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Abstract

This deliverable (D7.2.5) documents the results of the evaluation of the prototype of the DynaLearn (DL) software conducted by BOKU in Austria. Based on the *'Curriculum and content models'* (WP6, D.6.2.5), lesson plans were developed and evaluations focusing on selected topics and models were conducted in real educational settings. The main feature that was assessed was the *'Conceptual Modelling'* (CM), with a special focus on Learning spaces (LSs) 1, 2 and 4. Evaluations were run at an Upper Secondary Technical High School (i:HTL Bad Radkersburg, Styria) with two undergraduate students and at BOKU, Vienna with 29 students, most of them being master students. The assessment methods included detailed video-monitoring of modelling activities, motivation questionnaires and pre- and post tests.

Additionally two master students who conducted their master theses within the DL project were keeping records on software usability during their modelling activities.

Finally, BOKU was involved in several evaluation activities by UPM related to the development and improvement of the *'Grounding'* and *'Ontology Based Feedback'* features of the DL software.

Internal Review

- **Michael Wißner and René Bühling (UAU), Human Centered Multimedia, University of Augsburg, Germany.**
- **Richard Noble (UH), Hull International Fisheries Institute, University of Hull, United Kingdom.**

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Document History

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Contents

1. Introduction

1.1. Project background

Based on promising results of introducing Qualitative Reasoning (Bredeweg & Forbus 2003), System Dynamics (Barrientos 2008) and Animated Teachable Agents (Bodenheimer *et al.* 2009) into classrooms for a better, more structured and engaging learning, the DynaLearn approach targets at the development of an individualised and engaging cognitive tool for acquiring conceptual knowledge in environmental science. The software integrates a diagrammatic approach to constructing qualitative conceptual models, ontology mapping and semantic technology to ground model building terms and compare models, and virtual character technology to provide individualised feedback and enhance motivation of learners.

The evaluation of the prototype and the final software represents an important part of the DynaLearn project that should offer new insights in the efficiency of the different features of DL, combined in this way for the first time, to contribute to an effective, engaging and self-directed learning. Key features of DynaLearn to be considered are:

1. **Conceptual Modelling (CM) – based on DynaLearn's specific modelling language, modelling process and 6 Learning Spaces (LSs).**
2. **Conversational agents (Virtual Characters, VC) - acting in various functions while interacting with the learner.**
3. **Semantic Technologies (ST) - individualization of learning via DynaLearn tools for ontology mapping, diagnostic procedures, and the semantic repository (Ontology Based Feedback, OBF).**

Based on this, accordingly to the description of work (DOW), the following main issues to be evaluated can be formulated:

- **Conceptual understanding - learning of content knowledge related to the causal behaviour of complex ecosystems.**
- **Scientific reasoning and modelling skills through qualitative reasoning - acquisition of scientific reasoning skills and ability to cope with complexity, through the DynaLearn approach and language.**
- **Motivation and attitudes towards learning environmental science and learning by modelling.**

Furthermore, there is the necessity to evaluate the usability of the software, to detect bugs and collect ideas for improvement especially during the prototype phase of the software as an important basis for adjustment and improvement of the final release.

1.2. The purpose of modelling and knowledge abstraction

"A fundamental characteristic of human cognition is the ability--actually necessity--to exploit knowledge abstraction"… "Abstraction allows people to maintain large amounts of information about concepts and objects in an efficient and economical fashion. Higher order conceptual structures organize themselves into hierarchies according to generality-specificity, superordinate-subordinate relationship" **(Alpert 2003).**

Therefore, modelling represents a proven and central scientific practice (Morgan & Morrison 1999) and science itself can be seen an ongoing process of developing, testing, refining, and improving models to explain the world (Windschitl *et al.* 2008) (from Fortus et al., year not indicated). In general models (also mental models) are seen as the prime mediator between theory and reality (Develaki 2007). For educational purposes, it is generally important to combine the elements of the practice (constructing, using, evaluating, and revising scientific models) and the meta-modelling knowledge that guides and motivates the practice (e.g., understanding the nature and purpose of models) for a successful application of modelling in classrooms (Schwarz *et al.* 2009). "*In particular, it will be important to investigate authentic and motivating ways of incorporating modelling into curricula, as students often have difficulty understanding the purpose and payoff of modelling"* (Schwarz & White 2005).

