Incidental and explicit learning from Animations in different pedagogical settings

Thesis presented by Ruedi Borer for the Master in educational technologies

TECFA
Faculté de Psychologie et des Sciences de l'Education
Université de Genève

April 2008

Jury:

Mireille Bétrancourt	Professor, TECFA*	Director
Daniel Peraya	Professor, TECFA*	Examinator
Cyril Rebetez	Research collaborator, TECFA*	Examinator

*Institut des Technologies de Formation et Apprentissage
Faculté de Psychologie et des Sciences de l'Education
Université de Genève

Index

Abstract

While in past years most of the theories on learning have merged to a theoretical framework unifying neobehaviourist, cognitivist and many constructivist approaches, an additional and equally important way of learning, which has been shown to be very important for and tightly linked to explicit learning, still waits to be fully integrated in this framework: Incidental learning. Because of its importance in every day learning some researchers have called this aspect of learning 'the forgotten dimension of learning'. In the present study we aimed at a quasi experimental approach to study incidental and explicit learning from animated multimedia documents. We also focused on the influence of different pedagogical settings on incidental and explicit learning. Firstly we studied the influence of different degrees of interactivity on learning from animations, since this has been shown to be an important factor for learning from multmedia. We secondly studied the influence of a collaborative setting on learning to test for the importance of interactions in collaborative learning and their interaction with learning from animations.

For this purpose a learning unit consisting of 9 animations covering the topics of Diffusion and Osmosis was created in two different versions. One version allowed maximum interactivity, while the other version limited interactivity to navigation (stop, go, replay). The experiment was done with 41 particpants, 28 worked in pairs, 13 worked individually.

While our experiment yielded no statistically significant results, the observed data tend to show a interaction between high interactivity and collaborative working. Our results do not support correlation between incidental and explicit learning. On a conceptual level our work points to the importance of further investigating the influence of animation type on learning.

Résumé

Même si au cours des dernières années la plupart des théories sur l'apprentissage ont fusionné dans un cadre théorique unifiant les approches neobehaviouristiques, cognitivistes et constructivistes, un autre type d'apprentissage, qui s'est révélé très important et étroitement lié à l'apprentissage explicite, attend encore d'être pleinement intégré dans ce cadre théorique: l'apprentissage incident. En raison de son importance pour l'apprentissage de chaque jour certains chercheurs ont appelé cet aspect de l'apprentissage " la dimension oubliée de l'apprentissage".

Dans la présente étude nous avons choisi une approche quasi expérimentale pour étudier l'apprentissage implicite et explicite à partir de documents multimédias. Nous avons mis l'accent sur l'influence de différentes approches pédagogiques sur l'apprentissage. Tout d'abord nous avons étudié l'influence de différents degrés d'interactivité sur l'apprentissage à la base de documents multmedia, car l'interactivité a été démontrée être un facteur important pour ce type d'apprentissage. Nous avons ensuite comparé l'apprentissage collaboratif et individuel, pour analyser l'importance des interactions au cadre de l'apprentissage collaboratif et pour étudier l'interaction des deux facteurs collaboration et interactivité pour l'apprentissage.

Pour cette approche une unité d'apprentissage composée de 9 animations portant sur les thèmes de la Diffusion et de l'Osmose a été conçue en deux versions différentes. Une version permettait une interactivité maximale, tandis que l'autre version offrait une interactivité limitée à la navigation (stop, go, replay). L'expérimentation a été faite avec 41 participants, dont 28 ont travaillé en groupes de 2 et 13 ont travaillé individuellement. Bien que notre étude n'ait pas donné de résultats statistiquement significatifs, les resultats observés indiquent une interaction positive entre l'interactivité et le travail collaboratif. Nos résultats ne soutienent pas la corrélation entre l'apprentissage implicite et explicite. Sur le plan conceptuel notre travail souligne l'importance d'une poursuite de l'etude au sujet de l'influence du type d'animation sur l'apprentissage.

1. Introduction

In this chapter we will first give an overview of current learning theories and their influence on computer supported learning environments (CSLE). We will then show, that one aspect of learning - incidental learning - still waits to be integrated in the current theories on how we learn. We finally will give an overview of current research on this poorly known type of learning, its possible connection with explicit learning and its dependence on external factors. We then will present the hypotheses which were tested in the present study.

Since more than 50 years theories on learning and learning technologies have influenced and inspired each other and led to a continous development of both our knowledge on how people learn and on the utility of modern technology as a support for learners. While research on learning processes often inspired development of new learning technologies - one of the notorious examples being Skinners "learning machine" (US Patent 2,846 779, Skinner 1961) these same learning technologies often led to deepened insight in learning processes and thus prompted new fields of research. In this context the tremendous development of computer technology has strongly influenced the way of teaching and learning.
Initially newly emerging theories on learning were often seen as contradictory to and incompatible with prevailing paradigms. But from a distance all these theories now merge to a very differentiated picture of learning and thinking, in which each theory has its place. Far from contradicting each other they yield a conclusive model of what are the neurological mechanisms, the personal factors and the social influences for information processing, learning and thinking.

Neobehaviourism

The neobehaviouristic approach on learning is based on the assumption as formulated by Skinner that learning may not be scientifically studied on a 'psychological' or 'physiological' level but conclusive evidence can only be drawn from externally measurable parameters - behaviourial actions (Skinner 1950). From this point of view learning is seen as operant conditioning in a chain of subsequent reflexes. Skinner developed a model for teaching and learning which consisted in decomposing and linearily structuring the learning content into numerous learning units, each of which was checked by the student before he could proceed to the next unit (Skinner 1954). Since the theoretical framework of this approach is based on externally measurable actions of the learner and claims that only a sufficient number of reinforcements yields a satisfactory level of learning (which the average teacher is in no means able to provide for all of his students) it can be seen as the logical starting point for the development of learning machines. Skinners learning machine thus used the principles of operant conditioning in a setting which asked for active answering of questions from the student and procured (immediate) reinforcement for correct answers. Skinner propagated this type of learning as "learning without errors".
While Skinners approach to learning was linear, some other researchers developed ramified learning programs, which - depending on student performance in the test questions - gave feedback to wrong answers as well (Skinner was convinced that negative feedback was useless) and guided each learner individually along the program. Crowder argued that not only erroneous responses are useful by helping to learn to avoid them but that by taking into account erroneous answers it is possible to even more adapt the material to learning strategies of the individual learner (Crowder 1954).

Behavioural objectives in Teaching Technologies - Instructionalism

To develop behavioral objectives a learning task must be broken down through analysis into specific measurable tasks. The learning success may be measured by tests developed to measure each objective. In 1956 Bloom and his colleagues started the development of a taxonomy in the cognitive, attitudinal (affective) and psychomotor domains, which in some aspects already points forward to a more cognitivistic view of learning.
Mastery learning had originally been developed by Morrison in the 1930s. His formula for mastery was "Pretest, teach, test the result, adapt procedure, teach and test again to the point of actual learning." (Morrison 1931, in Saettler 1990). Mastery learning assumes that all students can master the materials presented in the lesson if teaching strategies are sufficiently adapted to their needs. Bloom further developed Morrison's plan, but mastery learning is more effective for the lower levels of learning on Bloom's taxonomy (Saettler 1990).
For military and industrial training, "behavioral objectives were written descriptions of specific, terminal behaviours that were manifested in terms of observable, measurable behavior." (Saettler 1990). Robert Mager wrote *Preparing Instructional Objectives* in 1962, which prompted interest and use of behavioural objectives among educators. Gagné and Briggs who also had backgrounds in military and industrial psychology developed a set of instructions for writing objectives that is based on Magers work. Probably due to its military use the taxonomy of Gagné was published only 1972 (Gagné 1972).
Computer-assisted instruction (CAI) was first used in education and training during the 1950s. Early work was done by IBM and such people as Pask and Moore, but CAI grew rapidly in the 1960s when federal funding for research and development in education and industrial laboratories was implemented. The U.S. government wanted to determine the possible effectiveness of computer-assisted instruction and developed two competing companies, (Control Data Corporation and Mitre Corporation) who came up with the PLATO and TICCIT projects. Both projects developed computer-assisted instruction which was very much 'drill and practice', controlled by the program developer rather than the learner. Little branching of instruction was implemented, although TICCIT did allow the learner to determine the sequence of instruction or to skip certain topics. Due to quality problems and lack of success the TICCIT-program was abandoned in the mid-seventies (Saettler 1990).
Criticism of Programmed Instruction and its limited branching possibilities nurtured the idea of achieving a more effective form of individualization by introducing an increased variation of methods. Although Bruner only wanted to illustrate the pedagogical consequences of cognitive psychology (see further down) and did not intend founding a new theory, he may not only be responsible for popularising the concept of discovery learning but also, since he provided a first approach for a theory of instruction in his book »Toward a Theory of Instruction« (Bruner 1966), for the change from learning theories to theories of instruction that occurred in US psychological research and the Association for Supervision and Curriculum Development (ASCD) from 1965 onwards (Snelbecker 1983). Generally, however, Gagné, Ausubel and Scandura are considered the true founders of the theory of instruction. Seels (1989) gives a detailed historical synopsis of the development of instructional psychology.

Cognitivism and Constructivism

While classical Neobehaviourism admits only external stimuli for learning, and does not further study disposition and activity of the learner (which nevertheless are seen as preconditions sine qua non for learning), other researchers postulated that internal parameters, positioned between the external stimulus and the response of the learner, influenced learning as well (Hull 1943, Guthrie 1946).
The cognitivistic and constructivistic view of what is learning focuses on exactly these processes which have been put apart by neobehaviourism. According to this approach the processing of information and the building of mental representations are in the center of the learning process. What the teacher can do is offer material and assignments that encourage and facilitate these processes which take place within the learner and without direct control of the teacher.

Cognitivism

The cognitivistic approach is based on the belief that cognition consists in discrete, internal mental states (representations or symbols) whose manipulation can be described in terms of rules or algorithms and mechanisms of information processing and filtering which can experimentally be studied and analysed.
Atkinson an Shiffrins model of information processing and memory provided an important framework for learning and memory theories to evolve from (Atkinson and Shiffrin 1968). As shown in Figure 1 this model proposes a three step mechanism for transfer of external information (environmental input) into long term memory (permanent memory store).

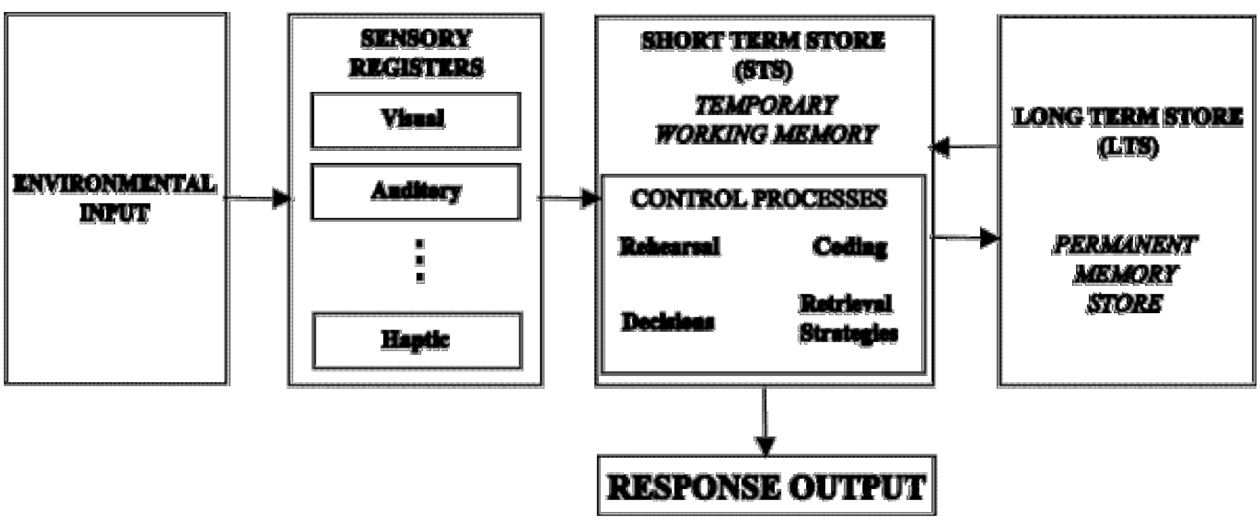


Fig 1: Atkinsons model of Sensory, short term and long term memory stores
(Redrawn from Atkinson and Shiffrin (1971). This graphic Copyright © 2002, Derek J. Smith.)

As had already been shown by Miller our sensory memory has a limited capacity for storage of sensory input. Stimuli are thus filtered and only a minute part of all information moves on to conscience and to the short term memory (= working memory). Whithout being further processed information in the short term store has a lifetime of about 20 seconds before it is lost. Once passed to the long term memory information is permanently stored.

Much research was done on mechanims that promote transfer of knowledge to the long term memory. Rothkopf coined the term of mathemagenic behaviour, which can be seen as identical with the 'intermediate variable' proned by Hull (Hull 1943) and which beholds the concept of behaviourism that learning should be seen as (and can only studied through) 'behaving' (Rothkopf 1970, 1996). Even though Rothkopf was aware that many external factors like eg social and cultural context influence 'mathemagenical activities' and thus was close to the view of constructivistic aproaches (see further down), he also assumed that only little insight can be gained in their actual mechanism: "These processes control the flow and transformation of information during learning and comprehension. Their functions may include selection, analysis, or interpretation. The invisibility and importance of covert processes makes them ripe for speculation, but this temptation should be resisted." (cited from Rothkopf 1996).
Other researchers have analyzed different registers of long term memory and distinguish episodic memory (simple facts and situations), semantic or declarative memory (concepts) and procedural memory (for chains of automated mouvements like driving a car, playing piano, but also for cognitive 'chains of argumentation'). Based on these concepts for long term memory Anderson has developed an elaborated model for the mechanisms of thinking and information retrieval from LTM. The adaptive character of thought theory (ACT-R) claims that problem solving is essentially based on tuned interaction between declarative and procedural memory. Declarative memory (and knowledge) consists in so called 'chunks', "that are schema-like structures consisting of a isa-pointer specifying their category and some number of additional pointers encoding their content" (cited from Anderson 1996). Procedural memory and knowledge consists of socalled 'production rules', which can be seen as procedural elements of strategies for solving a problem. Anderson argues that this seemingly (too) simple model works because of the tremendous amount of information which is stored in the human brain. Based on experimental evidence the ACT-R model also proposes a mechanism by which appropriate chunks and production rules are chosen in a given situation: "Declarative knowledge is a fairly direct encoding of things in our environment; procedural knowledge is a fairly direct encoding of observed transformations; and the two types of knowledge are tuned in their application by encoding the statistics of knowledge use in the environment." (cited from Anderson 1986). Obviously the ACT-R theory does not say much about how (episodic) information is processed, stored and transformed to declarative chunks or production rules. It even claims that before all the astonishing power of human thinking is based on strategically screening enormous amounts of information units, which per se are very simple in structure.
Other researchers have focused their work more on semiotic aspects of learning and on theories of language processing. Based on Paivios dual coding theory and on research in the field of learning from multimedia Schnotz and Bannert (2003) have proposed an integrated model for text and picture comprehension (see Figure 2).
The model posits that both visual and verbal information are processed differently and along distinct channels with the human mind creating separate representations for information processed in each channel. Both visual and verbal codes for representing information are used to organize incoming information into knowledge that can be acted upon, stored, and retrieved for subsequent use.

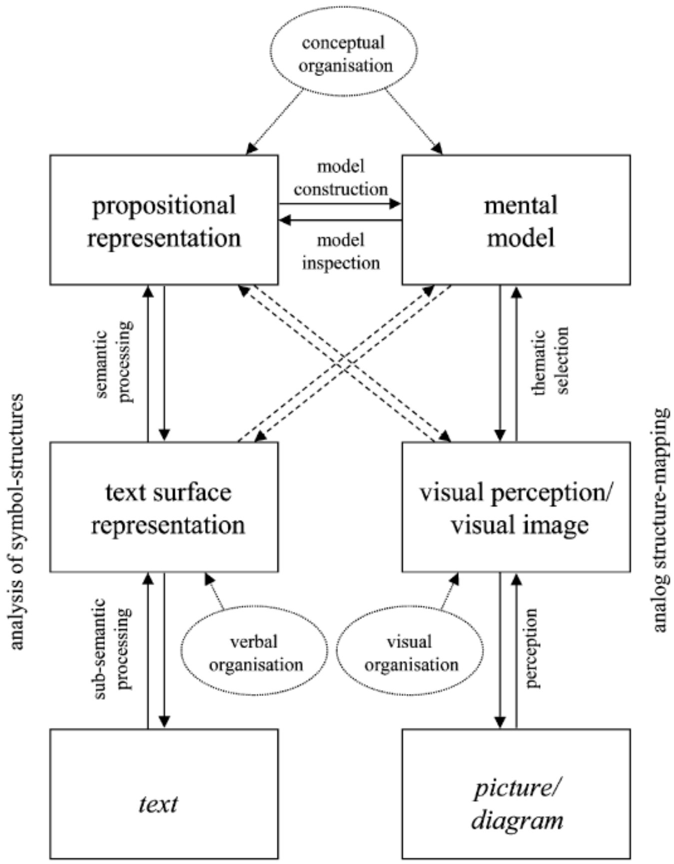
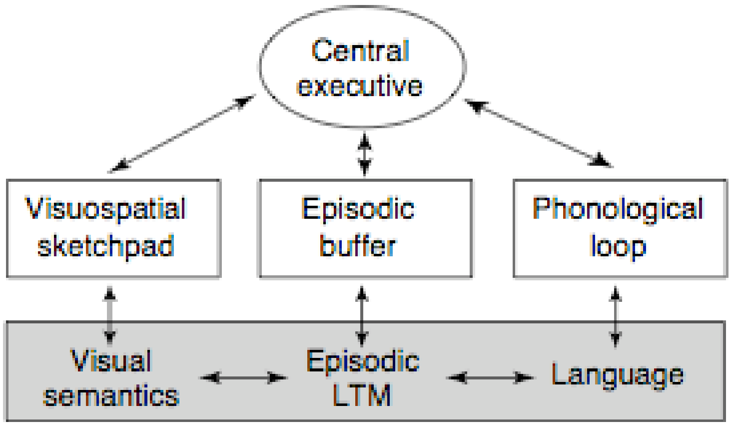


Fig 2: Integreated model of text and picture comprehension (taken from Schnotz and Bannert, 2003)

Also in accordance with Paivios model of dual coding and with findings on learning from verbal and visuo-spacial information, this model does not account for a number of additional findings in patients with neurological deficits and does not integrate the concepts of working memory and longterm memory (Atkinson and Shiffrin 1968).
Based on these findings Baddeley has presented a more elaborated model for a multi-component working memory (Baddeley 1986). As shown in Figure 3 this model also tries to integrate the known interactions of LTM with the processing activity of the working memory and is supported and anatomically substantiated by extensive psychological and neurophysiological evidence (for details see Baddeley 2000).



trends in Cognitive Sciences

Fig. 1. The current version of the multi-component working memory model. The episodic buffer is assumed to be capable of storing information in a multi-dimensional code. It thus provides a temporary interface between the slave systems (the phonological loop and the visuospatial sketchpad) and LTM. It is assumed to be controlled by the central executive, which is responsible for binding information from a number of sources into coherent episodes. Such episodes are assumed to be retrievable consciously. The buffer serves as a modelling space that is separate from LTM, but which forms an important stage in long-term episodic learning. Shaded areas represent 'crystallized' cognitive systems capable of accumulating long-term knowledge, and unshaded areas represent 'fluid' capacities (such as attention and temporary storage), themselves unchanged by learning.

