapping (Eden et al., 1995), process mapping (Hunt, 1998), mind mapping (Buzan, 1996), and flowscaping (De Bono, 1994).

The SMILE concept mapping method[(1)] is a synergy between mapping approach and some creative problem solving techniques. It combines in an idiosyncratic way objective “hard” data and personal interpretative schemes. SMILE supports what managers really do every day when trying to deal with different ill-structured business situations. Formally, SMILE concept mapping method consists of four types of units: map information collection, map idea generation, map idea selection, and map idea implementation. Each map has a particular purpose and some creative problem solving techniques are incorporated in it.

The map information collection is purposed to get all available information in problem space. Map idea generation is aimed at generating as many problem solutions as possible. Map idea selection has to find the best candidate among the alternatives. The objective of map idea implementation is to operationalize a problem solution in the terms of sequence of activities and events. Because SMILE is both learning and a problem solving tool the user profile sub-model is divided into learner and problem solver sub-models. Learner sub-model is defined by four learning styles: activist, reflector, theorist and pragmatist (Honey & Mumford 1992). What is important here is that each learning style reflects the subject’s preferences to one of the learning events? Theorist is very likely to choose explanation. Reflector should look for example. Pragmatic should start with procedure, and activist should go directly to practice. Problem solver sub-model describes four problem-solving styles: seeker, diverger, converger, and practitioner. Each of them demonstrates a bias to one of the stages of SMILE concept mapping method. Seeker has preferences to map information collection, diverger feels comfortable with map idea generation, converger is strong in idea selection and practitioner might go fist to the implementation. SMILE identifies explicitly or implicitly a user according to either a problem solving style or learning style. In the second version of the SMILE two more characteristics: locus of control and prior knowledge. SMILE Maker proposes an option for selecting a scenario that matches best to the user’s individuality. Scenarios are particular modes of interrelationship between four sub-models. Four scenarios are put in disposition: ready-made, tailor-made, self-made and atelier. In the *Ready-made* scenario *Content* units are presented in a predetermined order starting with *Map information collection* and finishing with *Map idea implementation*. The order of *Instructional Events* also is fixed. *Explanation* is the first and *Practice* is the last one. A user should start with map information collection and than each page is associated with particular instructional event. When a user enters the *Practice* a graphical editor is opened automatically and he/she could apply what has been learned. The *Tailor-made* scenario adapts instruction to the learning preferences. The user gets an opportunity to identify him/herself as one of the learning styles and than is assigned to a specific path. It is conditioned by the user’s fixation to a learning event. What makes differences from the first scenario in respect to *Learning Events* is that each path is self-contained. It is dominated by one of the instructional events, but also includes pieces from other events. The sources of variation in the *Self-made* scenario are both *Content* and *Learning Events* there is not predefined sequence of problem solving maps. However, the content is still SMILE concept mapping method. The user can start picking up any of the SMILE concept maps and then select any of the learning events. The assumption is that the user selects a specific option because of need to perform specific actions.

Atelier scenario might be appropriate for people who are self-confident in building up own concept mapping approach. There are several components, which a user could select from: Ideas, Maps, Templates, and Software. *Ideas* stands for creative problem solving techniques. Maps presents some mapping approaches like concept mapping, cognitive mapping, mind mapping, and flow-scaping. *Templates* shows some examples of combinations between mapping approaches and problem solving techniques. *Software* gives opportunity to select and download concept mapping software - Inspiration, Decision Explorer, Mind Manager, Axon Idea Processor, Smart Ideas, Atlas.ti).

3. Experimentation as Learning Style in a VR Learning Environment

The fast growing attention for multi-modality, full 3-dimensional VR (Virtual Reality) and the avoidance of anisotropy has partly supplanted the designer's attention for the students' conceptual states. One additional promising aspect is to prepare and structure the VR course for Educationalists on the Web and bring an overview of ongoing research into the urgent question how to orient students in conceptually complex domains using VR. The central theme to give an overview of VR learning environments that enable learners to explore new physical spaces, but even more important: To let them experiment with new materials, complex processes like kinesthetic, extruding, casting, etc. VR becomes a substantial and ubiquitous technology and subsequently penetrates applications for education, learning and training. In addition to multimedia, VR places the user in a 3 dimensional environment. The user feels 'in the middle of another environment'. Most of the VR systems allow the user to travel and navigate. More promising for learning purposes is to let the user manipulate objects and experience the consequences. Especially the fast propagation of WWW-based tele-learning can benefit from the VR prospects in the coming years, as VR programs can now be accessed by the most common web browsers like Netscape and Explorer.

Throughout the many stages of media they have helped us to extend our perception, imagination and manipulation. VR is just an extra step on the long road bringing the imagination as close and realistic as reality itself. After the first experiments in the fifties with complex kinesthetic devices like multiple cameras, senso-motoric devices and even smell generators, more elegant head-mounted devices were developed in the early nineties. Both defense research and the computer games industry were the main stimulators of VR so far. It is hard to describe what VR is not: it encapsulates all previous media, even books, slides, pictures, audio, video and multimedia. The typical contribution of VR is its effect of 'immersion'; the user feels as if (s)he is in a different world. Both the sensations and the actions of the user should resemble as much as possible to humans in a normal physical environment; seeing, hearing, feeling, smelling, tasting; but also speaking, walking, jumping, swimming, gestures and facial expressions. The VR utopia means that the user does not perceive that a computer detects his behavior, and also that he perceives the real world. The generation of proprioceptive and kinetic stimuli is only possible if the user is placed in a tilted room like the hydraulic controlled cabins for flight simulators. The generation of taste and smell, and the realistic enervation of the human skin as if one touches an object or another person may be one of the most challenging and complex steps for VR to take in the next years. Augmented reality occurs when the user faces the real world, but on top of that the VR environment superimposes a computer-generated message in order to assist the user to perform the right operations.