Modelling, due to the externalisation of own, personal and prior knowledge and its combination with new information in a constructive manner, can be seen as guided training in developing an abstract representation of the world, which is considered to significantly increase the ability of students to organize and structure larger amounts of knowledge and to reason about the world in a more adequate manner as a crucial basis of reflective behaviour.

The tools, concepts, archetypes, and *'habits of mind'* of Systems Thinking and System Dynamics are thought to provide an important background for environmental education (Cloud 2005), as especially a set of generic patterns of Systems Dynamics (the so called *'archetypes'*) proved to be applicable across a variety of disciplines and are supposed to significantly support systemic knowledge construction.

Usually the process of modelling can be triggered by two approaches, the model exploration (knowledge exploration) or the model building (knowledge representation) mode. Especially the combination of model-exploration (enabling learners to explore previously created models) with model-expression (enabling learners to create their own models within programming environments) is thought to maximise the benefit that learners have from modelling (Schwarz & White 2005). Both approaches are implemented in DL.

1.3. Causality

To evaluate the effect of DL activities on causal understanding and ways of representing environmental issues, it is necessary to understand, which possibilities for causal representation are provided by the DL workbench, as each tool and language used for modelling influences the way things are being represented and hence understood by students. Therefore, it is important to have a clear picture on the inherent potentials and limitations of these tools.

"The idea of causality is based on our belief that events in the universe are interconnected. Classical (linear / mono-causal) sciences use the term 'cause' for the first of two interconnected events and the term "effect" for the other. So the idea is that events occur in a special temporal order (post hoc ergo propter hoc). This

conception is hardened by our perception and experience, and it seems that the conception of causality is crucial for creating models of the world and hence for practising sciences at all" **(Arshinov & Fuchs 2003).**

In general, causality is considered to be a very complex concept (Khoo 1995), although *"causal models provide a natural method for understanding the dependencies that exist between variables in the world (Pearl 2000) and human learners tend to form beliefs about the causal relations between entities"* (O'Doherty *et al.* 2009). Causal reasoning is therefore inherent in our mental representations of the world, and hence in our language (Kempson 1990).

Causality can be described as the relationship between an event (cause) and the resulting situation (or effect), with the resulting situation being influenced by the first (causal) event. Up until the twentieth century, according to Born 1949, cited in Sowa (2001), mainly three assumptions were dominant in the definition of causality:

- ***"Causality postulates that there are laws by which the occurrence of an entity B of a certain class depends on the occurrence of an entity A of another class, where the word entity means any physical object, phenomenon, situation, or event. A is called the cause, B the effect.***
- ***Antecedence postulates that the cause must be prior to, or at least simultaneous with, the effect.***
- ***Contiguity postulates that cause and effect must be in spatial contact or connected by a chain of intermediate things in contact".***

However, according to Sowa (2001), relativity and quantum mechanics have forced physicists to question these assumptions as being valid at the most fundamental level of reality, although at the level of human experience they still provide an effective framework for explaining reality.

A prominent causal scheme, currently being widely uses throughout Europe, e.g. for the implementation of the EU Water Framework Directive, is the Driver-Pressure-State-Impact-Response (DPSIR) scheme taking into account the causal relationships between policy, society, economy and biodiversity (Maxim et al. 2009).

The main ingredients to build models in DL are *'quantities'* and *'entities'*. *"Entities are the physical objects or abstract concepts that constitute the system. Quantities describe the dynamic features of a system and typically hold qualitative information concerning the current magnitude and direction of change (='derivative'* information)*, using an interval scale, consisting of an ordered set of labels (without any numerical information), e.g. {Zero, Low, Medium, High}. Such a set of labels is called a quantity space"* (Bredeweg et al. 2009). Quantities can be divided into *'rates'* and *'state variables'*. *'State variables'* (according to stocks in System Dynamics (SD) models) represent the state of the system, whereas *'rate variables'* add or subtract a specific amount from these state variables representing the dynamic aspect the system.