Fig 3: Multi-component model of working memory (taken from Baddeley 2000)

Cognitivism and Computer assisted instruction

Although cognitive psychology emerged in the late 1950s and began to take over as the dominant theory of learning soon after, it wasn't until the late 1970s that cognitive science began to have its influence on instructional design. Cognitive science began a shift from behavioristic practices which emphasised external behaviour, to a concern with the internal mental processes of the mind and how they could be utilized in promoting effective learning. The design models that had been developed in the behaviourist tradition were not simply tossed out, but instead the "task analysis" and "learner analysis" parts of the models were worked out. The new models addressed component processes of learning such as knowledge coding and representation, information storage and retrieval as well as the incorporation and integration of new knowledge with previous information (Saettler 1990). Because Cognitivism and Behaviorism are both governed by an objectivistic view of the nature of knowledge and what it means to know something, the transition from behavioural instructional design principles to those of a cognitive style was not entirely difficult. The goal of instruction remained the communication or transfer of knowledge to learners in the most efficient, effective manner possible (Bednar et al in Anglin 1995). For

example, the breaking down of a task into small steps works for a behaviorist who is trying to find the most efficient and fail proof method of shaping a learner's behaviour. The cognitive scientist would analyze a task, break it down into smaller steps or chunks and use that information to develop instruction that moves from simple to complex building on prior schema. The influence of cognitive science in instructional design is evidenced by the use of advance organizers, mnemonic devices, metaphors, chunking into meaningful parts and the careful organization of instructional materials from simple to complex.
Computers process information in a similar fashion to how Cognitivism believes humans process information: receive, store and retrieve. This analogy makes the possibility of programming a computer to "think" like a person conceivable, i.e. artificial intelligence.
Artificial intelligence involves the computer working to supply appropriate responses to student input from the computer's data base. Below is a list of some programs developed since 1970 and their intended use (taken from Saettler 1990):

SCHOLAR - teaches facts about South American geography in a Socratic method
PUFF - diagnoses medical patients for possible pulmonary disorders
MYCIN - diagnoses blood infections and prescribes possible treatment
DENDRAL - enables a chemist to make an accurate guess about the molecular structure of an unknown compound
META-DENDRAL - makes up its own molecular fragmentation rules in an attempt to explain sets of basic data
GUIDION - a derivative of the MYCIN program that gave a student information about a case and compared their diagnosis with what MYCIN would suggest
SOPIE - helps engineers troubleshoot electronic equipment problems
BUGGY - allows teachers to diagnose causes for student mathematical errors
LOGO - designed to help children learn to program a computer
Davis' math programs for the PLATO system - to encourage mathematical development through discovery.

Much research has been done to structure the different approaches and define prerequisites for successful approaches in multimedia learning. As shown in Figure 4 Mayer has proposed the framework for a cognitive theory of multimedia learning which so to call translates the dual coding theory of Paivio and the integrated model of Schnotz and Bannert into the context of multimedia learning.

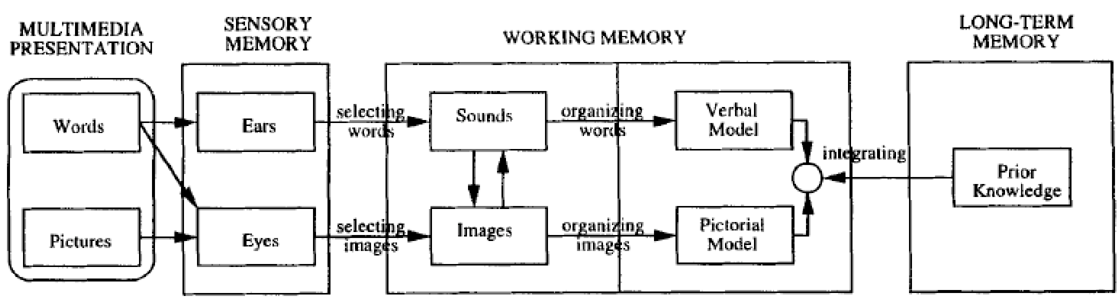


Fig 4: A framework for a cognitive theory of multimedia learning (from: Mayer 2003)

Multimedia learning - the role of integration and animation

Though it has been repeatedly found that adding pictorial illustrations improves text comprehension, this improvement clearly depends on the type of graphics and their connection with the accompanying text (Levin et al 1989, for review see Peek 1993). While some studies claim to clearly show a positive effect of graphic representations on learning outcome (eg Rieber 1990, 1991), other experiments have shown that especially animated graphics may even have a negative effect on learning (for review see Bauer 1993). These results have been broadly discussed on the basis of the cognitivistic framework and led to a more differentiated view for the preconditions of a positive role of animation in pedagogical documents.

1. Integration

Several research groups have been able to show that a well designed integration of graphic representation into the framework of a document leads to the expected positive effect on learning by yielding visuo-spatial information in addition to verbal information, thus allowing the cognitive system to take advantage of its dual code processing of external stimuli (Mayer 2001, 2003). In accordance with this interpretation of the data the researchers also have shown that when graphic representations contained redundant information or were poorly integrated, the additional cognitive load (for the working memory) hampered their positive effect on learning (Chandler et al 1991, Jamet 2001, 2002, Mayer 2003, Schnotz and Bannert 2003).
According to the tenants of the mental model theory and particularly Schnotz and Bannert (2003), the positive effect of picture in understanding text comes from the fact that pictures are analogic in nature, and thus aid the construction of the mental model that is supposed to be analogic as well.

2. Animation

A priori one would expect, that animated graphics ('animations') will help even better to construct a mental model, especially for dynamic processes. This has recently been stressed by a metaanalysis covering 80 comparative studies on the effect of static images and animated pictures on learning. Hoefler and Leutner (2007) found that the vast majority of studies show animation to be superior to static illustration. This effect is pronounced in animations covering dynamic processes. Several other studies have shown, though, that this is not always so (for a review see Bétrancourt et al 2001). Animated graphics release much more information in short time than static graphics, thus producing considerable cognitive load. In addition the information in animations is a priori futile. On the basis of this statement one can clearly define the preconditions for a positive role of animated graphics in multimedia learning:
Only if the massive cognitive load caused by animations can be processed by the learner we can expect to observe a positive effect on learning outcome. If the information transmitted by the animation cannot entirely be taken up and processed during 'running time' it is not only lost per se but during this period of time has hindered other cognitive processes from taking place.
Interactivity gives the learner the possibility to control the unfolding of the animation and to regulate the cognitive load. At the same time interactivity also creates additional cognitive load, since meaningful interaction needs to be planned, analysed and regulated. As would be expected some studies have shown that only a carefully designed degree of interactivity may increase the

positive effect of animated graphics on the learning outcome (Bétrancourt et al 2003, Rebetez et al 2008).
A further aspect of animated graphics has been analysed by Schnotz (Schnotz et al 1999), which have argued that in some cases animated graphics may cause less deep understanding because they induce a shallow processing activity by reducing or eliminating the need for active processing. Analogous results have been found in a study comparing the acquisition of route and survey knowledge of map-based and navigation assistance system-based wayfinding (Münzer et al 2006). Map-based wayfinding resulted in significantly higher route and survey knowledge. The authors explain the results by the fact that reading a map necessitates several abstraction steps and thus leads to deeper processing of the information, while the navigation assistance system creates a significantly lower cognitive load - a fact which may be positive in the typical context of its use (GPS in cars) but which is primarily caused by allowing the user to remain on a very shallow level of 'understanding'.

Constructivism

In the 1990s various new theories emerged and challenged cognitivism and its positivistic view of thinking. As one of the most successful theories on learning and thinking the constructivistic approach which based on research done some 30 years earlier primarily by Jean Piaget and Lev Vygotsky focused on personal, social and cultural factors which influence the mental structure and thus mental processes. In sharp contrast to cognitivism radical constructivism claims that knowledge is a mental construct and thus much more than simply a compilation of empirical data, as eg it is seen in the ACT-R theory. (Ernst von Glasersfeld 1995).
During his developmental studies with children Piaget (1971) had observed a psychological mechanism somewhat contrary to what is normally linked to learning. He claimed that the cognitive system primarily tends to resist to new information which does not fit into the preexisting mental structures. Only if the new information does not contradict preexisting mental models it is assimilated (and thus learnt). A change in mental patterns due to non-fitting information only takes place if the new information persists long enough to cause 'accomodation' of mental structures. Learning, and especially acquiring new mental concepts thus depends on going through the process of a cognitive conflict which is absolutely necessary for substantial learning. In this process, which is tightly linked to activity and tangible outer reality, mental models of the outer world are gradually refined, adapted and developed to an ever-growing complexity.
In his work Piaget described a series of steps for mental development in children. These lead from a period in which only simple sensori-motor actions can be performed, over pre-operational and concrete actions to the last stage, in which formal or symbolic actions are performed. In each stage learning depends on coping with real situations and on going through cognitive conflicts. According to Vygotsky (Vygotsky 1966) this conflict often is evoked in contact with other persons (parents, teachers, peers) in the environment, and thus society and culture play an important role in the development of mental structures and even the way of thinking. Cultural constructivism claims that even scientific thinking is influenced by its cultural and social context and thus cannot be seen as 'objective' and universal (Collins 1985, Driver et al 1994, for a more moderated view see Harré 1986). This becomes obvious when we look at the central aims of science teaching: These are not just about the 'facts of nature' but about the concepts, symbols and conventions through which science explains nature. The role of the teacher consists in passing on a specific way of looking at nature, not only in transmitting facts; and learning does

not simply mean to develop mental concepts of the outer world but to assimilate the current mental concepts (current in the actual social environment) by which to look at the outer world.

Learning in groups

In spite of the fact that the sociocognitivistic assumptions concerning learning in groups are broadly accepted, theoretical issues of instructional approaches to collaborative learning are still poorly explored. The great variety of possible settings in collaborative learning has led to multiple approaches with mostly not comparable parameters. While many qualitative studies explore the positive impact of collaborative learning on learning outcome in specific pedagogical fields there exists until now only very equivocal evidence as to the effect of group learning on the outcome of learning processes. As Dillenbourg states in his survey (Dillenbourg 1999) central aspects like the notion of 'group', 'learning' and 'collaboration' still remain to be clearly defined. One interesting approach to guide and structure interactions especially in computer supported collaborative learning (CSCL) are scripts which define a number of parameters relevant for the processes in group learning and may help to develop a more clearly defined approach to group learning especially in CSCL environments.
Some important aspects of collaborative learning have been shown as follows:

Schwartz (1995) observed that pairs draw more abstract representations of the problem at hand, probably because of the need of integration of the two views. Collaboration thus encourages sociocognitive conflicts and building of negotiated mental representations. These negotiations are the result of a series of processes involved in collaborative learning situations, namely representation of the partner and his views, grounding, appropriation and others (for a detailed view of collaborative learning see Dillenbourg 1999).

Collaboration allows the maintaining of a shared representation (‘distributed cognition’) and may thus significantly reduce the individual cognitive load. At the same time collaboration creates considerable additional cognitive load (see eg Schnotz 1997 for cumulative cognitive load of animated pictures and collaboration and Dillenbourg and Bétrancourt 2006 for collaboration load).
Collaboration creates situations in which distributed knowledge may pay. The sum of skills of all group members can promote problem solving and be helpful for learning. At the same time distributed knowledge on the level of the outcome of collaborative learning situations may lead to fragmentary knowledge of group members.

Constructivism and CSLE

While behaviourism and constructivism are based on very different theoretical perspectives, cognitivism shares some similarities with both. An example of the compatibility with constructivism is the fact that both approaches share the analogy of comparing the processes of the mind to that of a computer.

Despite these similarities of cognitivism and constructivism, the objective side of cognitivism supported the use of models to be used in the systems approach of instructional design. Constructivism is not compatible with this approach, since its central belief is

" that if each individual is responsible for knowledge construction, how can we as designers determine and insure a common set of outcomes for learning, as we have been taught to do?" (Jonasson, http://ouray.cudenver.edu/~slsanfor/cnstdm.txt April 2007).
In the same article Jonasson names some implications of Constructivism for instructional design:

"...purposeful knowledge construction may be facilitated by learning environments which:

- Provide multiple representations of reality - avoid oversimplification of instruction by representing the natural complexity of the world
- Present authentic tasks - contextualize
- Provide real-world, case-based learning environments, rather than pre-determined instructional sequences
- Foster reflective practice
- Enable context- and content-dependent knowledge construction
- Support collaborative construction of knowledge through social negotiation, not competition among learners for recognition"

The technological advances of the 1980s and 1990s especially in the domain of the internet have enabled designers to move towards a more constructivist approach of instruction. One of the most useful tools were hypertext and hypermedia because they allow for a branched design rather than a linear format of instruction. Socio-constructivism has gained widespread interest with the availability of software-tools like WIKI and other environments for CSCL which allow cooperative construction of content and favour collaborative learning. Meanwhile complex and multifunctional learning environments based on a constructivistic view of learning and teaching, like eg the open source software MOODLE as well as a variety of tools for collaborative mind-mapping, argumentation, etc are available and influence developments in educational policies and may even fundamentally change the way of teaching and learning (see eg Dillenbourg 2002b). At the same time an intensive debate about the compatibility of (constructivistic) CSLE with instructional aims has led to new theoretical frameworks for guided forms of cooperative learning (for review see Dillenbourg 2002a).

Towards a unified theory of learning

As has been shown earlier in this chapter Cognitivism and Instructivism are commonly seen as further developments of Neobehaviourism. On the level of the 'learning event' they take into account the mechanisms of registering, processing, storing and retrieval of information. But as in Neobehaviourism learning is seen as a mapping of external stimuli to neural structures and 'mental patterns'. Constructivism in its radical philosophic currents sharply opposes to neobehaviouristic paradigms of knowledge and mind. Nevertheless it also shares a number of concepts with Cognitivism, most importantly the active role of the learner in creating knowledge. Even more important is the common view of the significance of preexisting mental concepts for learning. While in the view of cognitivism these preexisting mental concepts are activated and reinforced by fitting 'input', constructivism describes this same phenomenon as 'assimilation' and opposes it to the process of acquiring new information and adapting existing mental concepts through the process of 'accomodation'.
In addition to these concepts shared with a cognitivistic view of learning Constructivism takes into account developmental aspects of cognition and formative influences of the environment on cognitive processes and the generation of mental concepts. It thus adds a further level of

complexity both to information uptake and inner processes of knowledge building. Only few currents in Constructivism go even further and claim that the construction of mental concepts by the learner cannot be influenced directly from the exterior but is a process which can only be facilitated by the teacher.
From an ecclectic point of view learning is neither behaviouristic, cognitivistic or constructivistic but to a certain extent it is all of them. As is shown in Figure 5 (drawn from Ertmer and Newby 1993) both the level of learner's knowledge and level of required cognitive processing typically are lowest in behavioural and highest in constructivist learning environments. Depending on the complexity of content and the level of learners knowledge learning switches from pure information uptake via the learning of patterns and rules to the formation of ever more complex mental concepts of the outer world (be they directly linkable to reality or not).

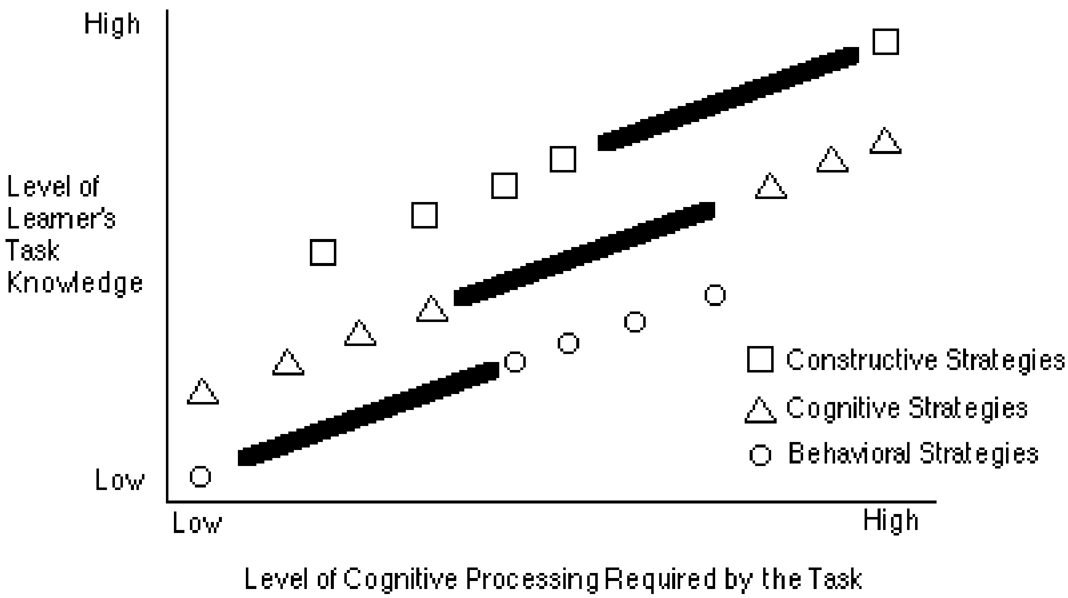


Fig.5: Comparison of the associated instructional strategies of the behavioral, cognitive, and constructivist viewpoints based on the learner's level of task knowledge and the level of cognitive processing required by the task.

Incidental learning - The forgotten dimension

All theories on learning presented so far deal with clearly defined learning situations and with the implicit assumption that learning is not only an active but also a conscious process. If at all a learner only learns what he explicitly intends to learn. But for a long time it has been clear, that there exists an additional and equally important way of learning, which by some researchers has been called 'the forgotten dimension of learning': Incidental learning.