VR is a desired technology for those applications in which reality itself does not exist (yet), cannot be accessed, or is too dangerous or expensive to betray. As for many of the to-days VR proponents *Reality* sounds as the only inevitable physical world, they rather prefer *Virtual Environments*. This leaves behind the idea that there is mainly one real world. Because of its widespread usage however we will maintain the term VR however. Computers in itself are inherently tools to emulate situations and environments which are not there in reality. VR in its current shape suggests the user that (s)he is in a fictitious environment. The next generation of VR suggests that you can really walk around there, and can manipulate and experiment. This environment does not necessarily need the same properties as the real world. There can be different forces, gravity, magnetic fields, etc. Also; in contrast to the real solid objects, in VR the objects can be penetrated. The properties of a good VR are like those of a good teacher; it allows the student to explore the basic laws of a new domain; location, scale, density, interactivity, response, time and level of intensity can be varied. It is not necessary to explain what the VR user sees, hears, feels and finally smells. Also textual descriptions are not optimal for this learning by intervention, as text (and also hypertext) is essentially not apt to describe complex spatial phenomena. In this sense, VR gives a substantial contribution to interactive learning environments; it combines the realism (like in a video recording) with the manipulative (fictitious) reality like in simulation programs. We may expect that within 10 years, VR is the default presentation mode of computer applications in general. Besides the visual/auditory and spatial aspects, VR can also provide support in the navigation through concept space. In this case, the dimensions are no longer corresponding to the Euclidean geometry; they can represent mental perspectives, rules and dependencies. Easier said: Virtual space allows traveling through a 3-dimensional concept map. VR is a three-dimensional simulation technique, which becomes more important as:

- mistakes during the learning process become more dramatic;
- reality itself cannot be accessed;
- parts of an emulated reality have to be smudged.

There are at least four VR aspects of importance for the perception by the learner:

1. The mechanism of avatars. They represent the user in a fictitious environment.
2. The mechanism of affordance. This is the user’s ability to orient in a new world, based upon distinguished features according to Norman (who refers back to J.J. Gibson (See Beck & Cunningham, 1989), affordance is a relation between an object in the world, and the intentions, perceptions and capacities of a person. As an example he mentions that a door with a push button instead of a handle for pulling has the affordance to push the door.
3. The man-machine interface gets an ever more prominent position. Initially the user interface was a kind of serving hatch between the user and the system. In case of very interactive systems sometimes one speaks about user intraface; in this case the whole application establishes the manipulation space for the user. The user’s intuition then needs to be sufficient to instruct the user. The user should not need meta-communication in order to understand the program’s potential.
4. The confrontation between the learner and the new (physical) environment should be ‘immersive’; rather than seeing a flat display, the user should feel himself in the VR. Especially if the task concerns complex three-dimensional orientations like surgery and rescue expeditions in complex areas, then a VR exercise is quite useful before going into reality itself.

Concerning the relevance of VR for education and training two aspects have to be taken into account:

1. VR is a default component of the user interface in the future. The desktop metaphor was a revolutionary one, as it took the human’s physical (spatial) reality for the organization of information in general. As long as it concerns 2D documents, this is a lucky choice. As soon as the user behaves in a 3D world, a more dynamic representation is needed. Also the acoustic consequences of moving through space should fit; the sounds’ amplitude, reverberation- and Doppler effects as one recedes or comes closer to the sound source, should resemble the reality.
2. The second is that the ability to increase realism also implies the possibility to introduce a specific element of non-realism. One can confront the student with an alien world and make it stepwise more or less realistic. Basic nature laws can be explored, like mechanics, chemistry, electromagnetic fields, etc. Viewed from a constructionist perspective, VR has an important function in the realization of understanding complex processes; the student is allowed to orient in several directions and subsequently find a way through the information space.

Educational VR systems seem to be a natural extension of computer-based simulations nowadays. The basic approach is to allow students to explore and discover the fundamental laws in a new environment and domain. For the initial confrontation with new tasks and for the stage of exercising, this approach seems logical and consequent. The effectiveness of the training for the mastery of the final task in reality is a subject for further research. Based on similar developments in interactive video, multimedia and telematics, it is not desirable to wait-and-see until the technology development has ‘finished’. Educational and training research should keep pace with the newest VR systems and think along its new potential for learning. Can VR be an Effective Tool for Education or Training? The answer depends partly on one's definition of VR and partly on one's goal for the educational experience. It may not be worth the cost if the goal of the educational experience is simply to memorize facts. However, if the goal of the educational experience is to foster excitement about a subject, or to encourage learning through exploration, or to give students a taste of what it is like to be a research scientist, then VR may be worth the expense. It seems an interesting option to take the VR technology as a candidate metaphor for learning environments in general. That’s why we introduce the more generic idea of *Virtual Learning Environments* in later stage of this article. Today it is a developing technology seen primarily in research labs, theme parks, and trade shows. Tomorrow it may be as common as television. Lanier (1989) likes to say that VR is a medium whose only limiting factor is the imagination of the user.

4. Thinking as a Result of Experimental Gaming

Exploring the laws of mechanics, getting acquainted with the basic formulas and progressively handling complexes of variables is all part of the Physics curriculum. Interactive

Physics is a learning tool that elicits the student to build up experimental configurations. The system presents multiple representations that facilitate different learning styles. The model animation helps students to visualize abstract concepts, building models, allows a student to observe changes in the key variable while running the simulation. Beyond the actual behavior of the mechanism also the vectors will be shown, and even tables with the sampled parameters can be exported for analysis in Excel, MathCAd or a statistical package.

Interactive Physics(2), allows the student to directly draw and manipulate models, closely to the way a normal physical experiment is arranged. The program provides springs, ropes, dampers, slots, joints, pulleys, actuators, meters, buttons, sliders, bodies and also allows to continuously change its properties like the chosen material, its elasticity, density, its texture and also its electromagnetic value. The primary approach in term of learning attitude is discovery learning. It is the ‘contract’ between the program and the student to repeat investigations after each other so that gradually the understanding arises from the link between put hypotheses and observed processes. The importance of the simultaneity of displaying the manifest behavior and its constituent parameters has been indicated by Min (1992, 1994 and 1995) in the ‘parallel instruction theory’. The students’ study approach can be articulated further by for instance tutoring guidance; a peer student who has a certain formalized understanding. A typical directive from the tutor’s side is to make systematic increments of one key parameter and try to formulate its effects on the other variables. The accompanying description in the Interactive Physics program formulates its goal as:

> … model-building for active, constructive problem solving. Modeling tools highlight important relationships and dependencies while filtering out distracting information…

The overall metaphor of the explorative modeling tools is Collaborative Mechanical Simulation: Draw it. Move it. Break it. Control it!

