EXPERIENTIAL LEARNING THROUGH CONSTRUCTIVIST LEARNING TOOLS

P. Kommers*

Abstract

As computer-based visualizations like those in virtual reality and modelling for design and idea generation become more common, research interest may shift into a new and highly intriguing field: the question of how to promote a new type of visualization that is based on human conceptual imagination rather than the conventional perception of the 3D world around us. This is not an essentially new step, as we have already 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, as in, for example, quantitative graphs, schematic displays of complex functioning, not to forget the topographical map itself. Maps may suggest that you see a landscape from a bird’s-eye 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 most 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—are 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, such as planning and decision-making. Some tasks address the more intuitional stages of human thinking, like learning, persuasion, or worship. Concerning learning and teaching, the so-called instructional approach has almost become synonymous with effective cognitive growth. Over more recent years we have seen, however, that the cybernetic aspiration of the 1960s and 1970 has mainly led to an over-organization of study programmes and to students complaining that the school is like a factory and at the same time like a hospital. The term existential learning attempts to indicate the complement to this, in which the student is the main character in his or her longer-term development. Here we again start to accept that learning has lot to do with mental and emotional growth in which information access plays only a subordinate role.

Key Words

Experiential learning, constructivist learning, learning tools, virtual reality, conceptual approach, concept mapping, cognitive mapping, experimental gaming

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 in pre-instructional learning theories the notion of meta-cognition has already 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.

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. [1, p. 6]

The cognitive apprenticeship model [2] 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 the students fully understand those problems.

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 activeness of knowledge during one’s life; simply storing and remembering transmitted ideas is less likely to result in those ideas popping up in new problem settings. The intriguing question for this article is how
we rely on pictorial, schematic, and iconic images during this process of intellectual “reverse engineering.” Is there any prearranged 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 found in the project “SMILE Maker” by Svetoslav Stoyanov. (SMILE stands for Solution, Mapping, Intelligent Learning Environment.) SMILE Maker is a web-based performance support system facilitating managers in solving ill-structured problems. It could be considered a substantial part of the human resource development (HRD) agenda in response to the increasing need 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, constructing a new strategic plan, promoting a new marketing strategy, developing a new training program, inventing a new product, or making decisions on new organizational design. One of the most reported issues of the HRD paradigm is that managers, otherwise very good subject matter experts, struggle to shape their problem-solving activities in an effective and efficient way [3, 4].

SMILE provides managers with a systematic, rational approach to problem solving. Problem solving is considered as a general process encompassing activities such as collection and analysis of the available information; generation of alternative solutions while breaking established patterns and escaping from the traditional way of looking at the problem; selection of the most appropriate solution candidate; and planning of necessary steps to implement it. SMILE could prevent managers from falling into some individual problem-solving style syndromes like “analysis paralysis,” “functional fixedness,” “lack of insight,” “one idea,” “too many ideas,” and “premature judgement” [5], and from some negative effects such as perceptual defence, stereotyping, and expectancy. SMILE capitalizes on the strong points of the rational approaches to problem solving such as explicitness, generality, and scientific soundness [4], but also takes into account the intuitive, nonlinear, and thinking-while-doing ways in which managers solve problems [6]. SMILE elicits managers’ tacit knowledge.

SMILE is primarily targeted to the group of senior managers but, if we place the matter within a more long-term business agenda, all people in a 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 [7]. SMILE offers good opportunities for all those activities. At a 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 the opportunity to apply a particular concept-mapping method when an ill-structured problem occurs. As a learning tool it builds up an intelligent user-centred learning environment for studying what the SMILE concept-mapping technique is about and how it should be applied when needed. SMILE tries to combine the advantages of some of the dominant educational doctrines. It attempts to set up an adequate balance between the Instructivist and Constructivist 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 4-ID theoretical models behind SMILE reflect this challenge. It consists of four submodels: 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 which (though they are not limited to these) are mind mapping [8], cognitive mapping [9], process mapping [10], and “flowscaping” [11]. 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 [12]. Managers have recently been recommending the use of 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.). The mapping approach has some obvious advantages over the 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 the 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 [13].