While we learn ‘formally’ only in some very specific situations and periods of our life (school, formation) incidental and informal learning are much more important for most of the skills and knowledge we learn during the vast majority of life.
The term incidental learning has originally been coined by Reber (1967) to describe findings in his research on artificial grammar learning. Many authors use the terms of incidental and informal learning almost as synonyms (Marsick and Watkins 2001, Stangl 2004) and define incidental learning as a subcategory of informal learning which is characterized as a frequently unconscious byproduct of some other activity. This tightly connects incidental learning and implicit learning which is defined as unconscious learning (Stangl 2004).
Formal learning is typically institutionally sponsored, classroom-based and highly structured. This form of learning is what usually takes place in school or other pedagogical institutions. Informal learning is intentional but unstructured learning in a mostly non-pedagogical context of every day life. While informal learning can be encouraged by an organisation or inhibited by the environment, incidental learning continuously takes place although people are hardly conscious of it (Marsick and Watkins 1990).
As a matter of fact incidental learning is seen today as the normal way of learning for children in non-scholar context: They appropriate themselves with much knowledge and skills “en passant” (Reischmann 1986) as a by-product of seemingly not aimed but selfguided activities with a high intrinsic motivation. This has even led some authors to argue that what is called formal learning is in fact ‘education’ and confounds and demeans incidental and informal learning processes (Rogers 1997).

The importance of incidental learning

For adults, informal and incidental learning are still of major importance: Many skills, rules and facts concerning the professional situation (eg unwritten social rules, hidden agendas, important facts about staff, but also shortcuts on the computer, etc.) are not formally instructed but are acquired incidentally or informally (for a review of the literature see Kerka 2001).
Incidental learning is tightly linked to self-regulated and intrinsically motivated learning. This has for example been shown in a study of incidental acquisition of vocabulary by seven year old children. In this study seven classes of seven-year-old pupils at Christchurch, New Zealand were read the story "Gumdrop at sea", read by their teacher, three times over the period of a week, without any explanation of the 20 target words. Comparison of the mean pretest and posttest scores showed mean gains of 15% overall, with benefits of over 30% for words that occurred more than once in the story (Elley 1989).
In several studies Mathews et al have analyzed incidental learning of grammar rules (Mathews et al 1989, 2000). They claim that simple grammar rules are learned almost as effectively via implicit learning as via explicit learning. More complex grammar rules on the other hand cannot be acquired by implicit learning alone, but a combination of implicit and explicit learning clearly shows synergistic effects.
The same researchers have shown that implicit learning of a simple artificial grammar can lead to acquisition of generative knowledge about this grammar. An interesting aspect of this set of experiments was the fact that those participants which had explicitly been instructed to build a model of the grammar were very confident about having solved the problem but did not show higher performance in generative knowledge.
Subsequent studies found less convincing results and claimed that incidental learning can only - if at all - support explicit processes (Saetrevik et al 2006).

More recently Haider and Rose (2007) in an interesting study on approaches to investigate insight have shown that participants which are confronted with a simple artificial grammar not only acquire implicit knowledge about the rules but a representative portion of them also gets explicit awareness of them. Interestingly, these participants are normally excluded from studies on implicit learning, since it is claimed that knowing the rule means explicit learning. All participants after some training show implicit learning, which can be detected by a reduced reaction time. Haider and Rose postulate that the reduced reaction time in connection with correct response (which as a matter of fact are caused by unconscious learning processes) are the triggers of a (mental) search process and finally lead to explicit knowledge.
Haider and Rose found similar results with a so-called number-reduction task in which implicit learning of a regularity in the order of subsequent numbers to be calculated was tested. Again implicit learning became visible by a flagrant decrease in reaction time, again a certain number of participants got explicit knowledge of the regularity.
An analogous order of implicit learning followed by awareness of the regularity was found by Navon and Kasten (2007) for the implicit learning of secondary attentional cues. This importance of incidentally acquired information may not be limited to simple contingencies.
In their study on the influence of incidentally presented gray-tone or similar volumetric objects on the interpretation of 3D Images Moore and Engels have shown that optical information of the environment is implicitly acquired and can rapidly change visuo-spatial models of the three-dimensional environment (Moore and Engel 2002).
Many recent studies also show implicit learning of semantic and phonetic knowledge (Declerqu and Le Ny 2007, Majerus et al 2004, Prior and Bentin 2007, Ku and Anderson 2001) and are in obvious accord with the ACT-R model of learning.

Incidental learning in pedagogical context

As already mentioned above the importance of incidental learning for language acquisition has been shown in a significant number of studies. Language learning in a pedagogical context has been shown to rely as much on incidental and implicit (unconscious) learning as on intentional and explicit learning (for an extensive review see Elley 2005). Several studies have shown that the acquisition of vocabulary, of spelling and of grammar rules are strongly promoted by incidental learning if the context is highly motivating. This holds for first language learners as for second language learners, for small children as for adults. Some studies even showed that intensive grammar training in a traditional way has almost no effect on a better understanding of these rules (Harris 1962, Elley 1982, Hillocks 1984).
The incidence and effects of incidental learning from multmedia instruction have been studied as well. A study of Rieber (1991) on the effect of computer generated static and animated graphics on incidental learning and motivation of 4th grade 'students' (topic: Newtons law of motion) has shown a high impact of animated graphics on incidental learning without impeding the intentional learning goals. This study also showed that the animated graphics had a considerable motivational effect on students as well. Both effects were much weaker for static graphics.
Schank and Cleary (1995) put forward a theoretical model which gives incidental learning a clearly defined place in the learning process. Stating that incidental learning is the natural way of easily appropriating otherwise dull and boring facts as a 'by-product' during activities aimed at completely different (and very attractive) goals they propose to use this form of learning as a starting point to enter a topic. Students are doing "gaming", "playing" or "exploring" activities

with high motivational value ("Computer game") which contain – so to say – hidden information which they learn 'by the way'. Incidental learning is then of course leading to more structured and conceptually refined forms of learning like case studies and explorative learning.
While the informal/incidental learning effect can a priori be seen as positive for both the learning of simple facts and of concepts, further analysis in the study of Rieber (1991) showed that it also 'encouraged' students to develop scientific misconceptions and for this reason can also be seen as dangerous. This notion is also supported by results in the study of Mathews et al (1989, see also below).

The possible dangers of incidental learning have been focused on in a study by Harp and Mayer (1998), which tested the damaging effect of 'seductive details' on learning of a science topic. This study clearly showed that 'seductive details' (= adjuncts interesting but irrelevant for comprehension) have a significant and negative effect on the learning outcome in science. Harp and Mayer also put forward a hypothesis for the reason of this effect, claiming that seductive details activate erroneous or irrelevant prior knowledge and mental concepts which then are (erroneously) used by the learner as the organizing (mental) schema for the learning content. They fail to analyse the significance of the actual content of the 'seductive details'. While the 'seductive details' in the aforementioned study have been shown to have a negative effect on learning one can also argue, that specifically chosen 'seductive material' can play an equally important but positive role as organizing schema for the learning content of a lesson.

Factors that influence incidental learning

As mentioned before incidental learning of vocabulary by reading has been shown to depend strongly on the perceived relevance of the text by the reader or listener and concomitant motivation (Elley 1989, 1997). Similarily several other studies have shown that the 'attentional potential' of details is important for their being incidentally learned (Rieber 1991, Harp and Mayer 1998, Jones 2005, Baylor 2001).
Rieber (1991) has shown that animated graphics in addition to a higher motivational effect have a much higher potential than static graphics for incidental learning.
Baylors extensive study (Baylor 2001) on perceived disorientation and incidental learning in a web-based environment (nine Webpages in different versions) describes several factors which influence incidental learning. The study focused on internal and external factors that influence incidental learning of factual details and main points of content when persons navigate through a website. They show that several factors reduce incidental learning capacity: A linear navigation mode (no possibilities for the user of choosing where to go) and optical distracters both significantly reduced the performance for incidental learning. While the second factor can be linked to a cognitive overload due to too much incoherent information, the first factor – navigation mode – clearly points to the importance of an active implication of the learner for incidental learning. The same study also showed that perceived disorientation had a negative effect on incidental learning thus linking the conscient perception of 'incoherent input' with the unconscient failure of incidental learning processes.

An interesting study of Martin and Jones (2007) on incidental learning of characters on mobile phone displays shows a rapid decline of incidental learning which is tightly correlated with automatisation of number dialing. This is clear evidence that the attentional focus is important for both implicit and explicit learning.

A further factor which influences incidental learning has been studied by Münzer et al (2006). As already mentioned further above they investigated incidental acquisition of spatial orientation knowledge. In their experiment they compared the use of a navigation assistance system with the use of a simple map and found, that both incidentally acquired survey and route knowledge are much higher when participants use maps instead of a navigation assistance system. The authors claim that only information which is actually encoded, transformed and/or memorized during the primary wayfinding activity is incidentally learned.
A meta-analysis of 23 reports generated between 1970 and 1980 by Klauer (1984) has confirmed the fact that stringent behavioral objectives (learning directions, questions and other preorganizers) clearly reduce incidental learning (of irrelevant facts) by focusing the attention of the learner away from goal-irrelevant material.
Somewhat in contradiction to this Barker and Hapkiewicz (1979) have shown that the level of the behavioural objectives given to learners influences the level of (unconscient) incidental learning. High level tasks (eg. compare Y and Z) leaded to learners incidental learning of the definition of X, while a low level task like define X reduced the level of incidental learning of definitions for Y and Z (cited from Jones 1989).
The paper of Jones – although not leading to many evident results – states that browsing webpages is connected with low cognitive load search methods of users. In connection with the aforementioned effect this would lead to an effect on incidental learning in the sense of favouring the retrieval of simple facts over more complex content.
In accordance with these findings Mathews et al (1989) in their extensive study have shown that incidental learning, although being limited in complexity, is still important for learning of more complex structures in that it clearly supports explicit learning processes. These authors also propose a theoretical model, which argues that two different learning processes are involved in complex cognitive tasks which correspond more or less to the notions about explicit and implicit memory (Reber 1976, Schachter 1987). The authors propose that subjects draw on two different knowledge sources to solve complex cognitive tasks. One source is based on explicit conceptual representation of mental models while the second source is derived from memory based processing and relies on automatically (and unconsciously) abstracted patterns of family resemblance with the task. Basically the two knowledge sources are independent, but in specific learning situations they can positively interact.
The model clearly gives incidental learning an important role in all learning processes. This role was particularly stressed in one of the experiments which has shown that implicit learning of presented material (letter patterns created according to a biconditional grammar) prior to performing an explicit task (discovering the grammar rules) led to best performances of learners.

Which place for Incidental learning in the framework of existing learning theories?

The main characteristic of incidental learning is that it takes place without the learners knowledge. To place Incidental learning in the framework of existing learning theories we thus need to have a closer look at those processes which take place unconsciously.
In the cognitivistic framework of working memory the filtering of incoming stimuli as described in the ACT-R model displays a number of features which would allow for an integration of many aspects of incidental learning and of experimental evidence for connections between incidental and explicit learning. The so-called tuning process in the ACT-R model consists in identifying

incoming information and comparing it with already registered cognitive patterns - 'chunks' (mental concepts) and procedures (mental 'rules'). These are reinforced (and thus learnt) by fitting information. In the model for working memory of Baddeley (Baddeley 2000) this process can be attributed to the episodic buffer, which has access to the episodic LTM and thus to its cognitive representations. As the name implies the episodic buffer also would sustain a model for contextualized and situated learning. Other authors sustain a modified model, which stresses that working memory could also be seen as an activated part of LTM which makes available to processing those contents which by some contingencies are linked to incoming stimuli.
Several studies already mentioned earlier have shown that at least for some contingencies in the environment there exists a pathway through implicit learning to explicit knowledge (Navon and Kasten 2007, Haider and Rose 2007, Münzer et al 2006).
Cognitive load as defined by Chandler and Sweller (1991) may be caused by the fact of divergent cognitive patterns being evoked during the 'tuning' (filtering) process of the incoming information on the two channels. Since this filtering process is mainly unconscious, (incidental) information present on the two channels may - depending on the specific situation - help or hamper learning.

In a constructivistic framework the cognitive conflict is clearly defined as the consequence of information which does not fit preexisting mental models. Only little is known as to the effect of information which fits the preexisting mental models. Would this information stabilize the mental concepts? And by which way would it do this? It seems evident to argue that this type of learning needs not be fully conscious if conscious at all.

Although not yet clearly situated within the framework of existing models of memory and learning incidental learning has been shown to be an important factor for learning processes especially in situations where large amounts of information need to be processed, as is typically the case in multimedia learning environments. Several studies also have shown the significance of implicit processes for explicit learning in a wide range of areas (Navon and Kasten 2007, Haider and Rose 2007, Münzer et al 2006). The present study aimed at situating the role and importance of incidental learning in the context of learning from multimedia documents and in different pedagogical settings.

2. Hypotheses

1. Incidental learning of minor structural features takes place when learning from animations

   Several authors have shown that incidental learning takes place in CSLE (Baylor 2001, Jones 2005, Rieber 1991, Mathews et al 1989). Incidental learning has also been studied for its effect on explicit learning. Some authors, as Mathews et al 1989, claim a positive effect. Others focus on possible negative interference with explicit learning (Harp and Mayer 1998). One aim of this study is to show, as Rieber (1991) found, the occurence of incidental learning from animated graphics.

2. Incidental learning depends on the degree of interactivity and on motivation.

In their article on informal and incidental learning Marsick et al (2001) name critical reflection and stimulation of proactivity on the part of the learner as conditions for enhancing incidental learning.
Several studies link incidental learning with an open attitude towards the task. Rieber (1991) has shown a correlation of intrinsic motivation and incidental learning from animated graphics on a scientific thematic. Baylor (2001) has shown that incidental learning in a webbased environment is significantly better with a nonlinear navigation mode than with a linear navigation mode and is negatively correlated with perceived disorientation. The present study tested the effect of the degree of interactivity on incidental learning.

3. Working in pairs will favour incidental and explicit learning compared to working individually

   Working in pairs favours socio-cognitive confrontation and leads learners to maintain a shared mental model of the situation. This has been shown to promote the formation of more abstract mental models. Since it has been shown that cognitive demands promote incidental learning (Barker and Hapkiewicz 1979) we expect a positive effect of the group situation on incidental learning as well.

4. Incidential learning is correlated to explicit learning

   Mathews et al (1989) propose a facilitating effect of incidentally acquired information for (explicit) learning. Rieber (1991) has shown a correlation of incidental and intentional learning. Similarily Schank and Cleary (1995) propose an architecture for learning material in which explicit learning is based on previous experience allowing incidental learning of basic relevant facts. To test the link between implicit and explicit learning both were measured and correlated in the present study.

5. A high level of interactivity will favour explicit learning

   One of the main factors which has been shown to hamper the possible advantages of animations on learning is cognitive overload (for review see Bétrancourt 2001). Well designed interactivity allows the learner to regulate cognitive load. Additionally a high level of interativity may favour active and selfregulated construction of mental models at least in instructional animations (Hoeffler and Leutner 2007). We thus expect a positive effect of interactivity on explicit learning.

3. Methodology

To assess these hypotheses we designed a quasi-experimental study involving learning from a series of multimedia instructions on biology for secondary school students. A set of 9 interactive animations covering the subjects of Diffusion, Osmosis and Plasmolysis have been developed in Flash MX2004.
Each animation has been created in two versions - the 'active' version (Animation1a, 2a, etc.) allowing maximum user control and interaction, while the 'passive' version (Animation 1b, 2b, etc.) allows only minimal interaction.
To test for incidental and explicit learning interanimation tests were created and set between animations or animation segments. These tests were the same for all users.
User activities were followed and registered locally in subjacent XML-Files, which at the end of the experiment were sent to the TECFA-Server.

3.1. Participants

Experiments were done during normal Biology lessons with 41 students of two Biology classes at the Kantonsschule Stadelhofen. Students were from 15 to 18 years old and were informed about the double purpose of the experiment: Learning unit for them and harvesting of experimental data for me.

3.2. Design

The two independent variables 'level of interactivity' and 'group setting' were manipulated. For the level of interactivity the two modalities were 'active' and 'passive'. For the group setting the two modalities were 'individual' and 'pairs'. As can be seen in Table 1, participants were accordingly subdivided into four groups:

Group name	Setting	Number of groups
PI	Individual students, low level of interactivity	7
PD	Pairs of students, low level of interactivity	7
AI	Individual students, high level of interactivity	5
AD	Pairs of students, high level of interactivity	7

Tab 1: Group settings for experiment

3.3. Materials and Methods

3.3.1. Animations

Animation content

The animations covered the topics of diffusion, osmosis ans plasmolysis, as they are teached during normal curricular lessons in secondary school classes (10th school year).
Annex A shows an overview of the 9 animations and their content.

'Active' and 'passive' versions of Animations

Conceptually the animations are based on a step-by-step approach: Students are led through the learning unit, where each animation is based on the previous ones. As to the animation content emphasis is laid on presentation of the phenomenon and subsequent analysis of observations made by the students.
The difference between the two versions of each animation lies primarily in the navigational control of the animation. In the 'passive' version students only can start, stop and replay the animation, while the 'active' version allows and asks much more interaction and decisions.
The differences between active and passive versions are presented in detail for Animation 2 in Annex B.

Interaction possibilities in 'active' versions of animations

While the interaction possibilities in the passive versions are the same for all animations (play, stop, replay), the active versions of the animations show different types and degree of interaction. These are listed in Annex C.

'Incidental content' of animations

Since one of the aims of this master thesis was to study incidental retention of later relevant facts, care was taken to identically arrange this animation content (which we call 'incidental content') of both animation versions in order to allow a subsequent testing of incidental learning. Annex D shows the relevant 'incidental content' in the animation set.

3.3.2. Tests

Pretest and Posttest
A pretest and posttest with the same open questions checked for previous and acquired knowledge of the basic concepts for diffusion and osmosis. For details see Annex H.

Interanimation tests
Interanimation tests (in Flash MX2004) tested for retention of explicit learning content and incidentally retained details ('incidental content') of the animations. A table of the number and type of questions for different animations can be found in Annex K.These tests were the same for all users and allowed only few interactions. For most answers testing for explicit content a specific feedback was given, since the explicit function of the tests was to check for and ensure retention of relevant facts (explicit learning), which were to be relied upon in subsequent animations. Each test ended with a summary of explicit learning content. Annex E shows one example of the basic structure of Interanimation tests. Annex I gives an overview of evaluated implicit and explicit content.

3.3.3. Capturing and registration of user data

User data were captured during experiments by the means of an underlying XML-structure, which collects relevant data. At the end of each experiment the completed XML-file was sent to and saved on the TECFA server.

Data structure

The basic data structure is represented in Annex F by the DTD. Some concessions to stringency had to be made, though, because of limitations of XML-handling in the used version of Flash (The XML-file is continuously created during experiment).

Data registration

At the end of each experiment an XML-file was sent to and saved on the TECFA-Server. An example of one data file is shown in Annex G (only in part).

Statistical analysis of results

For statistical analysis the XML-files of all groups were merged to one single file. Data for different statistical analyses were then extracted with the aid of php-scripts and imported into SPSS for evaluation.

3.4. Procedure

Basic structure of the learning unit

The basic structure of the learning unit is shown below in Figure 6. As can be seen animations were created in two versions, Interanimation tests were the same for all users.