An example of learning with Collaborative Mechanical Simulation:

> At a planned height of 508m, the Taipei Financial Center will be the world’s tallest building. Because of its height and location in a typhoon region, it is subject to wind-induced sway motion, resulting in high accelerations that could cause occupants of the upper levels to feel discomfort. To solve this problem, engineers at Motioneering, Inc. used MSC.visualNastran products to design a tuned massed damper that would disperse the energy caused by wind acceleration.

The key mechanism in the tool-based provocation is the learning by demonstration; memorization, explanation, theoretic proof and now the challenge to ‘make what you mean’. As formulated by J. Fox at SED: “We have a new mechanism with a very unique motion that requires people to think in 3D in order to understand it. That can be really difficult, but MSC.visualNastran 4D enables us to

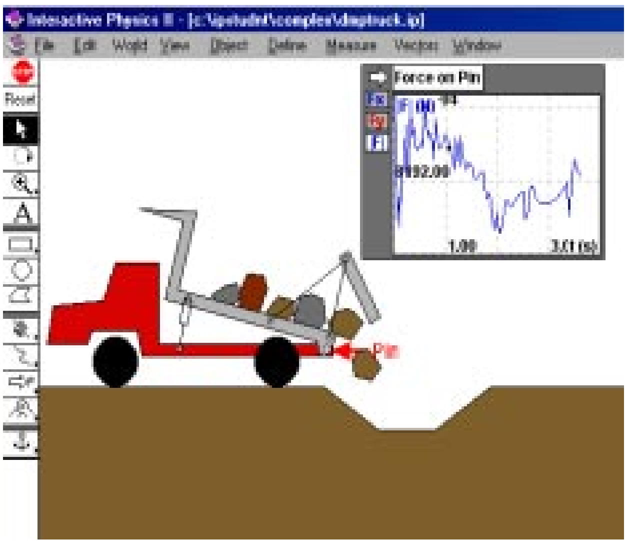

Figure 1. Animation of the rolling, sliding and dumped stones in relation to the force to the pin

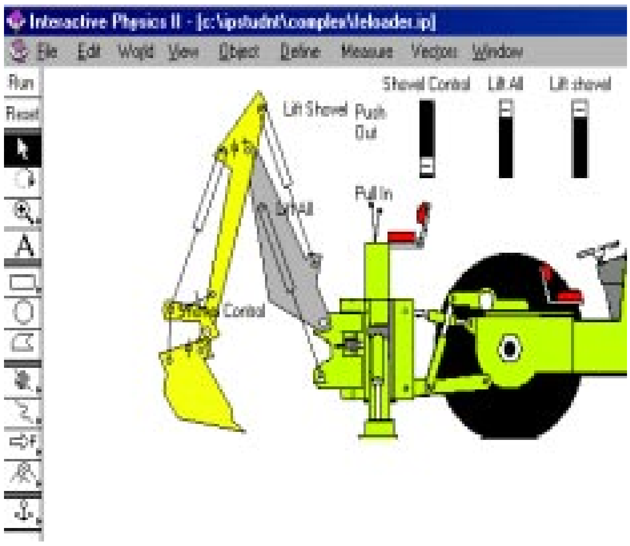

Figure 2. Multiple representations of the hydraulic taps, the position of the shovel vectors and evolving oscillations

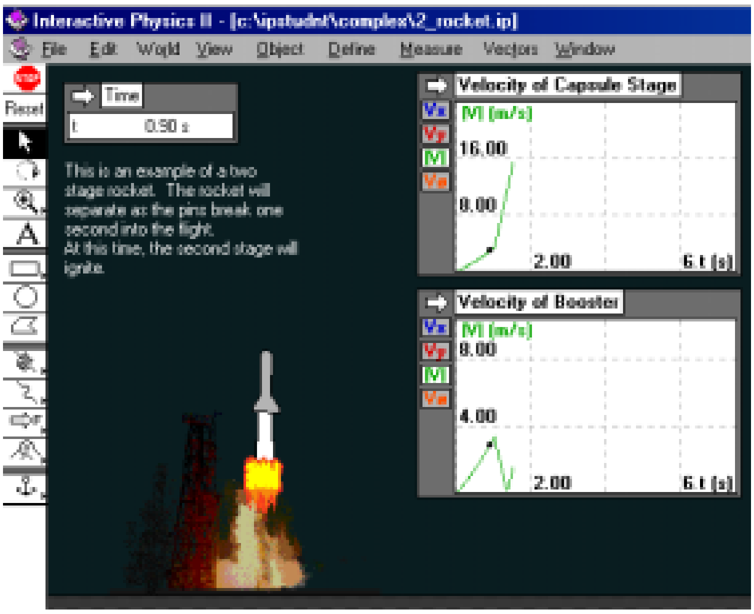

Figure 3. Embedded simulation models in rich environments. The parameter values can still be seen in the two graphics simultaneously

demonstrate the concept with a virtual prototype. By speeding the understanding of our mechanism, as well as verification of the analysis stress and strain on the parts and bearings, we are able to engage in collaborative relationships with the manufacturers substantially quicker". The students' attitude is to ask "What if?", while the tool's metaphoric role is to say "Why not?" all the time. The learning is in the short time span between student exploration and the full execution of its consequences in the model on the screen.