The SMILE concept-mapping method is a synergy between the 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, the 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 intended to get all available information in problem space. Map idea generation is aimed at generating as many problem solutions as possible. Map idea selection finds the best candidate among the alternatives. The objective of map idea implementation is to operationalize a problem solution in terms of sequence of activities and events. Because SMILE is both a learning and a problem-solving tool, the user profile submodel is divided into learner and problem-solver submodels. Learner submodel is defined by four learning styles: activist, reflector, theorist, and pragmatist [14]. What is important here is that each learning style reflects the subject’s preferences for one of the learning events. A theorist is very likely to choose explanation. A reflector should look for an example. The pragmatic should start with procedure, and the activist should go directly to practice. Problem-solver submodel describes four problem-solving styles: seeker, diverger, converger, and practitioner. Each of them demonstrates a bias towards one of the stages of the SMILE concept-mapping method. Seeker has preferences for map information collection, diverger feels comfortable with map idea generation, converger is strong in idea selection, and practitioner might go first to the implementation. SMILE identifies a user explicitly or implicitly according to either problem-solving style or learning style. The second version of SMILE contains two more characteristics: locus of control and prior knowledge. SMILE Maker proposes an option for selecting a scenario that best matches the user’s individuality. Scenarios are particular modes of interrelationship between four submodels. 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. A user should start with map information collection, and then each page is associated with a particular instructional event. When a user enters the “Practice” a graphical editor is opened automatically and he/she can 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 preferring one of the learning styles and then is assigned to a specific path. It is conditioned by the user’s fixation to a learning event. What makes the 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 no predefined sequence of problem-solving maps. However, the content is still the 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 a need to perform specific actions.

Atelier scenario might be appropriate for people who are self-confident in building up their own concept-mapping approach. There are several components that 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 flowcharting. “Templates” shows some examples of combinations between mapping approaches and problem-solving techniques. “Software” provides an opportunity to select and download concept-mapping software: Inspiration, Decision Explorer, Mind Manager, Axon Idea Processor, Smart Ideas, “Atlas Ti.”


The fast-growing interest in multimodality, full 3D virtual reality (VR), and the avoidance of anisotropy have partly supplanted the designer’s attention with the students’ conceptual states. One additional promising aspect is to prepare and structure the VR course for educationalists on the web and bring ongoing research to bear on the urgent question of how to orient students in conceptually complex domains using VR. The central theme is 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, and so on. 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 3D 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. This article introduces the potential impact of “immersion” on learning environments, the current state of the art in VR, its drawbacks, the overall metaphor of virtuality, and the most feasible application areas. The main section of the reporting is the research agenda for VR in the next coming years. The recommendations involve VR and collaborative aspects (MOOs); its integration with videoconferencing, drama, and constructionism; temporal awareness; and finally, the integration into special curricular topics. The targeted goal of this work is the gradual embedding of VR elements in current research and developmental practices. The fast propagation of WWW-based telelearning in particular 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 VR has helped us to extend our perception, imagination, and manipulation. VR is just an extra step on the long road to making the imagination as close and realistic as reality itself. After the first experiments in the 1950s with complex kinesthetic devices like multiple cameras, senso-motoric devices, and even smell generators, more elegant headmounted devices were developed in the early 1990s. Both defence research
and the computer games industry have so far been the main stimulators of VR. 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 he or she is in a different world. Both the sensations and the actions of the user should resemble as much as possible those of humans in a normal physical environment, whether seeing, hearing, feeling, smelling, tasting, and also speaking, walking, jumping, swimming, gestures, and facial expressions. The VR utopia means that the user does not perceive that a computer detects his/her behaviour, and also that he/she 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 in performing the right operations.

VR is a desirable technology for those applications in which reality itself does not exist (yet), cannot be accessed, or is too dangerous or expensive to venture into. As for many of today’s VR proponents the term “reality” connotes the only, inevitable physical world, they prefer to use the term “virtual environments.” This leaves behind the idea that there is one real world. Because of its widespread usage, however, we will continue to use “VR.” Computers in themselves are inherently tools to emulate situations and environments that are not there in reality. VR in its current shape suggests to the user that he/she 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, and the like. Also, in contrast to real, solid objects, in VR objects can be penetrated. The properties of a good VR are like those of a good teacher; it allows students to explore the basic laws of a new domain, that is, 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 smells. Also, textual descriptions are not optimal for this learning by intervention, as text (and also hypertext) is essentially not able to describe complex spatial phenomena. In this sense, VR makes a substantial contribution to interactive learning environments; it combines the realistic (like in a video recording) with the manipulative (fictitious) reality (like in simulation programs). We may expect that within 10 years, VR will be the default presentation mode of computer applications in general. Besides its visual/auditory and spatial aspects, VR can also provide support in navigating concept space. In this case, the dimensions no longer correspond to Euclidean geometry; they can represent mental perspectives, rules, and dependencies. Or, better said: virtual space allows one to travel through a 3D concept map. VR is a 3D simulation technique, which becomes more important as mistakes during the learning process become more dramatic, reality itself cannot be accessed, and parts of an emulated reality have to be smudged.