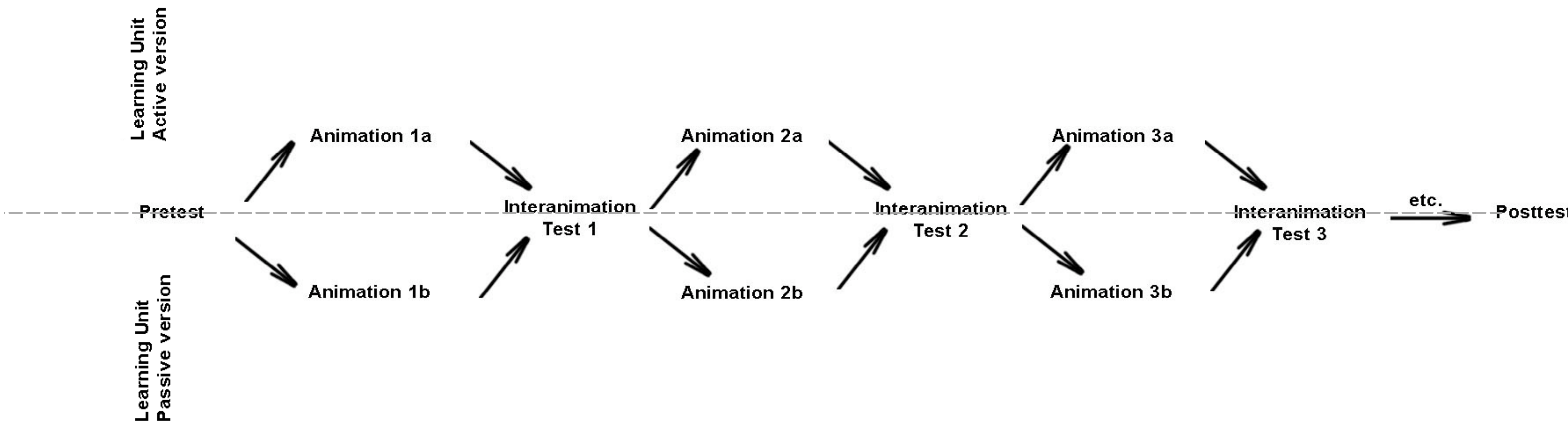


Fig 6: Basic structure of the two versions of the Learning unit

Experimental setting

The experiments took place in one of the multimedia classrooms of our school which is equipped with 12 computers (Macintosh G4) in a setting which allows +/- independent working of the groups.
The animations, which lay on the TECFA server, were shown on Safari browser (online being necessary to register and save experimental data in the end).
Before starting the learning unit all groups passed a pretest to check for previous knowledge of the subject.
All groups then passed the learning unit during the 90 minutes of the double lesson. After completing the learning unit each group (pairs passed the test as a group) passed a posttest corresponding to the pretest.

In all of the groups, the dependent variables (see list below) were registered.

Dependent Variables

- number of interactions (clicks)
- score in Interanimation Tests for explicit and implicit retention
- time spent for animations
- time spent for Interanimation test questions
- score in posttest for retention of explicit content
- score in motivation

4. Results

4.1. Pretest

Score in pretest was close to zero for all participants (results not shown). This showed that the concepts of diffusion and osmosis were not previously known by any of the participants.

4.2. Overall Score in Interanimation tests

Overall score in Interanimation test was calculated for the four different groups. Since questions with overall score > 90% and < 10% were not used, 47 ‚explicit' and 24 'implicit' questions were retained for evaluation.

4.2.1. DV Score explicit content

As can be seen in Figure 7, the factor interactivity has no major effect on performance if participants work in groups. Interestingly, while the degree of interactivity had no effect on participants working in pairs, participants working individually seemed to do better in passive condition than in active condition.
Both Interactivity ($F = 1{,}45$ $p = 0{,}24$) and Group setting ($F = 1{,}41$ $p = 0{,}24$) showed no significant effect on the score in explicit content. The interaction of the two factors was not significant either ($F = 1.9$ $p = 0.17$).

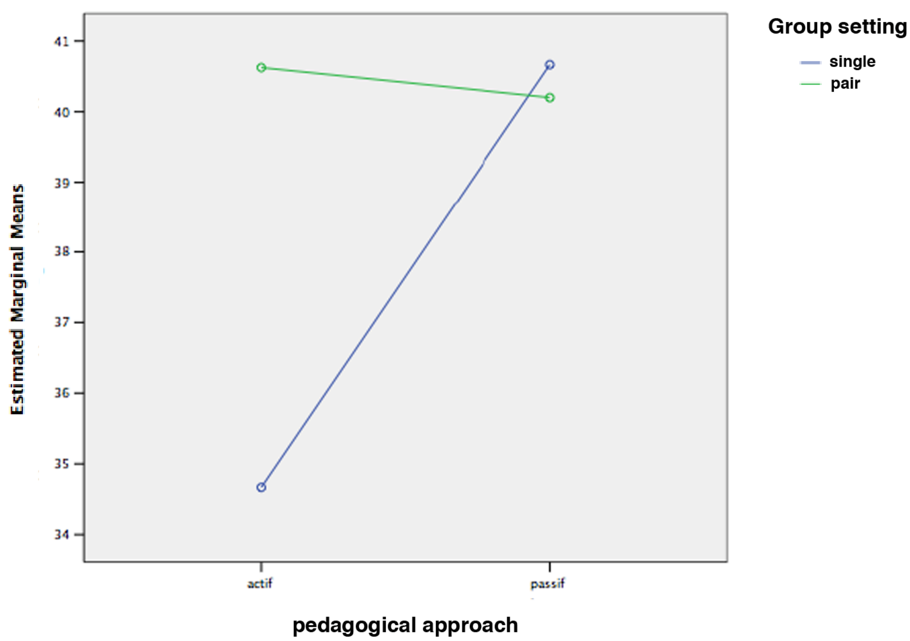


Fig 7: Score in explicit learning as measured by marginal means of correct answers (%). Total number of evaluated questions: 47

4.2.2. DV Score implicit content

As is shown in Figure 8 high interactivity had a negative effect on the score in incidental learning for both groups and individuals, but generally pairs were performing better than individuals. Both factors had no statistically significant effect on performance in incidental learning (Interactivity: $F = 0{,}32$ $p = 0{,}57$ and group setting: $F = 0{,}73$ $p = 0{,}4$).

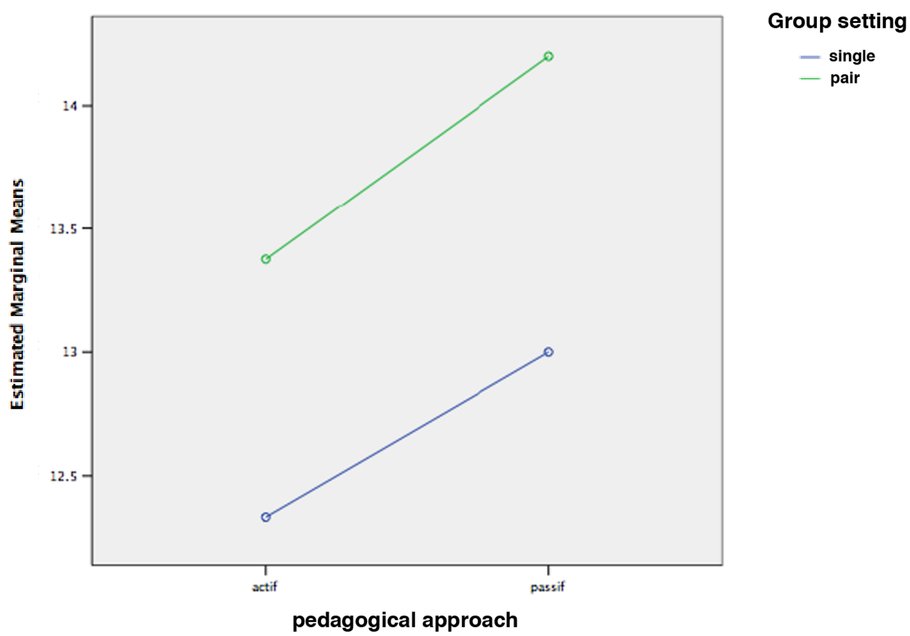


Fig 8: Score in implicit learning as measured by marginal means of correct answers (%). Total number of evaluated questions: 23

4.3. Score in Posttest

An open questionnaire was used to check for retention of basic concepts of Diffusion and Osmosis. Answers were weighted on a scale between 0 and 12 dependent on retention of these basic concepts (see Annex H). Results are shown in Figure 9. Although there was no statistically significant interaction of the two factors ($F = 0{,}4$ $p = 0{,}5$) results were similar to those observed for expicit learning, indiciating that a high level of interactivity was useful only for those working in pairs.

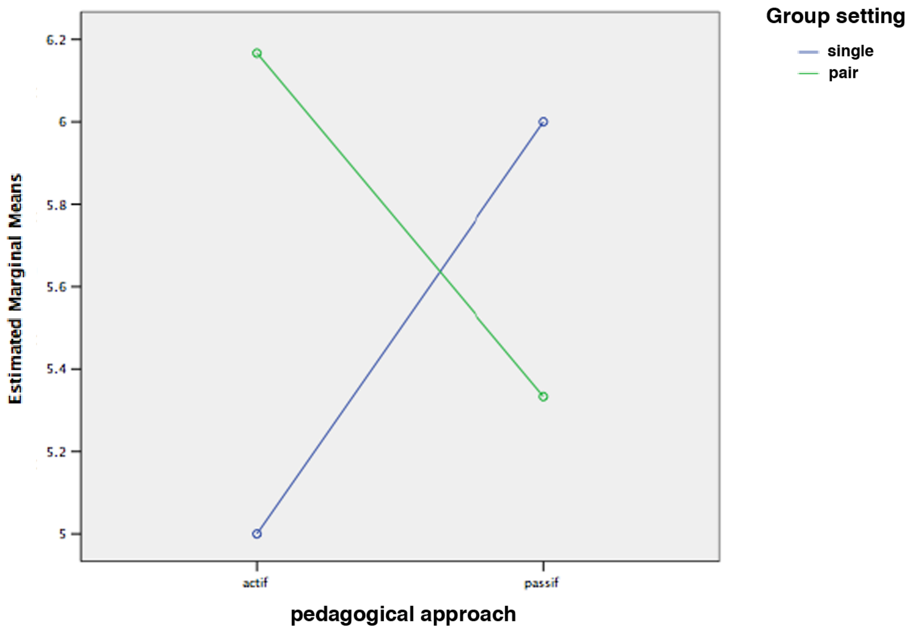


Fig 9: Score in Posttest. Retention of basic concepts were captured by analysis of open questions (weighted on a scale of 0-12 for details see Annex H

4.4. Overall time

Overall time needed to completely finish the learning unit was measured by calculating the sum of the time spent on animations 3 to 9 in seconds. Time spent on Login-Screen and Introduction Screen in Animation 1 was not integrated in the evaluation. As can be seen in Figure 10 participants working in a low interactivity spent more time with the animations. This effect was even more pronounced for those working in pairs. But the observed effect of interactivity on overall time was not significant (F = 1,2 p = 0,28).

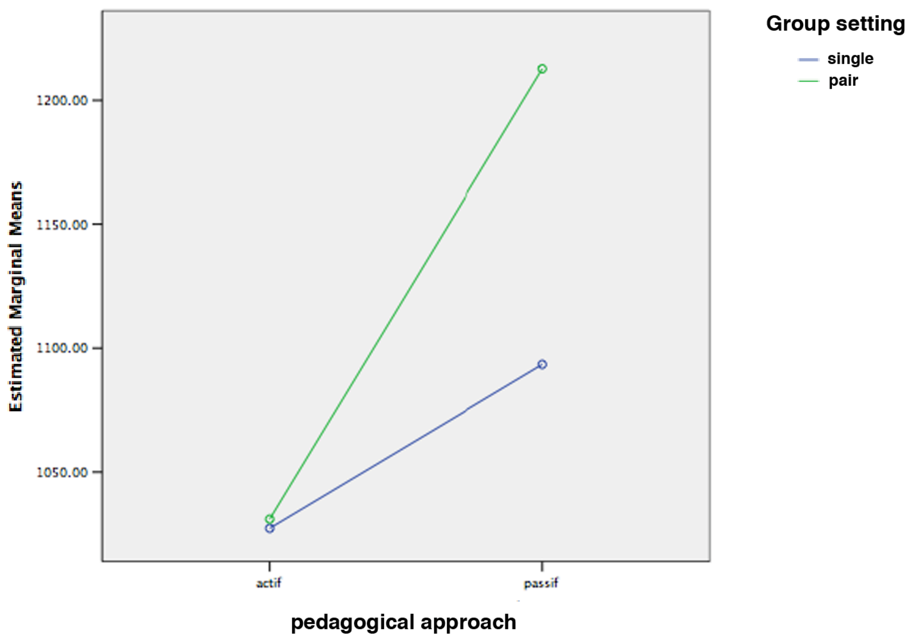


Fig 10: Total time as measured by subjacent scripts in the animation (seconds)

4.5. Motivation

Motivation was scored by the means of a questionnaire of 4 questions and weighted on a scale between 1 and 4 (for details see annex K). The results are shown in Figure 11. Astonishingly, groups working in the high interactivity setting felt less motivated than groups working with the passive pedagogical approach.
Motivation of participants working individually was generally lower than for the groups, but high interactivity increased motivation.
The results as to an interaction of the two IV were not statistically significant (F = 1,6 p = 0,22).

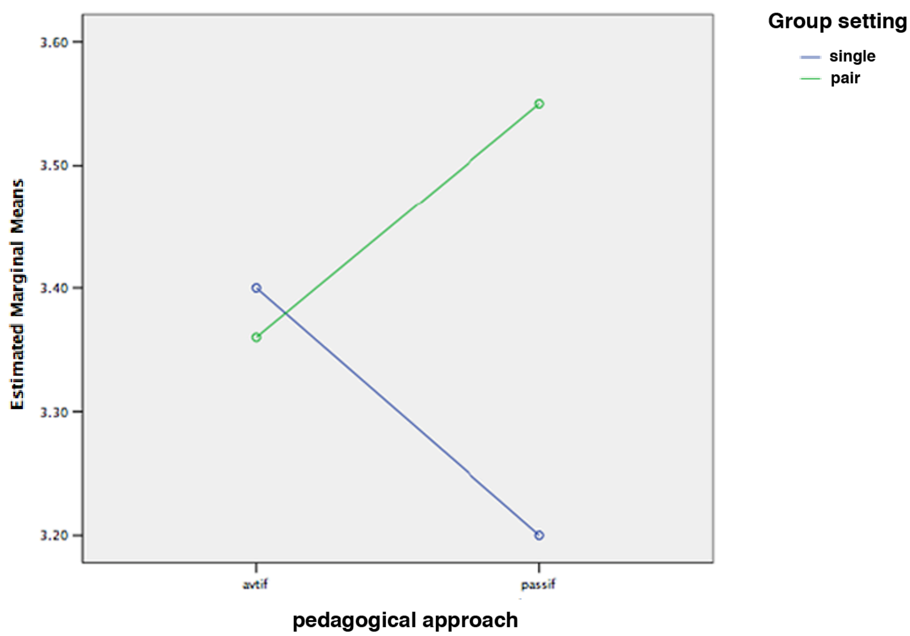


Fig 11: Motivation as measured by questionary (scale 1-4)

4.6. Degree of Interaction

The degree of interaction was measured indirectly by the total number of mouse interactions (klicks). As was expected from the differences between active and passive test versions, participants working with the active version of the test showed significantly more interactions independent of the group setting ($F = 151$,$p < 0.05$). The results are shown in Figure 12.

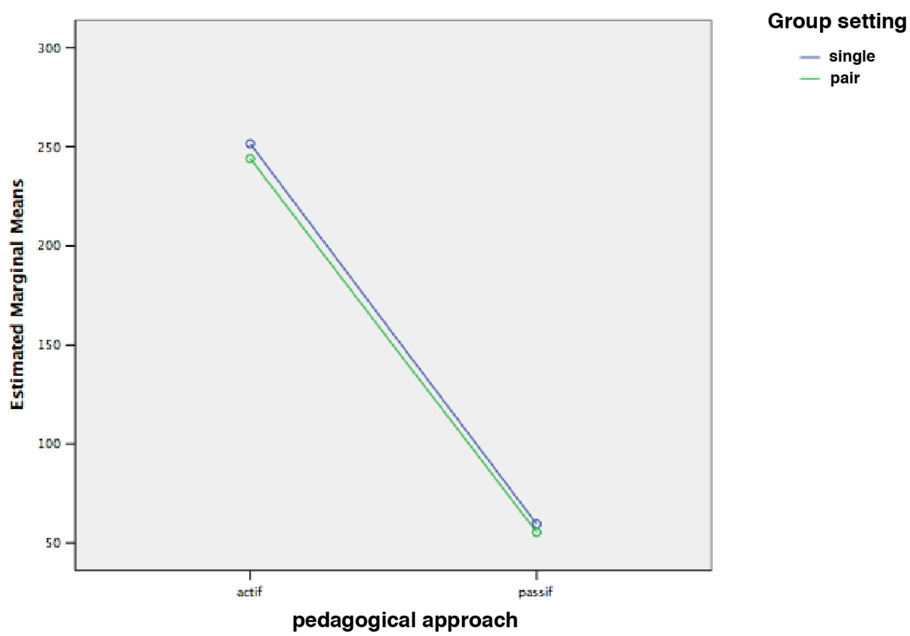


Fig 12: Interaction as measured by total klicks (number of klicks)

5. Discussion

5.1. Hypotheses

5.1.1. Occurence of incidental learning and effect of independent variables

One of the premises of this thesis was to integrate the experiments in the normal curriculum of Biology lessons at the Kantonsschule Stadelhofen. An integral learning unit of nine subsequent animations seemed the ideal means to check for incidental retaining of later relevant facts by participants on their way across the learning unit. Basically the course of the experiments seemed to confirm this view. Students were enthusiastic about the idea and feedback before and after the experiment was generally very positive as to the fact of doing something special and interresting. At a closer look, unfortunately, this enthousiasm does not necessarily correlate with motivation for learning. As was observed during experiments enthousiasm for animations need not automatically lead to positive attitude towards the actual content and demands of the animations. Attentional focus and motivation have been shown to be important factors for incidental learning and their lack seems to be the main reasons that the study did not yield statistically relevant hard facts concerning incidental learning.
On a general level the data obtained for incidental and explicit learning do not support ideas about the significance of incidental learning for the score in explicit learning, since data for the two variables do not correlate (see Figures 7 and 8). Our results, although not statistically significant, also seem to contradict the idea that minor differences in layout, basic conceptuality and conceptual paradigms in a series of animations may directly influence the learning outcome. A second important factor for the low level of incidental learning may be of more conceptual nature. In spite of a more open pedagogical approach in the 'active' versions of animations participants were tightly guided through the learning module anyway. This was necessary for later comparison of data from active and passive versions, but may at the same time have reduced incidental learning, since, as Klauer (1984) and Baylor (2001) showed in their respective studies, such a setting may be inhibitive for incidental learning.