In DL models there is the explicit notion of causality between different quantities (Liem et al. 2009). The main causal dependencies are represented using *'direct'* and *'indirect'* influences (Forbus 1984). '*Direct influences*', called influences or rates for short, can be either positive or negative. These influences are similar to the flow rates in SD models. But as the simulation does not provide the picture of a continuous increase of the quantity over time depending on a continuous rate/timer flow, but rather a ranking of discrete states of the system triggered by a positive or negative influence, in a strict sense one cannot talk about a rate, which is always a relative change in time.

The flow in SD models always has always the unit of '*stock/time unit (m^3/s)*'. The stock is the recalculated by '*stock (t_1) = stock(t_0) ± flow(t_0,t_1)*'. Within these simulations, time is cut into equal pieces for the

simulation, then the value of a stock is set, and then the flow per time unit is calculated and then applied to the new stock, before these steps are repeated until the end of the simulation.

The flows or rates in DL models in contrast represent a *'momentum'* that has the unit of the stock, and is the absolute change of the stock, and therefore the absolute difference between two stock sizes, which not necessarily have the same size between two steps. Therefore, it not clear if the contribution of the momentum between two simulation steps is always equal sized – the momentum between *'low'* and *'medium'* could be of a different size than between *'medium'* and *'high'*. However, there is no need for equal steps even at ordinal scales. Summarizing, a flow or rate in DL models can be best characterized as an unequally sized momentum being added during each step of the simulation as a result of the unequal distances between landmarks. The time it takes to reach a certain value is unknown, which leads to a generic way of representing system dynamics without the direct notion of continuous time using discrete, temporarily ordered time steps of unknown length.

The other important element to represent causality in DL models is the '*indirect influence*', called *'proportionality'* (Liem *et al.* 2009). Similar to *'direct influences'*, *'proportionalities'* can be either positive or negative. The positive proportionality will increase its associated quantity, will have no effect if it is stable, and decrease if it is below zero. For a negative proportionality, it is the other way around. From a modelling perspective it is important to understand, that proportionalities just transfer the information of the direction of change from derivative to derivative, whereas influences (or rates) transfer their information via their value to the derivative of a state variable. This means, that the magnitude of the rate it will be added to the derivative of the state variable after a certain time interval.

"The key concept to understand is that only 'influences' initiate change in a system and that 'proportionalities' only propagate change" (Liem et al. 2009). Additional elements like *'correspondences'* and *'inequality statements'* help to specify the causal relations between the quantities.

Finally, the *'configurations'* (which are the links between the entities) can be used to hierarchically or causally structure the model from a conceptual point of view. Although these elements of the models do not have an influence on simulation results, it is useful to use them consciously, as DL e.g. allows for an inspection of the simulation results in the *'dependencies'* mode, which provides a very insightful visualisation of the generic system structure allowing for a visual organization of the model ingredients in a hierarchical manner.

DL is built upon Qualitative Process Theory (QPT) (Forbus 1984). *"QPT organizes domain theories around the notion of physical processes. very change in the physical system is directly or indirectly caused by processes. Processes affect objects by causing quantities associated with them to change, and communicate with each other through shared parameters. QPT introduced the quantity space representation of numerical values in terms of ordinal relationships, and qualitative proportionalities, the use of monotonic functional dependencies to form a language for qualitative differential equations. Both techniques have been widely adopted and are now considered standard in qualitative physics"*.[1]

However, the DL workbench should allow for modelling not only physical systems, but also ecological, biological, social, political and psychological systems. Therefore the question arises, if the vocabulary and types of representations available in DL support the expression of these different systems.

A first analysis of literature showed, that the representation of different kinds of causality is not specifically a matter of how to represent things differently from physical systems, but more an issue of taking into account the different nature of the entities being involved and their potential differences in behaviour. For example, social causality does not necessarily follow the same rules as physical causality,

[1] http://www.qrg.northwestern.edu/ideas/qptidea.htm, accessed at 08.12.2010.

but has an emphasis on human agency, and also has to take into account people's freedom of choice (Mao & Gratch 2005). So when including humans into models one "*must refer to the real features of human information processing and decision making, which is characterized by emotional, subconscious, and kinds of affective and non-rational factors"* (Mainzer 2010).