5. From Mechanics to Kinematics

The traditional task of conceiving a mechanic construction relies upon one's experience with similar

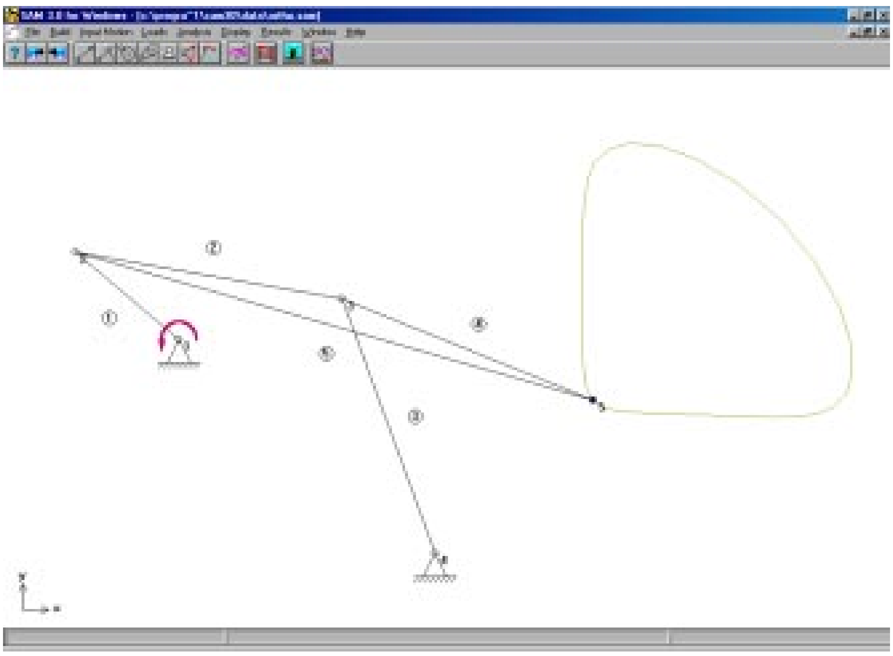

Figure 4. Rendered movement by the SAM system

solutions in the past. Mechanics and kinematics in itself are not sufficient to get at the right ideas.

SAM software (http://www.artas.nl/main_de.html); (Simulation and Analysis of Mechanisms) is an interactive PC-software package for the motion and force analysis of arbitrary planar mechanisms. The enclosed rational is that the first step in the design cycle consists of the synthesis phase, in which the designer attempts to find the type of mechanism and its dimensions, such that the requirements are met as good as possible. The traditional ‘learning by experience’ is no longer postponed into the stage of ‘learning on the job’; it is accepted as a valid and necessary component of learning the formalities like in handbooks. Traditionally designing constructions is the result of “having the right template in mind” Conceptual design and behavioral modeling techniques. Most available software on dynamics or kinematics is used to analyze the behavior of a mechanism. However, to start with, the Engineer has to 'invent' a mechanism before he can analyze it. This is not a trivial task. With available methods and handbooks this can take several days if not weeks.

6. Learning by Gaming in the Behavioral Modeling Software

Learners have not only incomplete knowledge; they lack the confrontations with the problem field so that new information is not even an answer to formulated questions. A large proportion of the initial learning is in the teasing between expert and novice to make the novice conscious about what actually has to be mastered. Preconceptions about ‘solid’ and ‘safe’ constructions have to be supplanted by new concepts like ‘elegance’, ‘autopoetics’ and ‘sustainability’. The Watt Mechanism Design Tool helps this process. From specification of the required movement and constraints on pivot locations, transmission coefficients, dimensions, etc… it searches and finds a variety of solutions within minutes; http://www.heron-technologies.com/support/index.html. Students can specify and decide upon his/her correctness and precision. The learning is no longer restricted to the validity of underlying formalisms like the Burmester design rules; in fact it stimulates the learner to participate in the community of best practice as there are

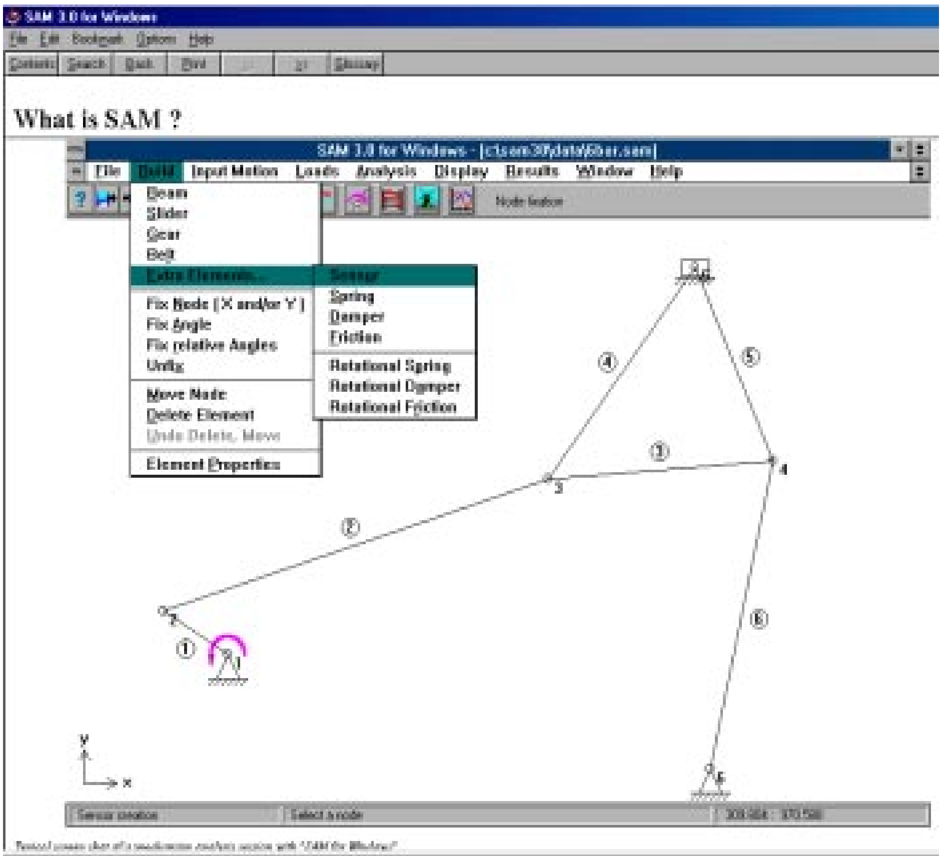

Figure 5. Students building the model for the motion and force analysis of arbitrary planar mechanisms

no formal restrictions to the scope of solutions, as long as they provide acceptable results for the posed goal.