5.1.2. Effect of independent variables on explicit learning

Both the score in posttest and the score in interanimation questions are higher in an active pedagogical approach if participants work in groups. This effect is clearly not dependent on time, since those groups, which worked in the 'active' setting were faster than those in the 'passive' setting. For participants working individually an active pedagogical approach has a negative effect both on the score in interanimation tests and in the posttest.
From a constructivistic point of view one could thus argue that the advantage of an active pedagogical approach may be dependent on working in groups since both approaches favour the construction of mental models. Thus the possible advantage of an active pedagogical approach may be hampered by cognitive overload and lack of a discussion partner (Schwartz 1995), if participants work individually. Another explanation may be that manipulations in the animations reduce mental processing activities (“hands on mind off”).

5.1.3. Time and interactions

Participants in the 'active' setting showed significantly more interactions than those working in the 'passive' version of the learning module.
This was expected, since the conceptual setting of the active pedagogical approach asked much more interactions (klicks and decisions) from participants. Participants working in active pedagogical setting did four times more klicks than those working in a passive setting.
Astonishingly this was not reflected by the time needed to pass the learning unit: Participants working in the passive setting needed more time to pass the experiment. This effect was even more pronounced for those participants working in pairs, which means that they needed more time thinking than in the ‘active’ version.
Collaborative work did not influence the degree of interactivity, since in both the active and passive setting the participants working individually and those working in groups showed a similar number of interactions.
Taking into account the influence of an active pedagogical approach on interactivity and time leads to an interesting conclusion. Participants in an active setting do more interactions in less time, thus implicating an intensifying effect of the active pedagogical approach on the learning process for those working in groups.
A last conclusion of the data may be that a passive approach is less adequate for pairs, since these needed even more time than participants working individually to complete the learning unit.

5.2. Conceptual considerations

The quasi-experimental approach of this study intended to create an experimental setting for the testing of incidental and explicit learning under different pedagogical approaches in the classroom. While the technical aspects of the experiment proved to match the expectations the conceptual approach clearly did not.
To keep a long story short: too much animations were tested under too much different experimental settings with a too small and heterogeneous group of participants.
For further work it seems to be advisable to take into account the heterogeneity of participants, to reduce the time of the experiment, the number of animations, and to focus on less learning content.
An additional aspect to be considered may be the conceptual differences of the animations. While some are simple transformations of real life experiments into a virtual environment (Diffusion of a dye, Plasmolysis) others try to visualize molecular processes (Factors of diffusion speed, Osmosis). A third type of animations tries to guide participants from the real world phenomenon to the molecular model view (molecular movement of Brown), while a last type simply delivers structured informations (Solutes, mixtures, molecules).
A possible focus of further research may be the analysis of the utility of interactivity for these different types of animations (see also Hoeffler and Leutner 2007).

5.3. Conclusion

While the primary focus of this study – incidental learning – did not yield many palpable results some other aspects of our experimental approach may be worth further investigation.

Some recent research has addressed the positive and negative aspects of animated graphics for learning. While on one hand animations are said to help constructing mental models other researchers claim that animation may replace deeper processing of information and thus lead to less deep understanding. What until now has not been taken into account is the type of animation. While some types of animation may as a matter of fact reduce cognitive load by reducing the necessity of deep processing, others may help deep processing by guiding the learning process. Others may simply structure factual knowledge and thus by reducing cognitive load leave more ressources for deep processing. One explanation for the diverging results concerning the utility of animated graphics for learning may have been caused by the fact that until now this differentiation was not taken into account.

The experimental approach of this study to compare different degrees of interactivity proved to be problematic. To be able to compare the two approaches the active and passive versions of the animations were created as similar to each other as possible. This led to ‚active' animations with a relatively low degree of freedom and with a quite linear structure. A a consequence we may not have compared an active and a passive version of animations but a version with full interactivity and a version with heavily restricted interaction possibilities with this approach. A direct analysis and comparison of different pedagogical approaches seems quite impossible and would have to be replaced by more adequate yet less stringent approaches.

Although the present study did not yield any stringent results as to the significance of incidentally acquired facts for explicit learning I still am convinced, that especially the first contact with a new thematic is concomitant with this type of learning. Since one aspect of incidental learning can be seen as the reactivation of preexisting mental concepts this may be important when a new topic should be linked to already learnt topics.
For the study of incidental learning the classroom setting proved not to be very helpful. One could imagine, though, to develop an experimental setting based on game and playing which would be free of the needs of classroom teaching and thus could focus on incidental learning in a more fundamental approach.

One of the most positive aspects of this research was the use of the animations for classroom teaching. Regardless of their usefulness in the present study all animations have been estimated by students.

6. References

Anderson, J. R. ACT: A simple theory of complex cognition. *American Psychologist*, 51, 355-365, 1996

Atkinson, R.C. & Shiffrin, R.M. Human memory: A proposed system and its control processes. In K.W. Spence and J.T. Spence (Eds.), *The psychology of learning and motivation, vol. 8*. London: Academic Press, 1968

Atkinson, R.C. & Shiffrin, R.M. The control of short term memory. *Scientific American*, 225(2):82-90, August 1971

B.F.Skinner The theory behind teaching machines. Journal of the American Society of Training Directors, 15, 27-29, July 1961

Baddeley, A. D. Working memory. Oxford: Oxford University Press, 1986

Baddeley,A., The episodic buffer: a new component of working memory? Trends in cognitive sciences Vol 4. No.11, November 2000

Bauer, M. I., & Johnson-Laird, P. N.. How diagrams can improve reasoning.

Psychological Science, *6,* 372-378, 1993

Baylor, A.L. Percieved disorientation and incidental learning in a Web-based environment: Internal and external factors J of Educational Multimedia and Hypermedia Vol. 10/3, 2001

Bétrancourt,M., Bauer-Morrison,J., B Tversky,B. Les animations sont-elles vraiment plus efficaces? Revue d'intelligence artificielle, 2001

Blandin,B., Are E-learning standards neutral ? Proceedings CALIE 04: International Conference on Computer, 2004

Bruner, J.S. Toward Theory of Instruction. John Wiley, New York, 1966

Clark, J. M. & Paivio, A.. Dual coding theory and education. Educational Psychology Review, 3(3), 149-170, 1991

Collins,H.M. Changing Order. London: Sage Publications, 1985

Crowder, N.A. Automatic tutoring by means of intrinsic programming. Automatic teaching: The state of the art, 109-116, 1954

Denis, 1984

Dillenbourg,P. What do you mean by collaborative learning? In P. Dillenbourg (Ed)

Collaborative-learning: Cognitive and Computational Approaches. (pp.1-19). Oxford: Elsevier, 1999

Dillenbourg,P. Over-scripting CSCL: The risks of blending collaborative learning with instructional design. In P. A. Kirschner (Ed). *Three worlds of CSCL. Can we support CSCL* (pp. 61-91). Heerlen, Open Universiteit Nederland, 2002a

Dillenbourg,P., Schneider,S., Synteta,P. Virtual Learning Environments in: A.Dimitracopoulou (ed.) Proceedings of the 3rd Hellenic conference „Information and Communication technologies in Education" pp.3-18, Kastaniotis Editions, Greece, 2002b

Elley, WB, Barham, I,Lamb, H & Wyllie,M The role of grammar in a secondary school curriculum New Zealand Council for Educational Research 1982

Elley, WB Vocabulary acquisition from listening to stories read aloud. Reading research Quarterly 24, 174-187: 1989

Elley, W.B., In praise of incidental learning: Lessons from some empirical findings on language acquisition, 1997, http//cela.albany.edu/reports/inpraise/main.html , Dez.2005

Ertmer, P. A., Newby, T. J.. Behaviorism, cognitivism, constructivism: Comparing critical features from an instructional design perspective. *Performance Improvement Quarterly,* 6 (4), 50-70, 1993

Gagné,R.M., Domains of learning in: Interchange Springer, 1972

Gagné, R.M., LJ Briggs,L.J., Principles of instructional design Holt, Rinehart and Winston New York, 1974

Guthrie, E.R.Psychological Facts and Psychological Theory Psychological Bulletin, 43, 1-20, 1946

Harré,R: Varieties of realism. Oxford: Blackwell, 1986

Harris, R. An experimental inquiry into the functions and value of formal grammar in the teaching of English. Ph.D. Dissertation, University of London,1962

Hillocks, G. What works in teaching composition: A Meta-analysis of experimental treatment studies American Journal of Education 93, 133-170, 1984

Hobbs, D.L. Aconstructivist approach to web course design : A review of the literature International Journal on E-Learning 60 – 65, April/June 2002

Höffler T. & Leutner D. Instructional animation versus static pictures: A meta-analysis. *Learning and Instruction, 17*, 722-738, 2007

Hull, C.A. Principles of behavior : an introduction to behavior theory New York : Appleton-Century-Crofts, 1943.

Jonasson, http://ouray.cudenver.edu/~slsanfor/cnstdm.txt, April 2007

Jones, T. Incidental learning during information retrieval: a hypertext experiment. Lecture Notes In Computer Science; Vol. 360 Proceedings of the 2nd International Conference on Computer Assisted Learning: 235 – 253, 1989

Kerka,S., Alert No.18
Incidental learning Trends and Issues, 2000

Klauer, K.J. Intentional and Incidental Learning with Instructional Texts: A Meta-Analysis for 1970-1980 American Educational Research Journal, Vol. 21, No. 2, pp. 323-339, 1984

Levin, J. R., and Mayer, R. E., Understanding illustrations in text. In Britton, B. K., Woodward, A., and Brinkley, M. (eds.), Learning from Textbooks, Erlbaum, Hillsdale, NJ, pp. 95–113, 1993

Mager,R.F. Preparing instructional objectives. Fearon Publishers, 1962

Marsick, V.J. and Watkins, K. Informal and incidental learning in the workplace. London and NewYork:Routledge, 1990

Marsick,V.J. & Watkins,K.J., In: New directions for adult and continuing education 89 25-34 Informal and incidental learning, 2001

Mathews, RC, Buss, RR, Stanley, WB, Blanchard-Fields, F, Cho, JR and Druhan,B. J of experimental psychology:Learning, Memory and Cognition Vol. 15/6 1083-1100: 1989

Mathews,R.C., Buss,R.R., Stanley,W.B., Blanchard-Fields,F., Ryeul Cho,J, and Druhan,B. Role of Implicit and Explicit Processes in Learning From Examples: A Synergistic Effect

Mayer, R:E: Multimedia Learning Cambridge University Press, 2001

Mayer, R.E. The promise of multimedia learning : using the same instructional design methods across different media Learning and Instruction 13 pp125-139 , 2003

Mayer, R.E., Heiser, J. & Lonn,S. Cognitive constraints on multimedia learning :when presenting more material results in less understanding Journal of educational psychology, 93 pp.187-198 , 2001

Milheim, W.D. How to use animation in computer assisted learning British Journal of Educational technology Vol 24, pp. 171-178 : 1993

Miller, G.A. The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing Information The Psychological Review, vol. 63, pp. 81-97, 1956

Paivio, A. Mental representations: a dual coding approach. Oxford. England: Oxford University Press, 1986
Peek, J. Increasing picture effects in learning from illustrated text. Learning and Instruction, 3, 227-238, 1993
Piaget, J. Biology and Knowledge. Chicago: University of Chicago Press, 1971
Reber, A.S. Implicit learning of artificial grammars. J.Verbal Learning Verbal behaviour. 6, 855-863, 1967
Reber,A.S. Implicit learning of artificial languages. The role of innstructional set. J of experimental psychology. Human learning and memory,2 pp. 88-94,1976
Rebetez, C., Betrancourt,M., Sangin, M., Dillenbourg, P., Learning from animation enabled by collaboration, 2008 (in press)
Reischmann, J. Learning “en paassant”: The forgotten dimension Paper presented at the American Association of Adult and Continuing Education Conference,1986
Reiser, R.A. A history of Instructional Design and technology : History of Instructional Design ETR&D No.2 pp57-67, 2001
Rieber, L.P.; The effects of visual grouping of textual and animated presentations on intentional and incidental learning. Unpublished raw data, 1989
Rieber,L.P, Animation, incidental Learning and continuing motivation J of educational Psychology Vol 83/3 318 – 328, 1991
Rieber,L.P., Seriously considering play: Designing Interactive learning environments based on the blending of microworlds, simulations and games ETR&D Vol. 44 1996, 43-58, 1991
Rieber,L.P., Animation, incidental learning, and continuing motivation Journal of Educational Psychology, 1991
Rieber,L.P., Using computer animated graphics in science instruction with children Journal of Educational Psychology, 1990
Rogers, A Learning:Can we change the discourse? Adults learning 8, no.5 116-117, Jan 1997
Rothkopf, E.Z. The concept of mathemagenic activities. Review of Educational Research 40, 325-36, 1970
Rothkopf,E.Z. Control of mathemagenic activities. In D.H.Jonassen, (Ed.), Handbook of Research on Educational Communications and technology. New York: McMillan, 1996
Rude, B.D., The case against incidental learning, http://www.brianrude.com/c-inci.htm Aug 2004
Schachter,D. Implicit memory : History and current status J of experimental psychology. Learning, Memory and Cognition, 13, pp. 501-518,1987
Schank,R.C. & Cleary,Ch., Engines for Education, In: Incidental learning 95-105 Lawrence Erlbaum Ass. Publishers Hillsdale NJ, 1995
Schnotz, W. and Preuss,A. Task-dependent Construction of Mental Models as a Basis for Conceptual Change. European Journal of Psychology of Education, v12 n2 p185-211 Jun 1997.
Schnotz, W., Sign systems, technologies, and the acquisition of knowledge. In J.F. Rouet, J. Levonen & A. Biardeau9-29). Amsterdam: Elsevier, 2001
Schnotz,W. and Bannert,M., Construction and interference in learning from multiple representation In: Learning and Instruction Elsevier, 2003
Schnotz,W., Boeckheler,J., H Grzondziel,H., Individual and co-operative acquisition of knowledge with static and animated pictures in computer-based learning environments. Proceedings of the European Association for Research on Learning and Instruction (EARLI), Gutenberg University Publications, 182–183, 1997

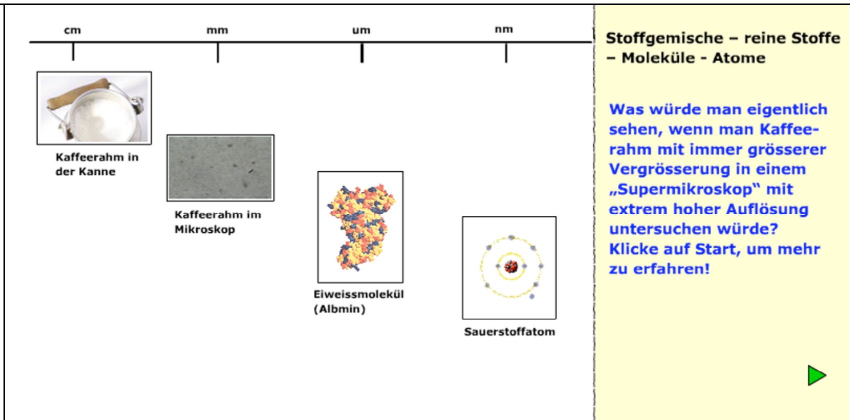
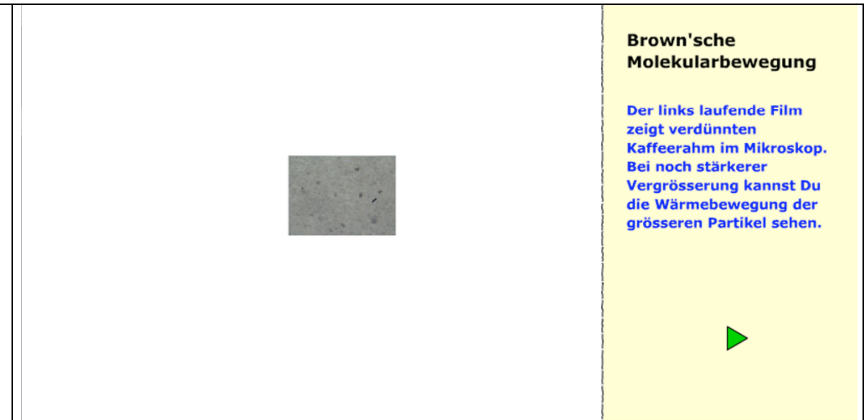
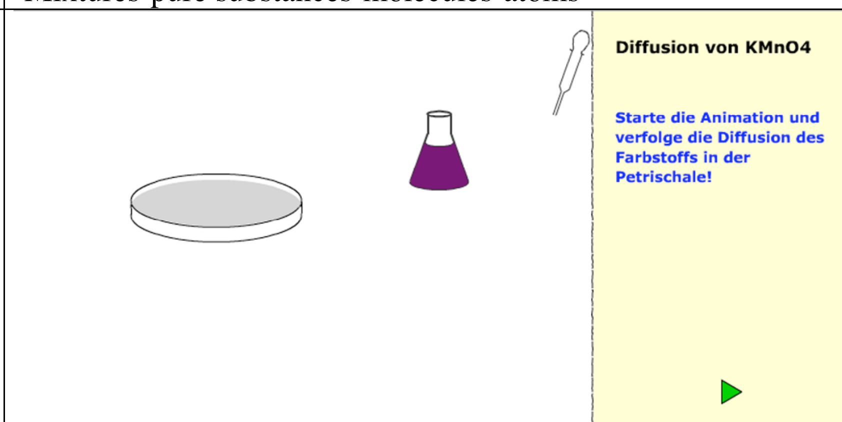
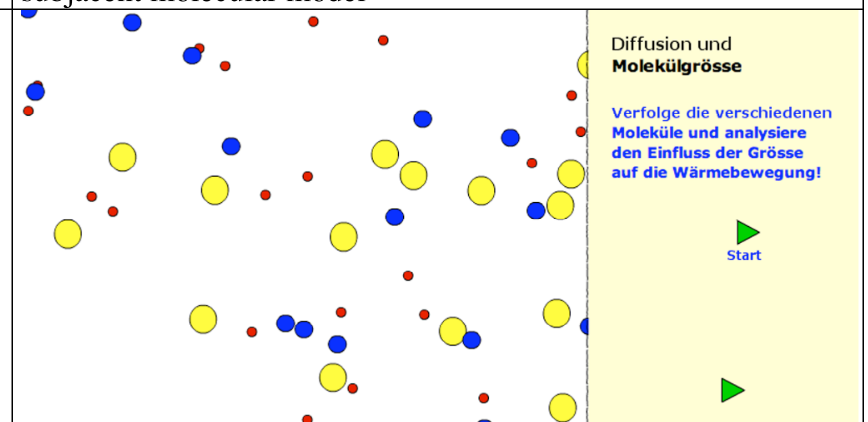
Schwartz, D.L.The Emergence of Abstract Representations in Dyad Problem Solving The journal of the learning sciences, 4(3), 321-354, 1995
Seels,B. The Instructional Design Movement in Educational Technology. Educational Technology, v29 n5 p11-15 May 1989
Harp,S.F. & Mayer,R.E. How seductive details do their damage: A theory of cognitive interest in science learning J of educational Psychology 1998, Vol. 90/3 414-434
Skinner, B.F. Are theroies of learning necessary? Psychological Review, 57, 193-216, 1950
Skinner, B.F. The science of learning and the art of teaching. Harvard Educational Review 24, 86-97, 1954
Stangl,W., Latentes, passives, implizites, inzidentelles oder informelles Lernen, 2004
Von Glasersfeld, E., Radical constructivism: A way of knowing and learning. Falmer PressLondon ; Washington, D.C., 1995
Vygotsky, L.S. Learning to Think. Genesis of the higher mental functions Source: Leontyev, A., Luria, A. and Smirnoff, A.(eds) Psychological Research in the USSR, vol. 1, Moscow: Progress Publishers, 1966