Even within pure physical systems, starting with simple linear causal chains, one easily can detect circular dependencies in many systems. Examples include simple technical feedback systems, like control circuits. Systems like that could be also named *'trivial'* systems, as the same input also leads usually to the same output, and they are highly predictable and are independent of their history (Simon 2008). However, humans and other biological entities well as ecosystems and human societies are *'non-trivial'* systems, as they are able to develop internal states that might have an influence on the reactions to a given input. These systems depend on their history; they are not predictable, which means that the same input might lead to different reactions given the internal state or history of an entity.

This issue can be implemented in DL models using different assumptions under which different causal behaviours depending on choice or present state of the system might be true (possible in LS 6).

However, in order to get more insights into the causal dynamics of complex systems and to understand the global trends and dynamics of our complex civilization, we need to know more about the factual causal acting of people, their cognitive and emotional behaviour (Mainzer 2010). Thus, there is demand for more interdisciplinary research between humanities, economics, natural and engineering sciences.

In the different sciences, there might be mixture of physical and probabilistic causal relations, which makes it hard to come to simple causal chains. Therefore, many sciences, like health science, might require a theory of causality that unifies its mechanistic and probabilistic aspects and it is argued that an epistemic theory of causality provides the required unification (Russo & Williamson 2007). That means one has to take the beliefs, knowledge, prior experience, social and environmental embeddedness, history etc. of the modeller, observer and observed biological entity or system into account to achieve an epistemic understanding of causality.

Williamson (2009) provokingly states, that neither probability nor causality exist, seeing e.g. probabilities as rational degrees of belief. All knowledge is personal knowledge of more or less high agreement with the real world around us. His epistemic theory of causality is therefore based on the assumption that the notion of causality is epistemic rather than physical and characterises causality in terms of the beliefs of an agent. However, causal beliefs are heavily constrained by evidence, giving them a certain degree of objectivity. Anyway, no one will deny that things in the world happen due to their causal interrelations, but any causal model as a result of human activity is *"a tool whose interpretation and usefulness depends on the existence of a representing agent with the power to intervene"* (Sloman 2005). *"All models are wrong, but some are useful"* (Sterman 2002).

Another important issue with regard to causality is emergence as a fundamental quality of self-organising systems. Emergence can be generally understood as the occurrence of specific features and/or patterns on top of complex systems formed by a multiplicity of relatively simple interactions, where the emergent properties cannot be directly explained by or related to the single contributing factors. Emergence represents a central concept in the theories of integrative levels and of complex systems. *"Emergent properties are anchored in structures, and do not exist independently of them, though they are not reducible to them*" (Arshinov & Fuchs 2003). Emergent properties can be modelled in DL on top of model fragments representing the underlying pre-conditions for emergent properties to arise. Again, it is more a matter of recognizing the underlying structure of the system and of decomposing the emergent property to its underlying causes.

Other typical features of causal systems are feedback loops leading to non-linear dynamics. As the states of the qualitative quantity spaces used in DL do not allow for a differentiation between linear and non linear systems, the effect of a feedback loop has to be interpreted from the structure of the model and the effect of the feedback loop on the derivative. The implementation of feedback loops is possible from LS4 to LS6.

Non linear dynamics can also appear, when a system flips from open state into another depending on the preceding development of the system. These non-linear dynamics can be implemented in LS5 (and LS6) using conditional statements (e.g. a process becomes only active, when a certain limit in the system is reached).

Another important feature of systems is the delay of reactions, which could be modelled using an intermediate variable, and/or using conditional statements.

One should be also aware of potential benefit of structuring models along basic physical laws like thermodynamics and accepted ecosystem theories like hierarchy theory (Jørgensen *et al.* 2007), or the already mentioned system archetypes (Kim 2000c,b,a; Kim & Anderson 2007; Meadows 2008). Even young children can be motivated to develop a systems view of the world e.g. using favourite stories (Sweeney 2001)

Finally the DL curriculum should take into account the above issues, to provide the students a clear picture of how to use the specific modelling features of DL to build models in the different scientific domains, and to provide a framework of how looking at environmental issues in the most effective manner. The main target is, to shape the consciousness about the fundamental importance of considering the different internal structures of physical and biological entities as well of whole (eco)systems.