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

- **The mechanism of avatars.** These represent the user in a fictitious environment.
- **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 [15])). Affordance is a relation between an object in the world and the intentions, perceptions, and capacities of a person. As an example, Norman gives a door with a push-button instead of a handle for pulling: the door has the affordance to push the door.
- **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 the 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.
- **The confrontation between the learner and the new (physical) environment should be immersive.** Rather than seeing a flat display, the user should feel him/herself in the VR. Especially if the task concerns complex 3D orientations like surgery and rescue expeditions in complex areas, 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:

- **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.
- **The ability to increase realism also implies the possibility of introducing a specific element of nonrealism.** One can confront the student with an alien world and make it, stepwise, more or less realistic. Basic natural laws can be explored like mechanics, chemistry, electromagnetic fields, and so on. Viewed from a constructionist perspective, VR has an important function in aiding the 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. The effectiveness of the training for 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 about 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 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 is why we introduce the more generic idea of "virtual learning environments" in a later stage of this article. Today it is a developing technology seen primarily in research laboratories, theme parks, and trade shows. Tomorrow it may be as common as television. Lanier [16] 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 helps 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 and to build models, allowing them to observe changes in the key variable while running the simulation. Beyond the actual behaviour of the mechanism, the vectors will also be shown, and even tables with the sampled parameters can be exported for analysis in Excel, MathCAD, or a statistical package.

Interactive physics$^1$ allows the student to directly draw and manipulate models, much like the way a normal physical experiment is arranged. The program provides springs, ropes, dampers, slots, joints, pulleys, actuators, meters, buttons, sliders, and bodies and also allows one to continuously change its properties like the chosen material, its elasticity, density, texture, and electromagnetic value.

$^1$Interactive physics (http://www.workingmodel.com/index.html).

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

Figure 2. Embedded simulation models in rich environments. The parameter values can still be seen in the two graphics simultaneously.

Figure 3. Multiple representations of the hydraulic taps, the position of the shovel vectors, and evolving oscillations.

The primary approach in terms 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 proposed hypotheses and observed processes. The importance of the simultaneity of displaying the manifest
behaviour and its constituent parameters has been indicated by Min [17–19] 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. Modelling tools highlight important relationships and dependencies while filtering out distracting information” (published in a newsletter at http://www.interactivephysics.com/). The overall metaphor of the explorative modelling tool is collaborative mechanical simulation: Draw it. Move it. Break it. Control it! An example of learning with collaborative mechanical simulation follows:

At a planned height of 508 m, 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 mass damper that would disperse the energy caused by wind acceleration (published in a newsletter at http://www.interactivephysics.com/).

The key mechanism in the tool-based provocation is 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 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?” 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 solutions in the past. Mechanics and kinematics in themselves 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 well as possible. The traditional “learning by experience” is no longer postponed to 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 behavioural modelling techniques. Most available software on dynamics or kinematics is used to analyse the behaviour of a mechanism. However, to start with, the engineer has to “invent” a mechanism before he/she can analyse 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 Behavioural Modelling Software

Learners not only have incomplete knowledge; they lack 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,” “auto-poetics,” and “sustainability.” The Watt Mechanism Design Tool helps in this process. From specification of the required movement and constraints on pivot locations, transmission coefficients, dimensions, and the like, it searches and finds a variety of solutions within minutes; http://www.heron-technologies.com/support/index.html. Students can specify and decide upon their correctness and precision. The learning is no longer restricted to the validity of underlying formalisms like the Burmester design rules; in fact the new approach stimulates the learner to participate in the community of best practice, as there are no formal restrictions to the scope of solutions, as long as they provide acceptable results for the posed goal.

The solutions displayed in the list at the left side of the screen (Fig. 6) are labelled 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 of the various parameters on the time scale c.q. the rotational angle: the path error, the path, velocity, acceleration, output, output velocity, output acceleration, and so on. The 12 partial screen dumps shown in Fig. 7 display the breadth in solutions. The student’s task is to navigate between the trade-offs and relax the initial constraints, for instance in the available space around the construction and the weight of the construction, but even arguments concerning ease of assembly or maintenance of the final construction.