See Figure 6. The solutions displayed in the list at the left side of the screen are labeled as Stephenson (1..x) and FourBar (1..x). In this case solution Stephenson 41 has been selected and its execution can be seen in the main window. The bottom window allows checking the various parameters on the time scale c.q. the rotational angle: the path error, the path, velocity, acceleration, output, output velocity, output acceleration, etc. The twelve partial screen dumps below display the breadth in solutions. The students task is to navigate between the trade-offs and relaxing the initial constraints for instance in the available space around the construction, the weight of the construction, but even arguments concerning the easiness to assembly or maintain the final construction.

The constructions under concern have all in common that they produce the vertical curve at the left. Besides the practical implications like the needed amount of material, it is also possible at this point to drag some elements manually and regenerate the entire solution process from scratch. This iterative approach is an important factor in the student's learning; it coaches the student to distinguish relevant from peripheral factors from the beginning and will reduce the problem space considerably in the future. The perceived added value from the 'what-if' exploration is the heavier responsibility for the student, not just the created freedom that is often associated with constructivism. An often-overlooked aspect is the role of these modeling tools as demonstrators during the lectures by the teacher. Here we can perceive that the explanatory approach is soon supplanted by the exploratory approach. It frees the time and mental load for new goals, like the restructuring of counter-intuitive solutions but also the trust that you as a learner may go in directions that are unknown to you and the teacher as well. The teacher and the student at that moment are swimming side by side. The benefit is that the learning will cover a larger domain of notions for the application of formal knowledge. The price is that students may finally not be keen enough on the typical problems that can be awaited for the final examination. It is clearly not a trivial problem what to do if a certain assessment regime tends to obstruct the natural evolution into new ways of learning and learning outcomes?

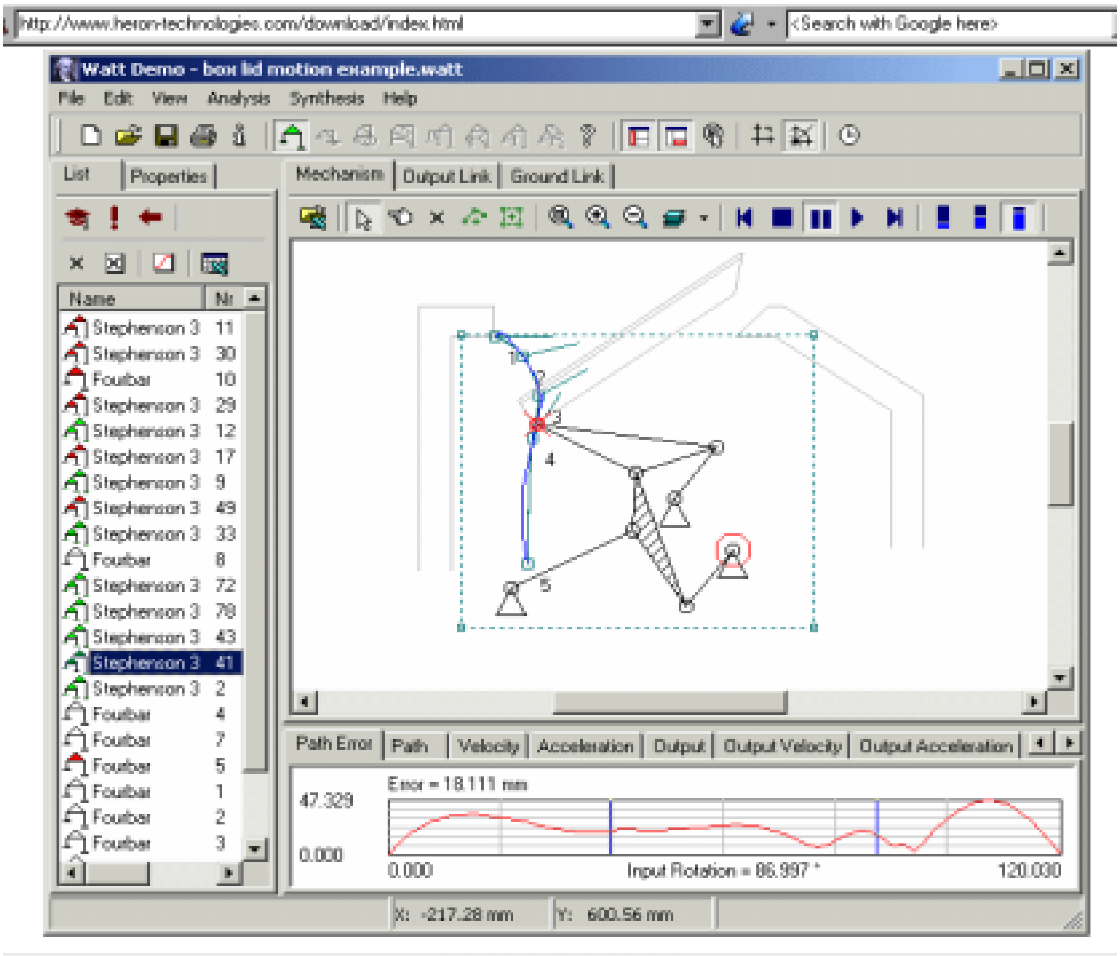

Figure 6 Watt Software elicits the student to experiment and prompts unforeseen mechanisms beyond the student's current intuition