Acknowledgements

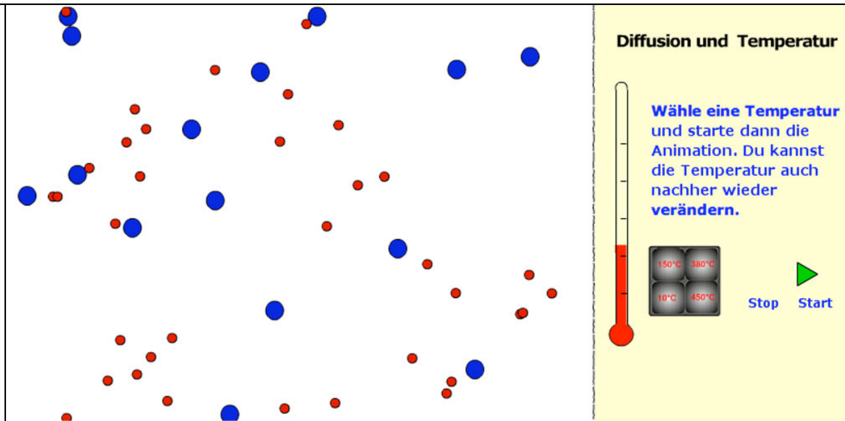
First I would like to thank Mireille Bétrancourt for continuous support and encouragement during my work. Without her many suggestions, hints, her constructive criticism and her belief in my work I would not have finished this thesis.
Many people of TECFA have supported me in one or the other way. I would like to mention Stéphane Morand, who was of immense help for technical problems, software installations and questions of all sort. Monica Gavota I thank for an introduction into SPSS, Daniel Schneider for his support in php, XML, SVG, and many programming questions. Charline Poirier showed me a way how to approach questions of interface and usability which still is of inestimable help to me.
In spite of gradually less meetings at the TECFA, the contact to my colleagues of the Khiah-group on the platforms, their feedback in thesis seminars and their own growing work inspired me and helped me to keep on.

Annex A: General content of Animations 1 - 9

For each animation a screenshot of the main screen, description of general content and the number of different screens are listed

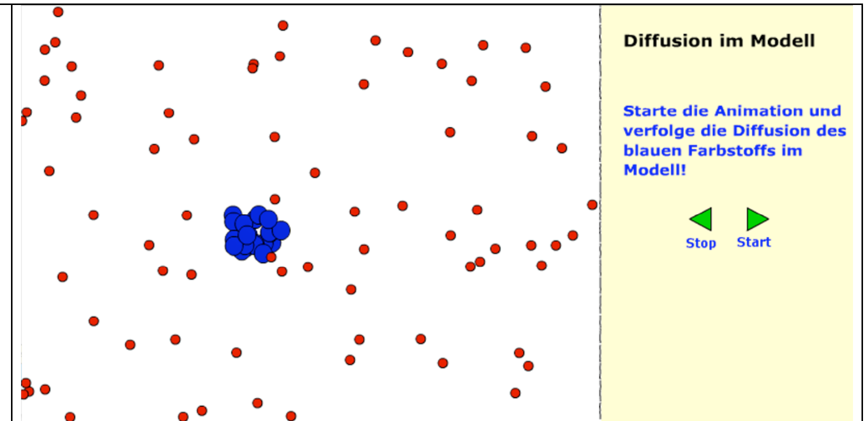
Animation1 - 9 screens		**Animation2 - 3 screens**	
	-Login, student data -Mixtures-pure substances-molecules-atoms		Molecular Movement - microscopic view and visualisation of subjacent molecular model
Animation 3 - 1 screen		**Animation 4 - 2 screens**	
	Diffusion of a dye in a petri dish		Molecular movement - influence of molecular size

Animation 5 - 1 screen



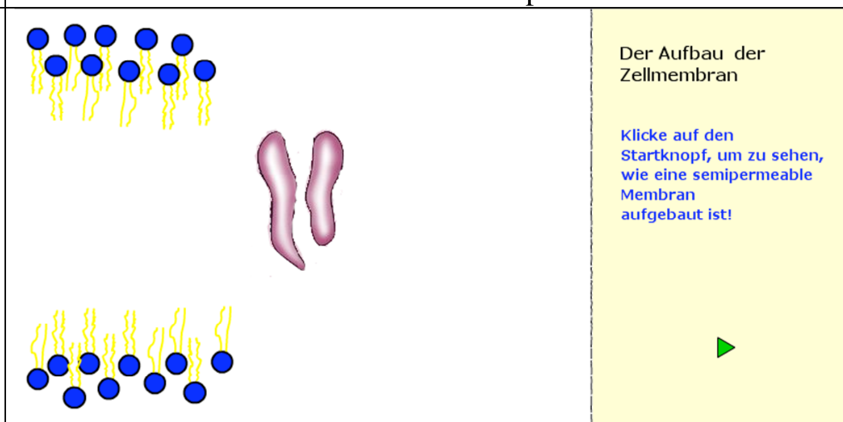
Molecular movement - influence of temperature

Animation 6 - 1 screen



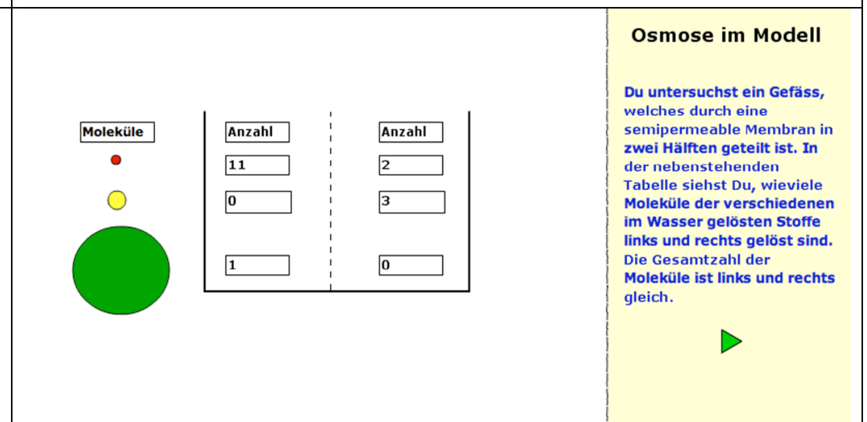
Diffusion - visualisation of the molecular mechanism

Animation 7 - 6 screens



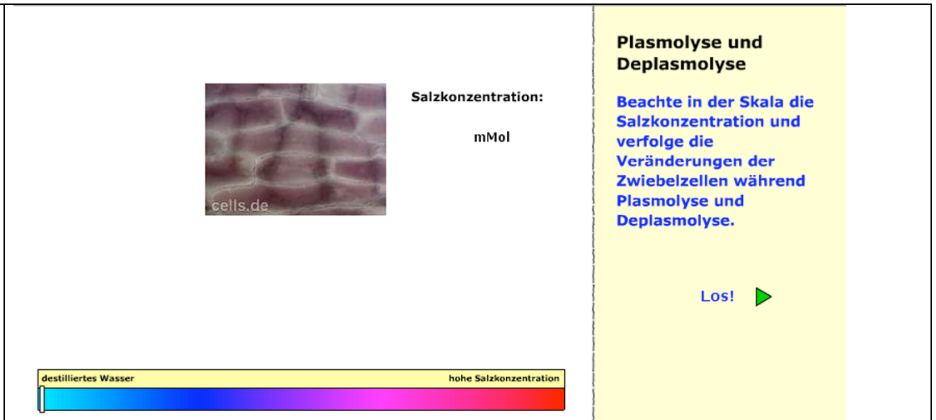
Structure of the cell membrane - membrane channels and what they let pass through

Animation 8 - 4 screens



Osmosis - theoretical considerations

Animation 9 - 1 screen



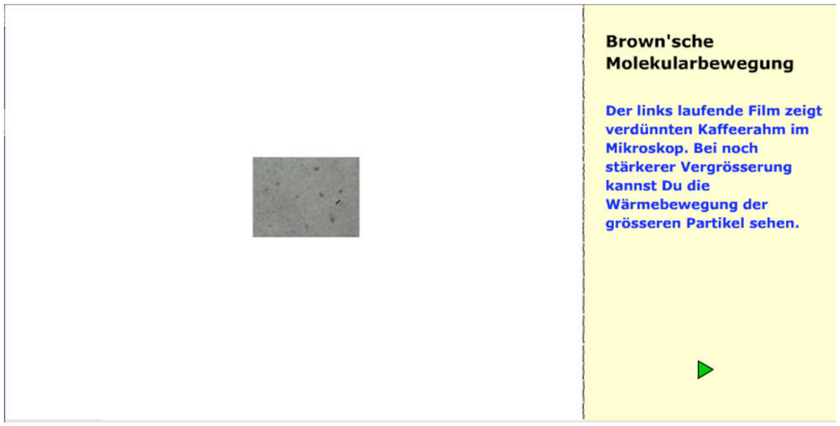
Plasmolysis in the microscope - effect of different salt concentrations on cells

<u>Annex B</u>: Comparison of Active and passive Version of Animation 2 (Molecular movement of Brown)

1. Welcome screen

As can be seen in Tab B-1 he 'Welcome screen' for both versions is identical

<u>Tab B-1:</u> Welcome screen for Animation 2a and Animation 2b



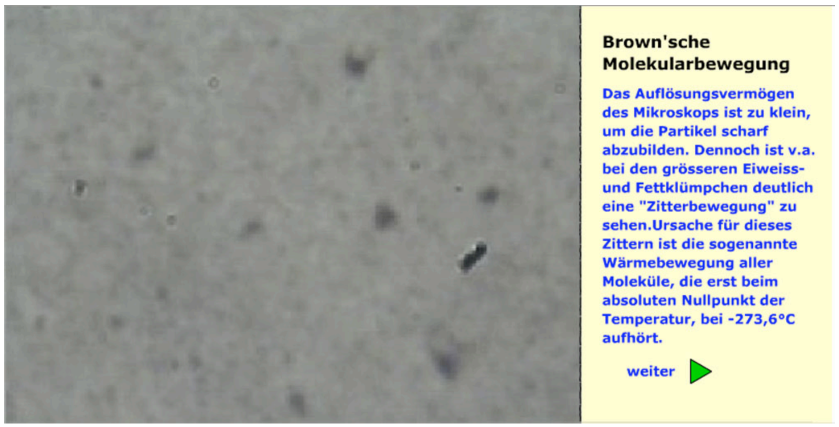
Welcome screen active version

Welcome screen passive version

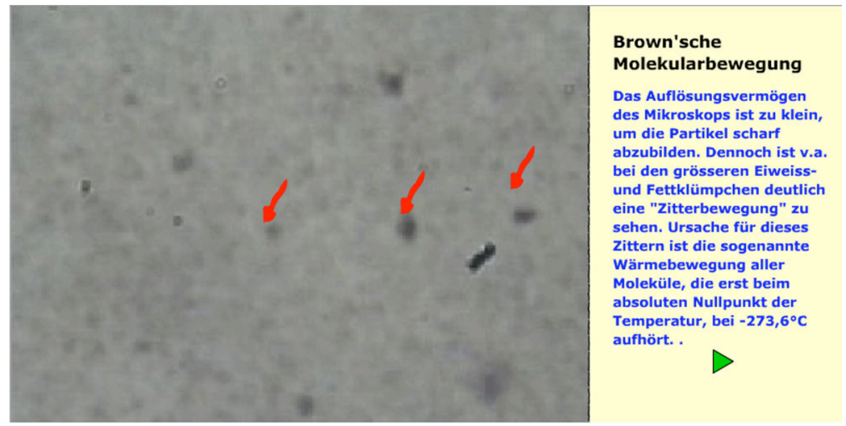
2. Observation Screen

The 'Observation screen' presents the microscopic view of the molecular movement of Brown (looped film) and gives an explanation for it. Again, both versions are almost identical, as is shown i Tab B-2.

Tab B-2: 'Observation screen' for Animation 2a and Animation 2b



'Observation screen' active version



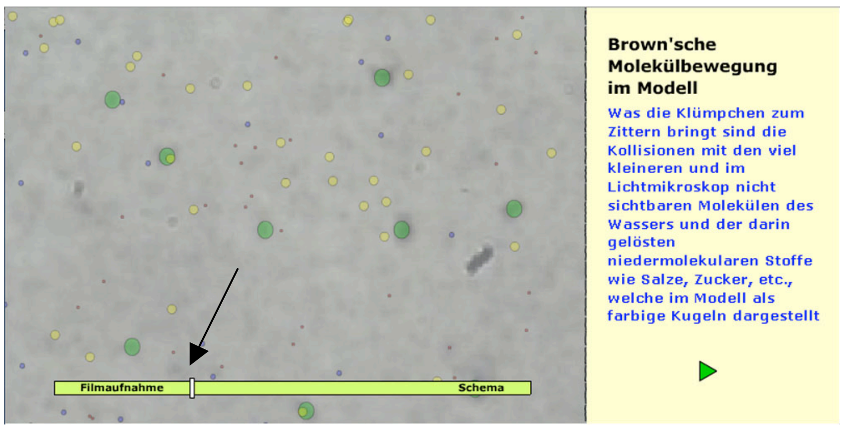
'Observation screen' passive version

3. Molecular model screen

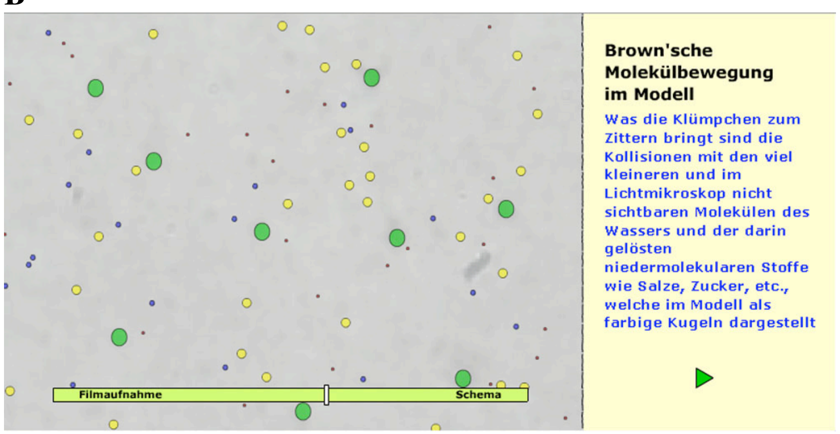
The molecular model screen presents a visualization of the molecular model. While the possibilities of interaction in this screen differ considerably explanatory texts in both versions are again almost identical. This is shown in Tab B-3.

Tab B-3: 'Molecular model screen' for Animation 2a and Animation 2b (Screenshots)

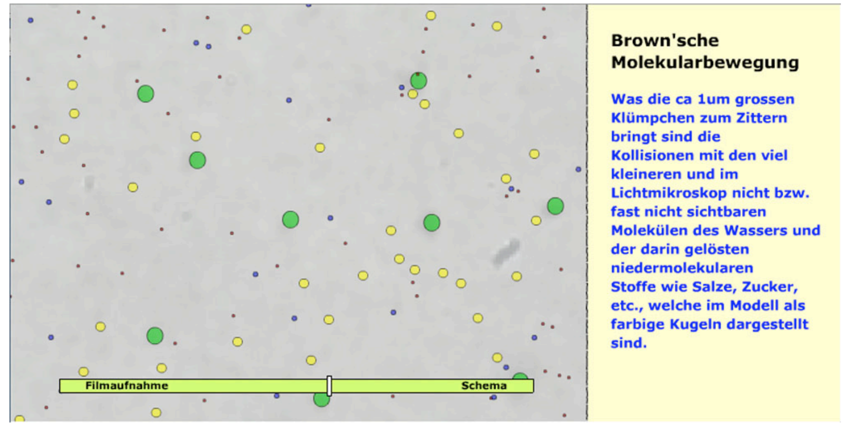
A



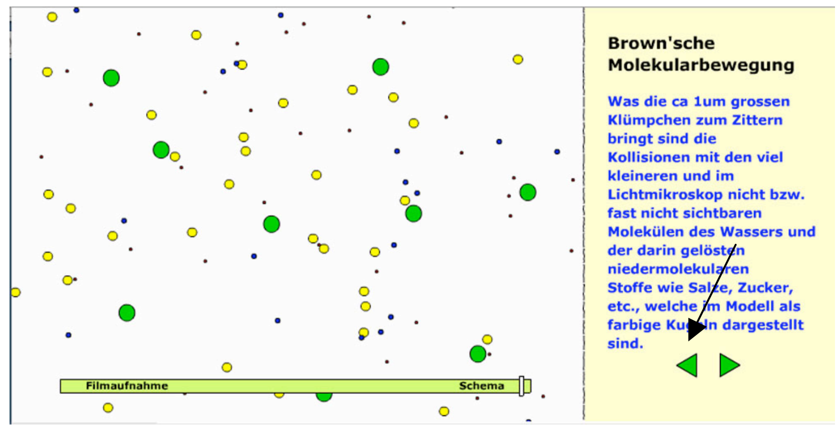
B



C



D

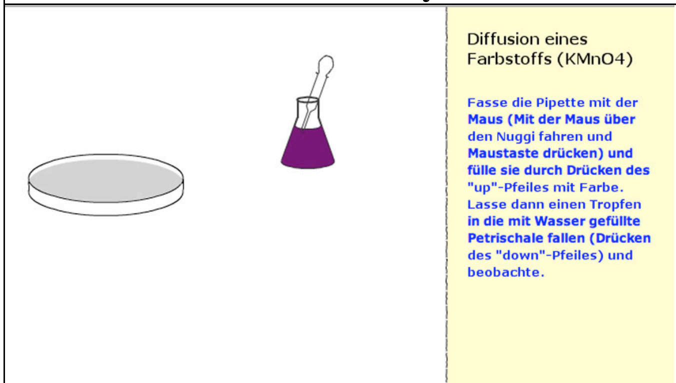
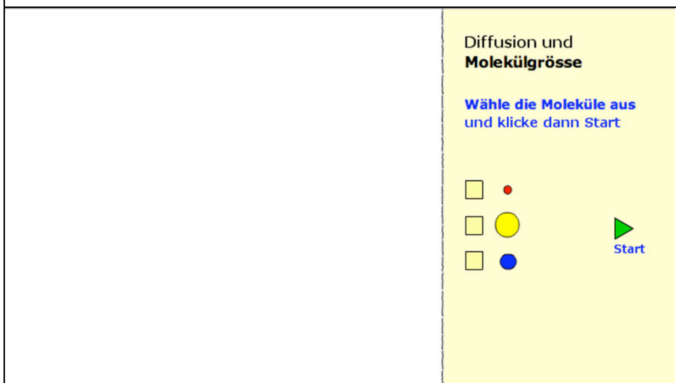
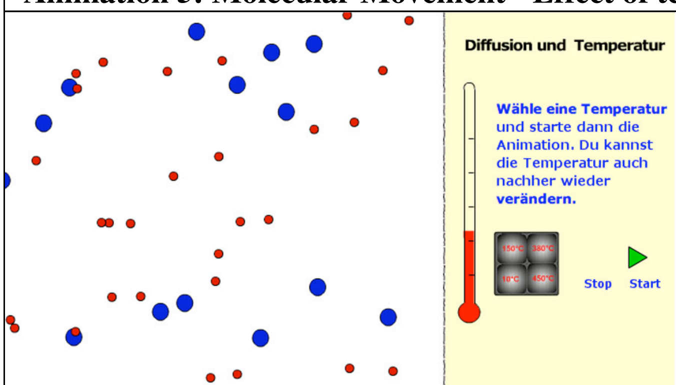
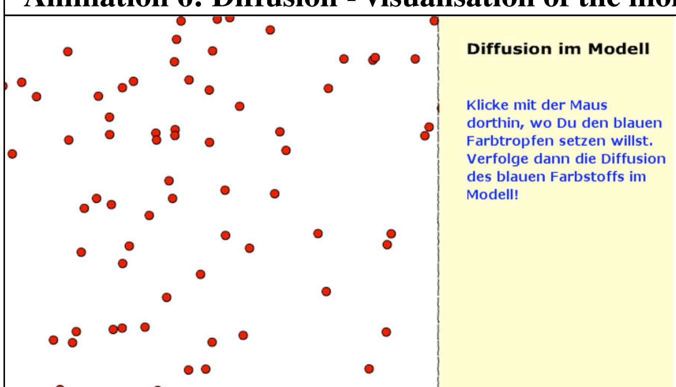