The constructions of concern all have 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 reduced 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 modelling tools as demonstrators during lectures by the teacher. Here we can perceive that the explanatory approach is soon supplanted by the exploratory approach. It frees up time and mental energy for new goals, like the restructuring of counterintuitive solutions, but also encourages 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 sufficiently well versed in the typical problems that await them on the final examination. This 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?

7. VR for Immersive Experiments

Though dynamic modelling for learning the laws of physics brings an immediate response to the students’ intuitive hypotheses, it is a rendered 2D view of the consequences of the prior intervention. The added facility of VR is that one can actually fly, walk, or swim in the target world, and experience the friction between imagined and perceived views during travelling 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.

7.1 Towards VR-Based Learning Paradigms

The inherent role of Information and Communication Technology (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 not only gives more emphasis to visualization, but also has the possibility of adding 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, the 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 a 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.

7.2 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 3D 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 of virtual environment because it allows sensing, synthesizing, manipulating, and bringing “total” visual, aural, and haptic sensations, subject to the user’s preferences and complete control.

8. 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 3D scenes and its components with adequate detail so as to evoke a visual response similar to that of real scenes. VR 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 the educational and training area, VR applications appear to be the most promising for visualization and representation.

NASA started the usage of applications in VR areas many years ago. Nowadays, virtual environments are used for medical training and education, science education, engineering training, and 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 of the science world.

Virtual environments are split into two areas, immersive and nonimmersive system elements, both of which have advantages and disadvantages. Recently, the nonimmersive system has become more popular, more often used, and more appropriate for learning and teaching at school or university because it can be used at little additional cost to a typical computer. The nonimmersive system, sometimes called desktop virtual environment, can be defined as a subset of the 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 VR are visualization and interaction. Visualization aims at representing information in a visible format; it makes the unseen 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 VR environment does not guarantee learners will gain a better understanding.

The usage of an external articulation database in VR helps in learning the simple components of more complex tasks or in reacting with infrequently occurring situations such as the preferred response to unusual events. An advantage of using articulation templates in VR environment is that it enables the user to interact with the real-time animation to conceptualize small part relations rather than one complex one, or to leave out 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 within 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. The 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 view of understanding, providing students with VR facilitates 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 are: articulation, interaction, exploration, navigation, freedom, orientation, immersion, spatial ability, and imagination.

Articulation in a virtual environment has influence on the cognitive ergonomic, usability and quality towards the learning process. Here the importance of the 13 articulation parameters comes into play: realism level of the objects, textual labels, shape distortion, shading, colour, view points, texture mapping, size, animation, appear and disappear, sound effects, jaggedness, and 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 situations, and enhancing students’ creativity and logic thinking.
Articulation control term in VR is broader than the term “navigation.” Navigation control focuses on the way in which users can alter their viewpoint position and orientation in VR, whereas articulation control addresses the freedom/responsibility of 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), and 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 themselves 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 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 Virtual Reality Modelling Language (VRML) navigation: see the Web3D repository on the WWW.

Such learning packages are designed to achieve specific objectives, usually to teach the user a particular structures and processes. The usage of an external articulation database is event driven. The external database does not have a preprogrammed 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 experience 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 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 as understanding information. Understanding information can be categorized into:
   - Understanding as facilitated by adapting information to suit personal cognition
   - Understanding as facilitated by being able to visualize the problem as a whole
   - Understanding as facilitated in an experiential way by attempting to relate things to past experiences
   - Understanding as facilitated by practical examples

9. 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. In her master’s thesis in educational technology Dewianty [20] developed three stages of the heart: the foetal, 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. 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 course “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 assessing the value of student-centred interactivity, in both an individual and a collaborative learning setting. 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 VR environment includes 3D objects, colour, texture, animation, sound, and so on. 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 may be augmented with reality.

Articulation could be varied from an abstract to a realistic level. The availability of an external articulation database could provide users with 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 one 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 VR 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 the 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 it possible for users themselves to experience autonomy.

2 Web3D repository (http://www.web3d.org/vrml/vrml.htm).
10. Immersive Experiences for Prerequisite Learning

Sivia Dewyanti began her master’s thesis [20] by asking the question how VR models of the heart of a mammal should be built in order to promote a swift and yet enduring understanding within the student. Experts in biology teaching claimed that understanding the “foramen oval” and its subsequent blood streams during and right after birth requires a complex act of imagination that will only survive if its simultaneous performance can be seen.