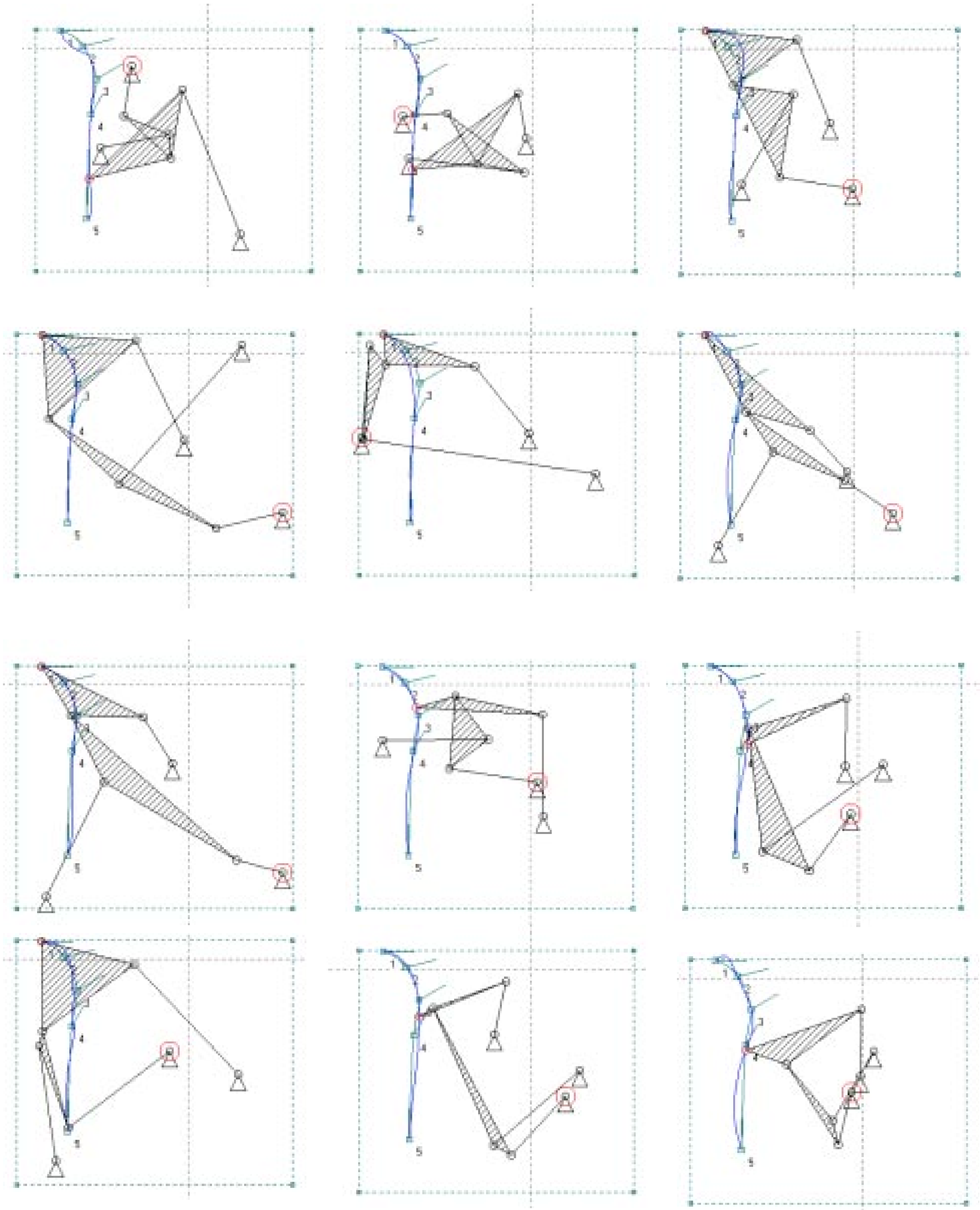

Figure 7 Twelve constructions generated by the Watt system

7. Virtual Reality for Immersive Experiments

Though dynamic modeling for learning physics' laws brings immediate response to the students' intuitive hypotheses, it is a rendered 2D view on the consequences of the prior intervention. The added facility of virtual reality is that one can actually fly, walk or swim in the target world, and experience the friction between imagined and perceived views during traveling and rotations. In a number of ongoing research projects we aim to provide constructional, theoretical and empirical evidence for the assumption that students' control of the visual and acoustical articulation in a virtual environment affects the quality and effectiveness of the learning process. The articulation strategy (described as an explicit model) is verified in terms of perception, interpretation, usability, cognitive compatibility and learning effects.

8. Towards VR-based Learning Paradigms

The inherent role of ICT in learning environments also manifests itself in virtual environments for teaching, learning and training. Virtual environments are a blend of art and science as they add new dimensions like immersion, transparency, free 3D navigation and amazement. As a new technology for visualizing scientific data, this application does not only give more emphasis on visualization but also possibilities to add other senses such as hearing (both naturalistic and synthetic sound) and feeling/touch (proprioceptive and kinesthetic). The implementation of virtual environments in educational and training areas has arrived and moves quickly in an attempt to extend the control range as far as it can be perceived in virtual environments. Virtual environments offer a great potential to computer-based systems. The realistic visual environment that is offered, together with its intuitive forms of interaction, makes it attractive for a variety of both learning and teaching applications. In order to ensure a successful transfer of knowledge in a learning system, the system itself must mimic the real environment, within the limits of the available technology. Hence, issues such as responsiveness, quality and accuracy of the virtual environment and the realism of the user interface all need to be considered. Recently, virtual environment has demonstrated its potential in the field of computer-based learning. The reason is that it offers the most important factors needed in learning field: realism and interaction. Another major issue in virtual environment is the fidelity of the system. Fidelity refers to the combination of accuracy and realism. The type of the objects performed in the virtual environment determines the need for accuracy or realism.

9. Prior Research into VR-Supported Learning

In order to enhance the likelihood of a more effective learning process it is essential to gain a better understanding of how students learn. VR is a research area that focuses on identifying and describing the object in which students are able to orient and control themselves in order to improve learning effects. Visualizations of data and virtual systems in the context of the real world can make information spatially indexed and more understandable. Rather than relying solely on a verbal description of the scene and problem, advanced technology produces a three-dimensional image of objects and its surroundings. With this capability, the problems are more naturally and clearly communicated and resolved as if the remote expert was physically there. These new models of learning and assessment are also required to measure student progress, and to guide them through a learning and problem-solving process. Virtual environment addresses a wide range of interaction and immersion capabilities. Interaction in virtual environment plays an important role in varying learner control during the virtual environment experiences. Visual, auditory, and haptic interactions and sensations are dominant communication modalities due to their familiarity and rich expressiveness. The senso-motoric interface is an important part in virtual environment because it allows sensing, synthesizing, manipulating, and bring rather 'total' visual, aural, and haptic sensations, subject to the user's preferences and complete control.

10. The Applications and Benefits of Virtual Learning Environments

The term 'virtual environment' refers to a human-computer interface that facilitates a highly interactive control over three dimensional scenes and its components with adequate detail so as to evoke a visual response similar to that of real scenes. Virtual reality is an advanced technology to produce a virtual environment that users perceive as comparable to real world objects and events. Users can interact with displayed images by turning, twisting, tilting or zooming in a way that creates a feeling of actual presence in the simulated presence. In educational and training area, virtual reality applications appear to be most promising for visualization and representation.