E

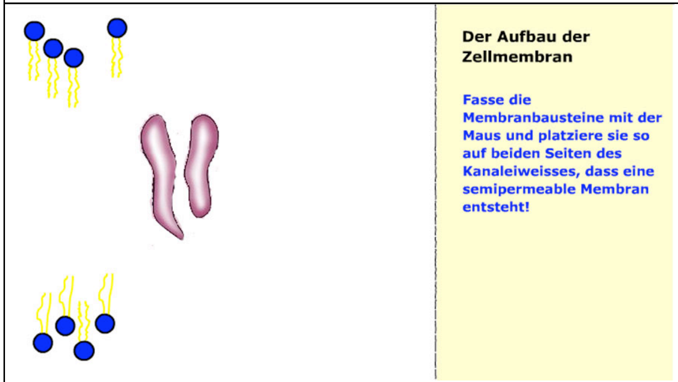
A-C: 3 Screenshots of molecular model screen of the active version. Students have to change from microscopic image to molecular model by moving the slide (arrow in B).

D-E: Screenshots of molecular model screen of the passive version. Students can start the film which shows a transition from microscopic image to molecular model. With the 'replay button' (see arrow in E) they can replay the movie.

<u>Annex C:</u> Interaction possibilities in further animations (active version)

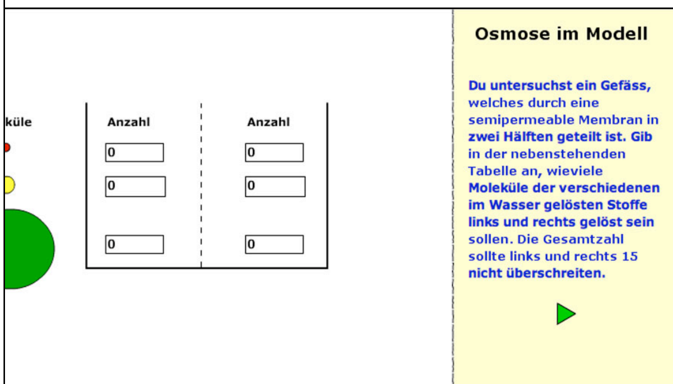
<table>
<tr><td colspan="2">Animation 3: Diffusion of a dye</td></tr>
<tr><td>
</td>
<td>Interactive Simulation of a laboratory experiment:
Taking the pipet, sucking in the dye, moving the pipet over the petri dish, putting a droplet of dye on the petri dish and observing its spreading due to diffusion</td></tr>
<tr><td colspan="2">Animation 4: Molecular Movement - Effect of molecule size</td></tr>
<tr><td>
</td>
<td>Controlling of parameters of a simulation:
Choosing molecules of different size and observing their molecular movement</td></tr>
<tr><td colspan="2">Animation 5: Molecular Movement - Effect of temperature</td></tr>
<tr><td>
</td>
<td>Controlling of parameters
Choice of temperature and observation of its effect on molecular movement</td></tr>
<tr><td colspan="2">Animation 6: Diffusion - visualisation of the molecular mechanism</td></tr>
<tr><td>
</td>
<td>Interactive simulation of a molecular process:
Putting dye molecules in a 'dish' and observing their spreading due to molecular movement</td></tr>
</table>

Animation 7: Structure of the cell membrane



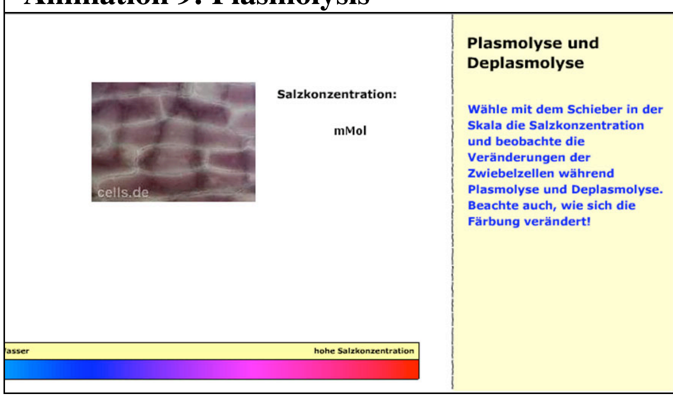
Interactive animation for the building of a cell membrane:
Active construction of a cell membrane, labelling of the structures,

Animation 8: Osmosis-theoretical considerations



Interactive Animation
Choosing the number of different molecules on both sides of the membrane, analyzing and verifying the effect on diffusion of water molecules through the membrane

Animation 9: Plasmolysis



Controlling of parameters of a simulation:
Choosing different salt concentration and observing their effect on plant cells

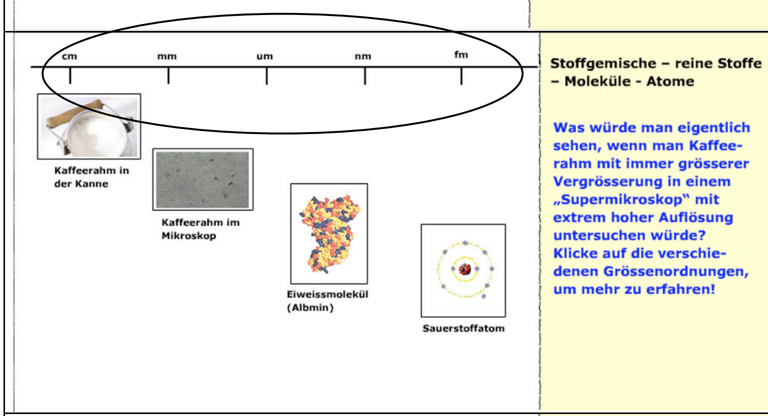
Annex D: 'Incidental content' of the Animations

Subsequent screenshots of animations are shown on the left, relevant incidental content is listed on the right

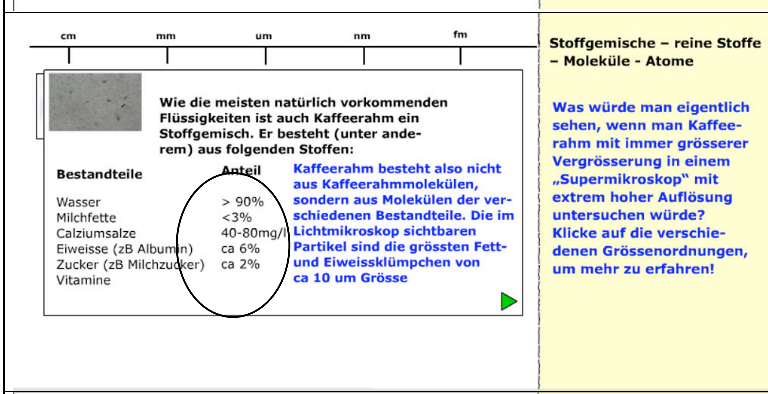
Animation Number — **'Incidental content'**

Animation 1

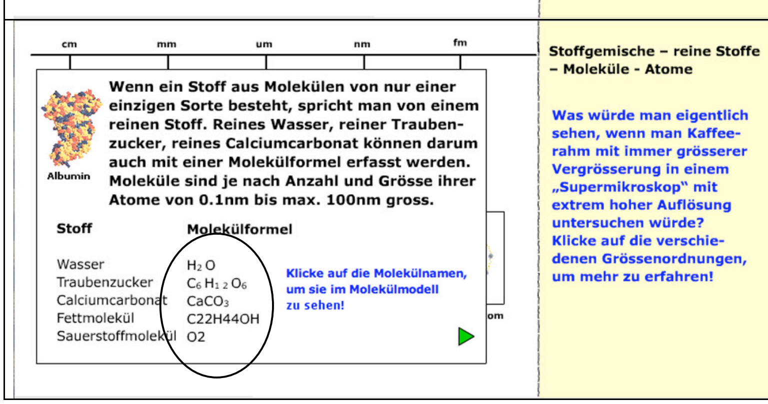
-



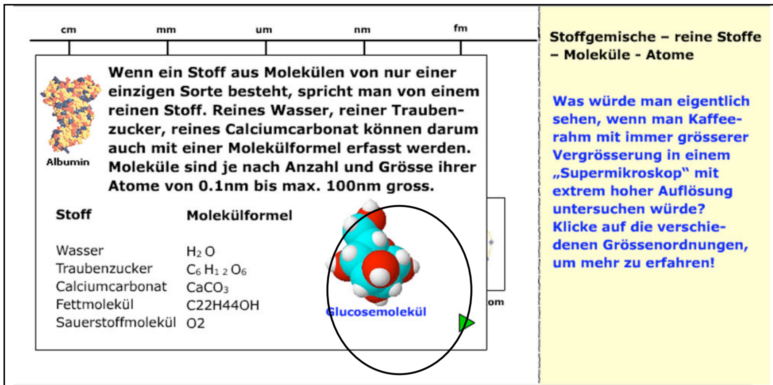
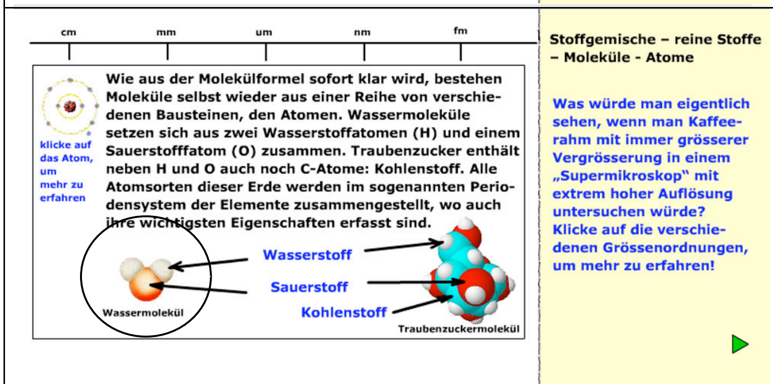
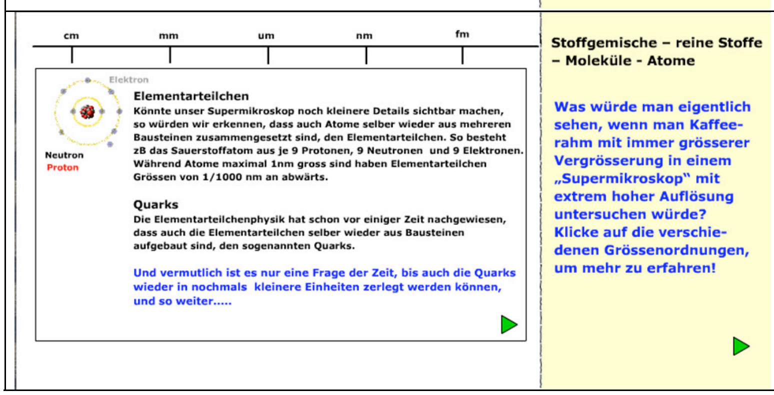
Size range of milk particles, molecules, atoms/elementary particles
(see circle in screenshot on the left)

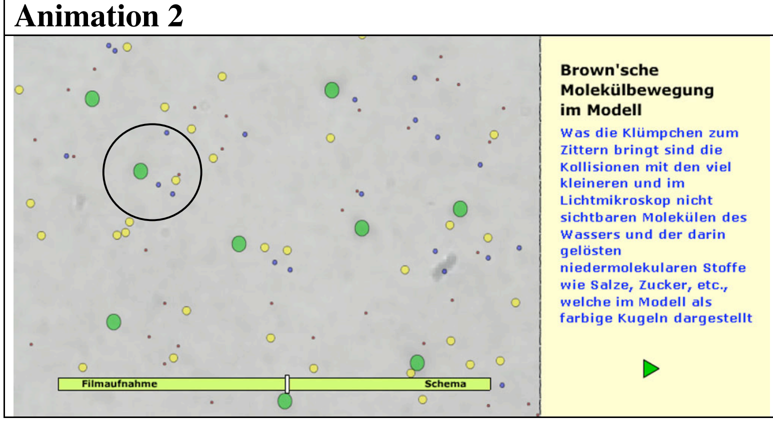


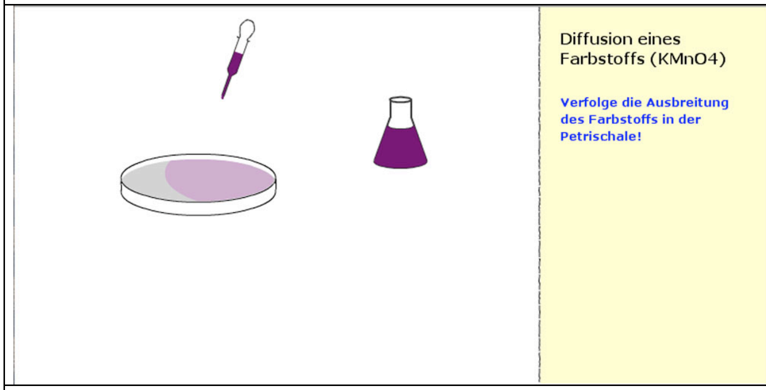
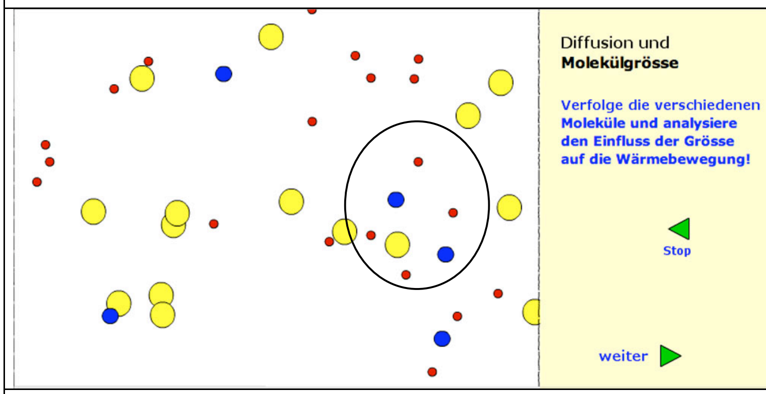
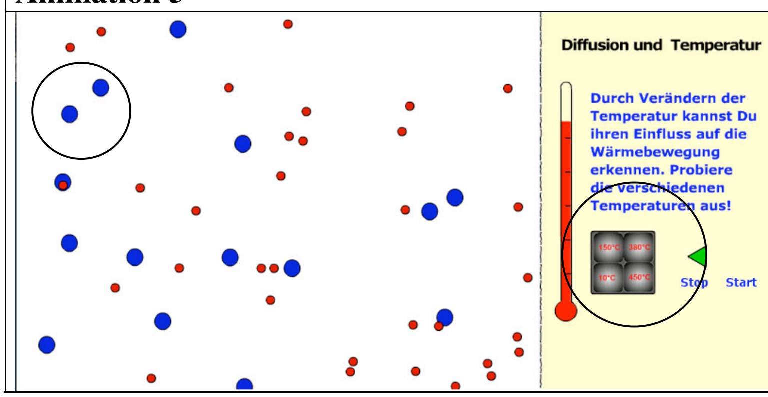
Percentage of content for the different components of milk,
Size of protein and fat particles (numbers)