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, and fluency of understanding of how to perform tasks and seeing what is going on. The 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 influencing VR learning in relation to the substantial body of research on the psychology of learning [21]
- Student responses to the experience of being immersed in VR [22]
- VR roles for teaching and training in engineering education [23]

This research project researches the theoretical and empirical evidence 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 those going on in natural tissues and organs. They are also expected to yield a better visualization of scientific ideas like inertia, entropy, and simultaneity. In this context the term “visual intelligence” should also be taken into account; it seems not an unearned benefit that the field benefit from the rich visual grammars and expressions [24]. Also, this trade-off between short- versus longer-term effects should be taken into account during the planned experiments.

11. Conclusion

The reintroduction of gaming and experimentation as valid modalities of learning will further propagate through the many upcoming 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. In particular, the (meta-)cognitive support during conceptual change, as happens during experimentation, is an important function of concept mapping. VR is becoming more and more the standard user interface for immersive learning experiences. The combination of VR and the constructivist contracts for experimentation will gather momentum and demand in-depth experimentation in coming years.

References

Concept mapping and navigational support tools were defined and evaluated in terms of sequential and retention effects and desired epistemic coherence. The conclusion was drawn that concept mapping mainly served the elicitation and meta-cognition process and supported less the navigation in hyperlinked documents. In the period 1983–1987 he coordinated in-service training programs for teacher training institutes concerning the integration of ICT in cross-curricular didactics. It led to the (INS) “PRONTO Testbed Project” that surveyed and supported Secondary School teachers in the process of didactic integration of conceptual representations in students’ study skills and History teaching. Varieties of team-teaching were introduced and evaluated. In the initial European DELTA SAFE and five subsequent projects he was responsible for the integration of hypermedia and concept mapping in multimedia design. In 1989 he co-defined and coordinated the NATO Advance Research Workshop on “Cognitive Technologies for Learning”. The key question during the workshop was to characterize the main process at the learner while using various cognitive learning tools. The conclusion at that moment was that “reconstructing prior experiences” and “articulating intuitive expectations” are helpful for the learner to orient in a new conceptual domain. During the period 1992–2001 his efforts were directed towards larger-scale integration of multimedia and telematic infrastructures in vocational and industrial training. The notion of REALs was developed: Rich Environments for Active Learning. The instructor’s role was differentiated in a tutor, coach and mentor. The question emerged: “Which additional teaching functions need to be attributed to the various instructor roles in order to complement cognitive learning tools like design-support, diagnostic and simulation software?” The European projects in the streams of Tempus, TACIS, Socrates and Leonardo brought his attention to institutional reform and the integration of ICT in didactics in Eastern European countries like Ukraine, Bulgaria, Uzbekistan, Russia and the Baltic States. Later he organized didactic workshops for teachers and school leaders in the former Soviet State’s institutions and in East-China normal University (Shanghai) and Capital Normal University (Beijing). From 1993 to 2002 he led in Turkey, Jordan and Cyprus the CogTech Summer Schools for teachers in the Mediterranean countries. Its main paradigm was that the crucial process in teaching is the learning; Didactic preparation can best be seen as a learning process where both experienced and novice teachers share essential learning experiences. In respect to the pedagogical moments in the learning process, the existential foundation is a crucial one; Teachers and learners need to face the courage to pose and question moral values, cultural and ethnic identity, the priority of peace and the respect for nature. Teaching should promote all-encompassing learning attitudes for continuous learning like curiosity, altruism and the virtuosity to see the other’s perspective. It seems evident that teachers need to be taught likewise as they are supposed to teach their students.

Biography

Dr. Piet Kommers is Assistant Professor in the Faculty of Educational Science and Technology at the Twente University in The Netherlands. His research field is the design and application of media in learning situations. His courses are Multimedia Design, Virtual Reality and Societal Effects of ICT. Concept mapping and metaphorical design stages play an important role here. Projects are undertaken in the field of multicultural communication. After few years of teaching at the primary school and art education, he started the study in Educational Science at the Utrecht State University in 1975. His specialties were psychology and media technology for observational and learning support. During his lecturership and the research at the University of Twente his main interest was adaptive mechanisms to accomplish the process of knowledge acquisition. His Ph.D. experiments showed that early hypertext methods obeyed the momentary interest of the learner but not necessarily his/her cognitive need.