NASA had started the usage of applications in VR areas for many years ago. Nowadays, virtual environments have been used for medical training and education, science education, engineering training, even for disabled users. In the field of science, this new technology provides students with a new learning experience in order to see the 'unseen' side in science world.

Virtual environments are split into 2 areas, immersive and non-immersive system elements; both with advantages and disadvantages. Recently, the non-immersive system is more popular, more often used and more appropriate for learning and teaching knowledge at school or university because it can be used at little additional cost to a typical computer. The non-immersive system that sometimes is called desktop virtual environment can be defined as a subset of virtual environment that does not require all four conditions of full immersion:

- a full field of vision display;
- the tracking of the position and attitude of the participant's body;
- the tracking by the computer of the participant's movements and actions;
- negligible delay in updating the display with feedback from the body's movements and actions.

The key-characteristics of virtual reality are visualization and interaction. Visualization aims at representing information in a visible format, makes the unseen to be seen. The interactive nature of virtual environments enables the user to visualize real life structures and events although sometimes the high level of realism in virtual reality environment doesn't give a guarantee for learners to gain a better understanding.

The usage of an external articulation database in VR helps to learn the simple components of more complex tasks or to react with infrequently occurring situations such as the preferred response to unusual events. An advantage of using articulation templates in virtual reality environment is that it enables the user to interact with the real-time animation to conceptualize small part relations rather than a complex one, or to leaving away parts of models that are difficult to visualize in a normal way. Moreover, by allowing users to select their own preferred articulation parameters, virtual environment can promote a more responsible cognitive attitude at the learner.

Virtual environments also highlight various articulation parameters that are understood by the student and the teacher to improve the quality of learning process. An important part of the learning process is the application of the theory to 'realistic' virtual environments. Relevance of the theory to 'real' virtual environments is understood to make the learning process more interesting and efficient. Learning and understanding can be made easier and interesting with visual support such as pictures and models as long as students can carry out independent control to enhance their understanding.

Articulation in VR also involves being able to see how things relate to each other. From the point of understanding, providing students with VR facilitate learning by adopting an appropriate articulation, and by providing a comfortable control device to the student him/herself. The nine factors that influence learning processes in VR include:

- Articulation
- Interaction
- Exploration
- Navigation
- Freedom
- Orientation
- Immersion
- Spatial ability
- Imagination.

Articulation in a virtual environment has influence on the cognitive ergonomic, usability and quality towards the learning process. Here the importance of the thirteen articulation parameters comes into play:

- Realism level of the objects
- Textual labels
- Shape distortion
- Shading
- Color
- View points
- Texture Mapping
- Size
- Animation
- Appear and disappear
- Sound effects
- Jaggedness
- Pulling away certain parts.

The advantages of the usage of external articulation in virtual environment are:

- Focusing the attention
- Supporting learning-by-doing through experimentation
- Enhancing learning experiences that progress from simple to complex situation
- Enhancing students' creativity and logic thinking.

Articulation control term in VR is broader than the term navigation. Navigation control focuses on the way users can alter their viewpoint position and orientation in VR, while articulation control addresses the freedom/responsibility for the users to optimize the articulation parameters for the sake of learning.

There are three possibilities for articulation control modes in virtual environment:

- structured (algorithms/program control)
- semi-structured (teacher control)
- unstructured (student control).

Knowledge is comparatively easy to define and measure. It is more difficult to define and measure understanding in a way that distinguishes it from knowledge. Learning is a process of development and it is different for each individual. By tradition educationalists emphasize the importance of understanding. Learning processes itself are influenced by individual learning styles. There is no evidence that one style is more effective than others but there is evidence that individuals learn better when allowed to recognize and utilize their personal preferred learning style. External articulation should be integrated in a way that allows freedom to choose other ways to learn. Learning is an iterative process so that it is important for the student to feel a sense of achievement at each stage. Many virtual environment-based teaching and learning packages have a procedural nature. The navigational control is often limited to standard VRML (Virtual Reality Modeling Language) navigation (see Web3D repository(3) on the WWW).

They are designed to achieve specific objectives, usually to teach the user in particular structures and processes. The usage of an external articulation database is event-driven. The external database does not have a pre-programmed sequence through which the user must navigate. External articulation models make it easier for users to take active control of the learning process, choosing which problems to solve, and which information to view but there is a risk that the user will be overawed by the complexity of the environment. How students go experiencing with the particular articulation in virtual environment is related to how the learning task is perceived by students. Learning processes can be categorized in two different ways:

1. Learning is seen as the memorization of information. Learning in this approach is seen in quantitative terms as an accumulation of knowledge relevant to what is required to complete the lesson unit. The focus in this category is on content given significance by the teacher.
2. Learning is seen as understanding information. Learning here is viewed as understanding information and can be categorized into:

   - understanding is facilitated by adapting information to suit personal cognition;
   - understanding is facilitated by being able to visualize the problem as a whole;
   - understanding is facilitated in an experiential way by attempting to relate things to past experiences;
   - understanding is facilitated by practical examples.

11. VR and the Need for an Exploratory Spatial Didactics

Currently we are in the middle of a project to investigate the effect of using an explicit articulation control mode in order to improve the learning process. During a master thesis in Educational Technology Sylvia Dewyanti developed three stages of the heart in the fetal, the neonate and the mature stage. Just after birth the open connection between the two atriums is closed to enable the double circuits in blood streams. The students in biology and medicine need to spatially and schematically understand the consequences of the constellations before and after the closure of this *foramen ovale*.

> "….In this preliminary investigation, three prototypes had an implicit articulation. It was developed with the purpose of improving the subject *Human Blood Circulation* for the Groningen University Biology curriculum in animal physiology. The experiments were restricted to a series of interactive visualization modules. They aimed at supporting the role of the teacher during lecturing, and to assess its value of student-centered interactivity, both in individual settings as well as in collaborative learning. The next step for this investigation is to build an external articulation database support system in a VR environment".