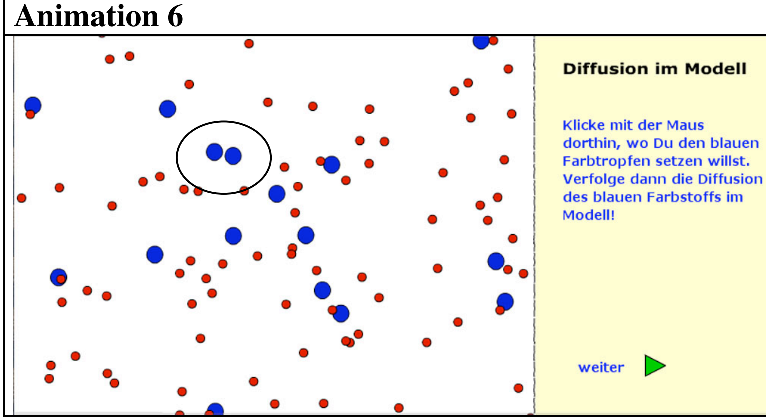


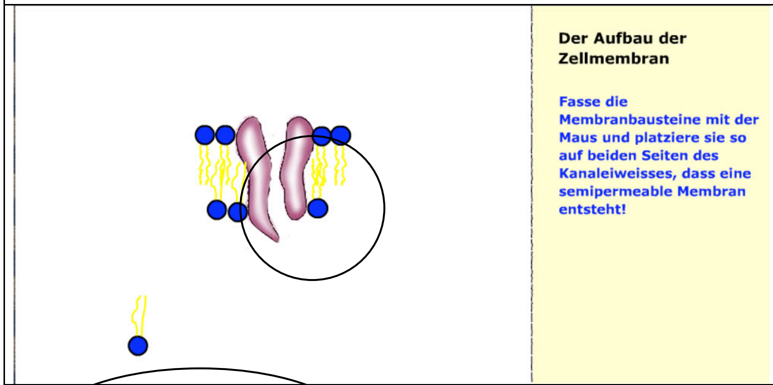
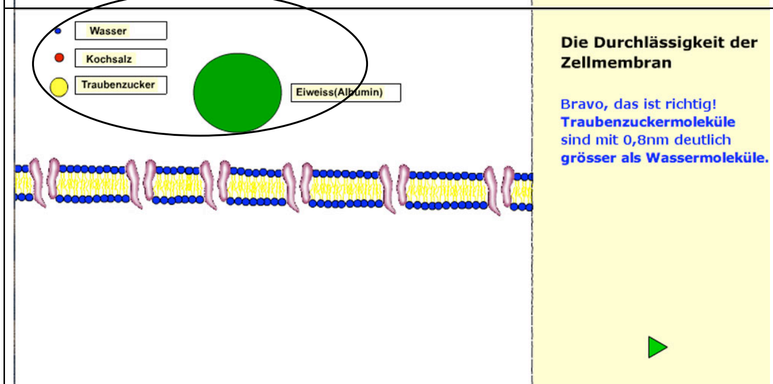
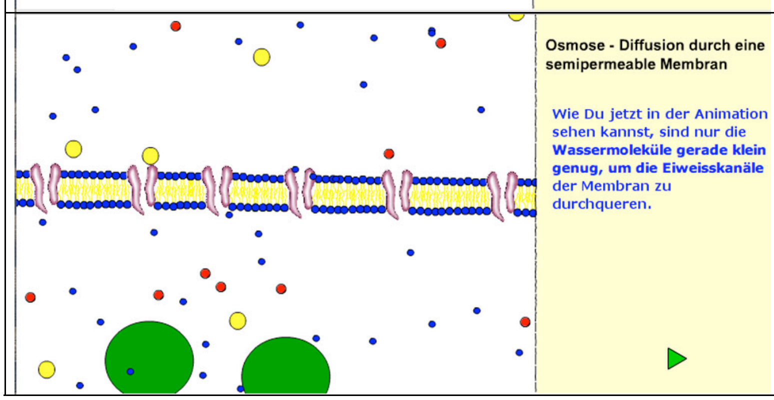
Average size of molecules (numbers),
Molecular formula of water, glucose, triglycerides, proteins

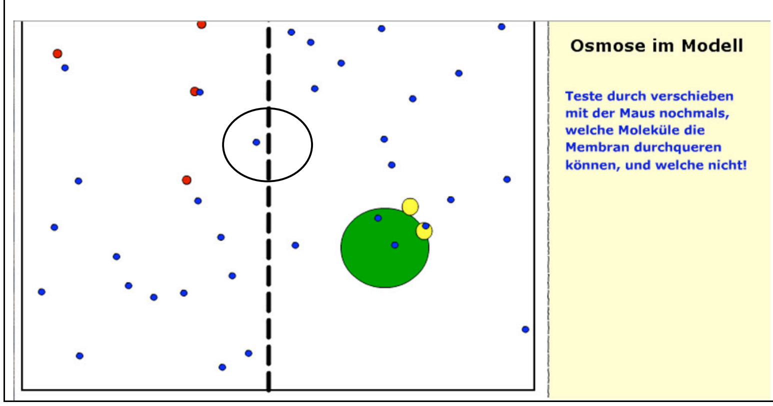
<table>
<tr><td>
</td>
<td>Molecular model of water, glucose, fat, oxygen,
structure and coloration</td></tr>
<tr><td>
</td>
<td>Molecular model of water, glucose, fat, oxygen:
- structure and coloration</td></tr>
<tr><td>
</td>
<td>Atom structure, name of elementary particles, size of atoms, elementary particles, quarks,</td></tr>
</table>

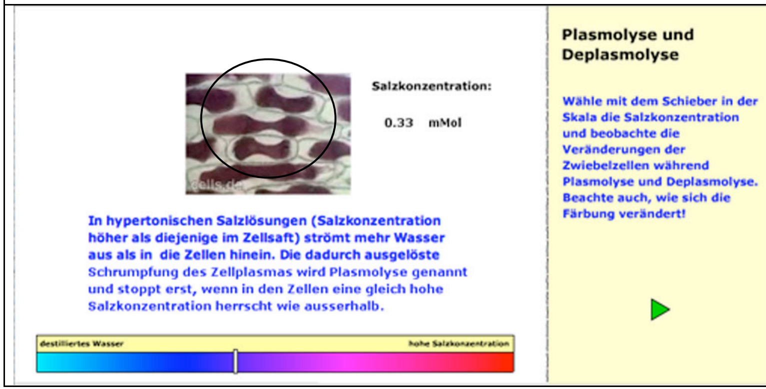
<table>
<tr><td>Animation 2</td><td></td></tr>
<tr><td>
</td>
<td>Color and size of the different circles
Movement parameters (speed, collision detection) of the different circles</td></tr>
</table>

<table>
<tr><th>Animation 3</th><th></th></tr>
<tr><td>
</td><td>Color of the dye
Speed of spreading (very slow)</td></tr>
<tr><th>Animation 4</th><th></th></tr>
<tr><td>
</td><td>Size and color of molecules
Collision detection (only yellow)</td></tr>
<tr><th>Animation 5</th><th></th></tr>
<tr><td>
</td><td>Collision detection (only blue)
Temperature values (on buttons)
Size and color of molecules</td></tr>
</table>

<table>
<tr><th>Animation 6</th><th></th></tr>
<tr><td>
</td><td>Collision detection (only blue)
Size and color of molecules</td></tr>
</table>

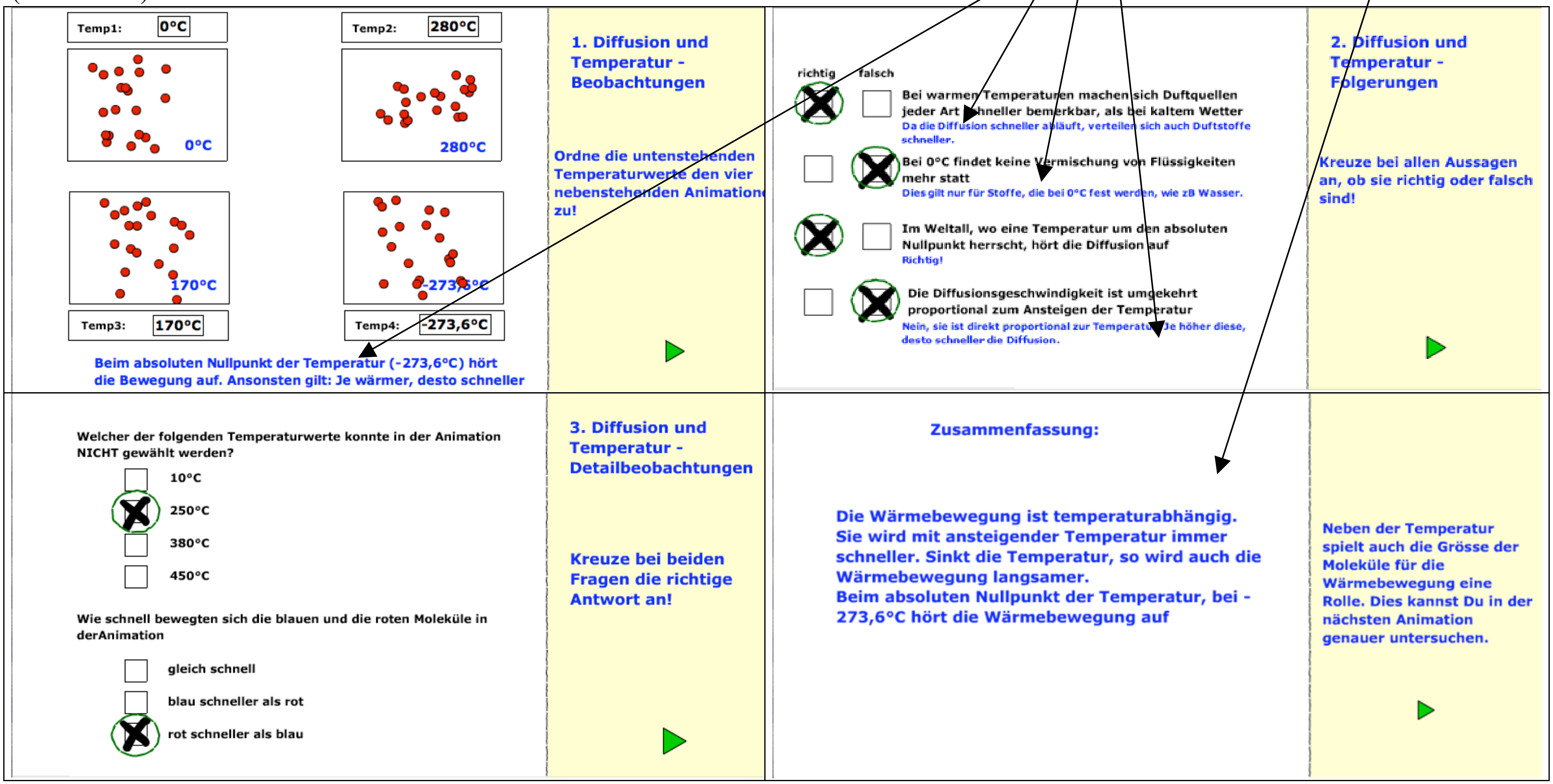
Animation 7	
	Color and symmetry of membrane channel Color of lipid molecules' heads and tails
	Color and size of water, sugar, fat and protein molecules Relative diameter of the membrane channel and of the molecule radii
	Order of appearance of the different molecules during the animation

Animation 8	
	Permeability of the membrane (water passes through also besides the gaps)

Animation 9	
	Individual reaction of cells during plasmolysis Salt concentrations in mMol Color intensity changes during Plasmolysis/Deplasmolysis

Annex E: Basic structure of Interanimation Tests

The basic structure of the tests is shown below for Interanimation test 5. (screenshots)



Annex F: DTD-Structure for user data registration

```
<?xml version="1.0" encoding="ISO-8859-1"?>
<!ELEMENT test (Item)+>
<!ELEMENT Item (Itemnumber, Datum, Testtype, Participant+,Verlauf, Questions)>
<!ELEMENT Itemnumber (#PCDATA)>
<!ELEMENT Datum (#PCDATA)>
<!ELEMENT Testtype (#PCDATA)>
<!ATTLIST Testtype choice (H1 | H2 | L1 | L2) #REQUIRED>
<!ELEMENT Participant (sex, name, klasse)>
<!ELEMENT sex (#PCDATA)>
<!ATTLIST sex choice (m | f) #REQUIRED>
<!ELEMENT name (#PCDATA)>
<!ELEMENT klasse (#PCDATA)>
<!ELEMENT Verlauf (Time, Anim+)>
<!ELEMENT Time (#PCDATA)>
<!ELEMENT Anim (animnumber, round+, animquestions+)>
<!ELEMENT animnumber (#PCDATA)>
<!ELEMENT round (roundnumber, roundtime, klick+)>
<!ELEMENT roundnumber (#PCDATA)>
<!ELEMENT roundtime (#PCDATA)>
<!ELEMENT klick (time, buttonnumber)>
<!ELEMENT time (#PCDATA)>
<!ELEMENT buttonnumber (#PCDATA)>
<!ELEMENT animqscreen  (checktime, aquklick+, animquestion+)>
<!ELEMENT aqklick (aqscreentime, aqbuttonnumber, aqklickresponse)>
<!ELEMENT aqscreentime (#PCDATA)>
<!ELEMENT aqbuttonnumber (#PCDATA)>
<!ELEMENT aqklickresponse (#PCDATA)>
<!ELEMENT animquestion (aqnumber, aqtype, aqresponse)>
<!ELEMENT aqnumber (#PCDATA)>
<!ELEMENT aqtype (#PCDATA)>
<!ELEMENT aqresponse (#PCDATA)>
<!ELEMENT checktime (#PCDATA)>
<!ATTLIST aqtype choice (implicit | explicit) #REQUIRED>
<!ELEMENT response (#PCDATA)>
<!ATTLIST aqresponse choice (correct | false) #REQUIRED>
<!ELEMENT time (#PCDATA)>
<!ELEMENT Questions (qunumber, qutime, qutype, quresponse)>
<!ELEMENT qunumber (#PCDATA)>
<!ELEMENT qutime (#PCDATA)>
<!ELEMENT qutype (#PCDATA)>
<!ATTLIST qutype choice (implicit | explicit) #REQUIRED>
<!ELEMENT quresponse (#PCDATA)>
<!ATTLIST quresponse choice (correct | false) #REQUIRED>
```

Annex G: Example of data file (part)


```
- <test>
  - <Item>
      <Itemnumber>3813</Itemnumber>
      <Date>6/29/2007</Date>
      <testtype>AE</testtype>
    - <Participant>
        <sex>f</sex>
        <name>Michelle </name>
        <klasse>1eM</klasse>
      </Participant>
    - <Verlauf>
        <Time/>
      - <Anim>
          <animnumber>1</animnumber>
        - <round>
            <roundnumber>1</roundnumber>
          - <klick>
              <time>53.226</time>
              <buttonnumber>1</buttonnumber>
            </klick>
            <roundtime>73.267</roundtime>
          </round>
        </Anim>
      - <Anim>
          <animnumber>2</animnumber>
        - <round>
            <roundnumber>1</roundnumber>
            <roundtime>32.818</roundtime>
          </round>
        </Anim>
      - <Anim>
          <animnumber>3</animnumber>
        - <round>
            <roundnumber>1</roundnumber>
          - <klick>
              <time>42.418</time>
              <buttonnumber>1</buttonnumber>
            </klick>
          - <klick>
              <time>79.028</time>
              <buttonnumber>2</buttonnumber>
            </klick>
          - <klick>
              <time>93.493</time>
              <buttonnumber/>
            </klick>
          - <klick>
              <time>97.037</time>
              2water
            </klick>
          - <klick>
              <time>105.822</time>
              <buttonnumber>1</buttonnumber>
            </klick>
          - <klick>
              <time>111.294</time>
```

Annex H: Pre- and Posttest for testing of basic concepts knowledge

1. Questions

Question 1:

Explain in detail what is diffusion.

Question 2:

Explain in detail, what is Osmosis.

2. Evaluation grid

Diffusion	**Terms and concepts**	**Points**
	Movement of moleculoes caused by ‚Wärmebewegung'	2
	Size and speed correlate/temperature and speed correlate	2
	Effect of molecular billiard is regular spreading of all componets in space	2
Osmosis	Cell membrane's protein pores are selectively permeable	2
	Only water molecules pass the pores: small enough	2
	Water accumulates on the side of the membrane which contains more solutes	2
Total points		12

Annex I: Number and type of questions in different animations

1. Explicit content - tests for learning of the pedagogical focus of the animation

Ef simple facts/details
Ec concepts/global questions

2. Implicit content - tests for incidential learning

If (Implicit focus) - tests for incidential learnig of information which was close to the focus of attention
Ip(Implicit peripheral) - tests for incidential learning of information which was on the periphery of the attentional focus
Ic (Implicit consecutive) - tests for incidential learning of information which will be used and focused on in consecutive animations

Anim Nr	Question	EF	EC	IP	IF	IC
1	Group 11 terms to one of the four types mixture, pure substance, elementary particles, else		x			
	Put 8 terms in grid according to their size in cm,mm,um,nm	x				
	Arrange 5 molecules according to their relative size					x
	Find the correct molecular model used for 4 molecules				x	
2	Molecular movement stops at	x				
	Who does molecular movement		x			
	which color moved least					x
	Which color showed collisions					x
	size of the moving particles				x	
	color of the secondlargest balls				x	
3	how does diffusion occur	x				
	formula of dye			x		
	colour of dye				x	
4	speed of the two molecules collision detection of the two molecules					x x

5	giving 4 animations the correct temperature	x	x			
	is smelling promoted by warm weather?		x			
	no mixing at 0 °C?		x			
	no diffusion at -273,6°C	x				
	diffusion rate is inversionally proportional to rising temp		x			
	blue molecules diffuse faster than red ones					x
6	size and speed		x			
	detailed definition of diffusion	x	x			
6a	water does not mix with hydrophils	x				
	heads of lipids are hydrophobic	x				
	the space inside the membrane ist hydrophobic	x				
	lipids convey semipermeability to the membrane		x			
	meaning of semipermeability	x				
	form of membrane channel				x	
6b	size of molecules			x		
	color of molecules				x	
7	what goes through the membrane?		x			
	water goes in one direction					x
	color of the second balls				x	
8	which molecules can pass?	x				
	which molecules can pass?		x			
	where goes more water?		x			
	water goes only in one direction		x			
	netto movement of water		x			
	effect of damged membrane		x			
	osmosis and temp		x			
9	plasmolysis and salt conc	x				
	concept of pl		x			
	salt causes shrinking	x				
	shrinking = deplasmolysis	x				
	adding water = synchronous swellling				x	
	swelling = loss of color intensity				x	
	size of color molecules		x			

Annex K: Scoring of motivation

1. **<u>Questions</u>**

Ein paar allgemeine Fragen zum Schluss

nichts	wenig	viel	sehr viel	
☐	☐	☐	☐	Wie gut hat Dir die Arbeit mit dem Computer gefallen?
☐	☐	☐	☐	Wie gut konntest Du Dich konzentrieren?
☐	☐	☐	☐	Findest Du es nach Deinen Erfahrungen besser, in Zweier-Gruppen oder alleine zu arbeiten?
☐	☐	☐	☐	Wie gut haben Dir die Animationen dabei geholfen, die Vorgänge der Diffusion und Osmose zu verstehen?
☐	☐	☐	☐	Wieviel Neues hast Du mit dieser Lerneinheit gelernt?

2. **<u>Scoring</u>**

qualification	nichts	wenig	viel	sehr viel
Points	**1**	**2**	**3**	**4**

Motivation level was calculated by dividing the total points of all questions by 5.

Tests and Animations

1.Synopsis of active and passive versions of animations

A synopsis of active and passive animations can be found at

http://tecfa.unige.ch/staf/staf-k/borer/Memoire/memoirekurz.htm

2. Test versions

The two versions of the tst can be found here:

High interactivity version:

http://tecfa.unige.ch/staf/staf-k/borer/Memoire/Animakt_XML/Animakt.html

Low interactivity version:

http://tecfa.unige.ch/staf/staf-k/borer/Memoire/Animpass_XML/Animpass.html