Articulation can be described as jointed parts or components in virtual environment that function to express ideas clearly and understandable. The articulation in virtual reality environment includes three-dimensional objects, color, texture, animation, and sound, etc. In virtual environment technology, articulation has a close relationship with the philosophy behind virtual environments: "To give the illusion of immersion in an environment mainly computer-generated and maybe augmented with reality".

Articulation could be varied from an abstract unto a realistic level. The availability of an external articulation database could provide users with a more flexible individual control to determine in which level they want to start learning. Flexibility in control provokes users to structure their personal interests in learning certain new notions.

The first level of interaction in virtual environments needs a user interface that allows you to walk through a virtual world, interact with its content, trigger animations, and listen to 3D sound effects. The external control of the articulation in virtual environment system addresses a second level of interaction in which users can customize and modify the articulation model in the virtual reality environment that matches the user's momentary interest.

A virtual environment is a dynamic and responsive presentation medium. It has a particular effect called immersion in which the user will interact with learning environment. Virtual environments are created from diverse components using contiguity and articulation. Articulations determine the presentation accents and also the allowed degree of interactivity, realism and immersion. In order to provide users with simulated experiences in virtual environment system, control modes for articulation parameters make a possibility for users themselves to experience autonomy.

12. Immersive Experiences for Prerequisite Learning

Sivia Dewyanti started her Master Thesis based on the question how VR models of the heart of a mammal should be built in order to promote a swift and still enduring understanding at the student. Experts in Biology teaching claimed that the 'foramen oval' and its subsequent blood streams during and right after birth needs a complex imagination, that will only survive if its simultaneous performance can be seen.

VR provokes us to express our momentary understanding of for instance the human heart in a dynamic 3D model, where flow and pressure are articulated and where transparency allows seeing processes in several layers at the same time. Our experiments intend to find adequate rules of thumb how to facilitate navigation and how to sequence the graphical articulations in order to promote the students' intuitive understanding of its functioning.

VR environments influence learning outcomes especially in cognitive abilities such as spatially related problem solving, memory retention and memory recall. Other advantages in using virtual environment for education and training are the pleasure, enjoyment, fluency of understanding how to perform tasks and seeing what is going on. Virtual environment has produced a number of applications both in education and training fields by bringing experience based learning to all students and addressing the needs of students with alternate learning styles.

The research outcomes about the effectiveness of virtual environment have been expressed as follows:

- Cognitive factors that is influencing virtual reality learning in relation to the substantial body of research on the psychology of learning (Wickens & Baker, 1995).
- Student responses to the experience of being

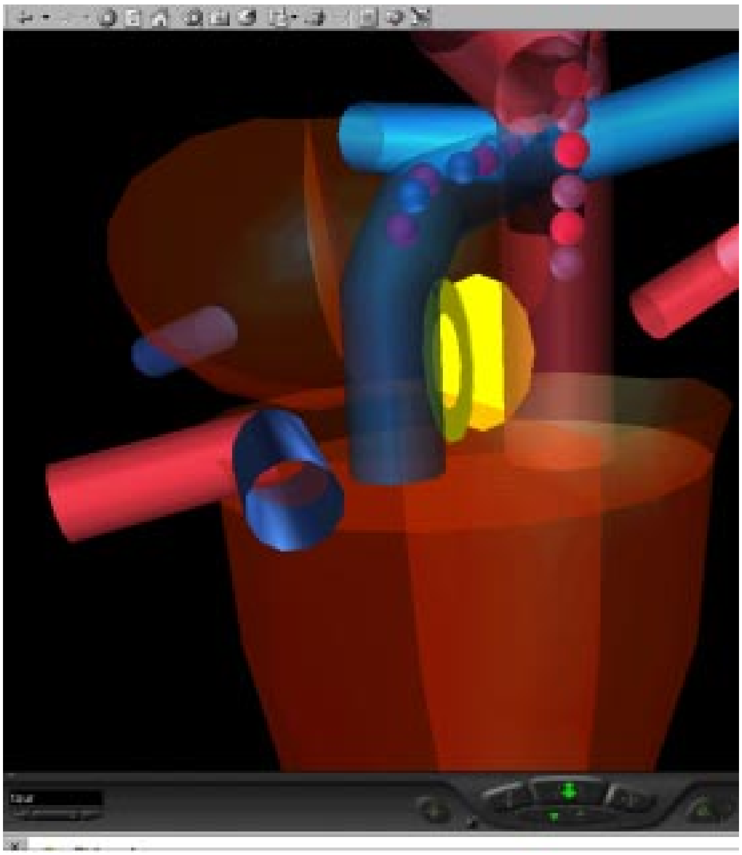

Figure 8. Entering the pumping heart and witness the effect of the foramen oval

immersed in virtual reality (Taylor, 1997).
- Virtual reality roles for teaching and training in engineering education (Pantelidis, 1997).

This research project searches the theoretical and empirical evidences on the effects of control modes for external articulation in virtual environment in order to increase the quality of the learning process. The expectations are that the external articulation control mode should offer more flexible methods to express complex realities like going on in natural tissues and organs. They are also expected to yield a better visualization of scientific ideas like inertia, entropy, simultaneity, etc. In this context the term 'Visual Intelligence' should also be taken into account; it seems not to be a gratuity donation to mentally benefit from the rich visual grammars and expressions (Kommers & Zhiming, 1998). Also this trade-off between short- versus longer-term effects should be taken into account during the planned experiments.

13. Conclusion

The re-introduction of gaming and experimentation as valid modalities of learning will further propagate through the many new-coming WWW-based learning tools. The main contract between the learner and the learner tool is to explore, discover and formalize the basic laws in a certain knowledge domain. The learning tools help the learner to transform intuition into understanding and to consolidate certain experiences into pervasive rules. Concept mapping can best be applied when a computer program assists in updating the dynamic links between concept entities. Especially the (meta-) cognitive support during conceptual change as happens during experimentation is an important function of concept mapping. Virtual Reality is becoming more and more the standard user interface for immersive learning experiences. The combination between VR and the constructivistic contracts for experimentation will get momentum and ask for in-depth experimentation the coming years.

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Remarks

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2. Interactive Physics, (http://www.workingmodel.com/)
3. Web3D repository (http://www.web3d.org)

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