The intentional introduction of these issues into the modelling practice relates also to the issue of the development of meta-modelling knowledge relevant for a successful application of DL in environmental science education.

1.4. Representation of time

In general, the two modes of modelling changes over time can be formalized to two distinct concepts: discrete time and continuous time (Lesne 2007; Ossimitz 2008). *"The concept of discrete time is based upon a distinction between time-points and time intervals. Typically the time axis is divided into a number of adjacent time-segments (which usually are of fixed length)"* (Ossimitz 2008).These time segments are not necessarily required to have the same length, as it is the case in DL models.

"The concept of continuous time models time as a continuum of subsequent time-points. This implies that data given for some time-span are specified as a continuous function over time" (Ossimitz 2008). This is how flows work at SD models.

DL models follow a discrete mode of time representation, and the notion of time is indirectly included, as the quantity spaces consist of temporarily ordered states of a system. Therefore *"the simulation output of a QR model is a state space representation of all possible behaviours that may evolve over time, starting from an initial scenario"* (Brandl *et al.* 2008). In other words, *"time is represented as a graph of states"* (Bredeweg *et al.* 2009). The exact time intervals between the changes of the state variable are unknown. If needed,

one could also introduce an intermediate variable as a time axis, to specifically point out the relation of the system components to specific temporal landmarks.

Another very typical feature of systems is the delayed reaction of a variable, which can be modelled in DL via an intermediate variable, and the use of a conditional statement.

In general, certain states of different system compartments can be reached before, directly after, after, during, overlapping with different start and end points, and exactly in parallel to other events (Allen 1991).

But when targeting at the representation of these generic temporal statements in DL, it is important to consider the compatibility of the different quantity spaces. This issue mainly relates to the so called '*epsilon ordering*'.

"The epsilon ordering concept distinguishes between immediate terminations (from a point, and from equality) and non-immediate terminations (to a point, and to equality). This concept is based on the idea of dealing with quantities behaving as continuous functions of time and that a point occupies no space. Therefore if a quantity is on a point and it changes, it will leave that point immediately without any passage of time. On the other hand, a quantity changing towards a point will always have some epsilon amount of space between itself and the point. Therefore the transition to that point is not immediate. As a result of this, immediate transitions take precedence over non-immediate transitions" **(Bredeweg *et al.* 2009).**

If necessary, one can overrule the application of the epsilon ordering by changing the simulation preferences of the DL software, which also allow for the option '*equal quantity spaces have equal points*'.

1.5. Virtual agents & feedback

The development of self regulated learning capabilities is considered as one of the main goals of modern education (Baumert *et al.* 2000), also being of high relevance to the so called PISA evaluations. A generic overview and elements and models for self-directed learning can be found in Zimmerman & Schunk (1989).

Virtual agents (VA) (called Virtual characters, VC, in DL) in combination with meta-cognitive feedback along self regulated learning paths (Leelawong & Biswas 2008) are thought to improve the learning performance significantly in computer based learning environments. Especially Teachable Agents (TA) supporting a learning by teaching approach are thought to be very effective in supporting learning (Biswas *et al.* 2005).

In most evaluation setups, normal tutoring of the students, a situation where the student teaches a virtual agent, and situation where a student teaches a virtual agent with meta-cognitive and self regulated feedback possibilities are compared (Biswas et al. 2004; Wagster et al. 2007; Leelawong & Biswas 2008). The results showed, that combining the learning by teaching paradigm with an appropriate mix of directed and guided meta-cognitive feedback will lead to the design of powerful constructivist learning environments helping novice students become independent learners who are better prepared for future learning tasks (Leelawong & Biswas 2008). Although corrective direct feedback may allow the student to achieve immediate goals set by the learning environment quickly, it was demonstrated that guided meta-cognitive feedback better prepares the student for future learning tasks even in situations where the meta-cognitive support is removed (Tan *et al.* 2006; Leelawong & Biswas 2008).

The teachable agent, the quizmaster and the teacher represent the main virtual characters in the DL environment. Both, VC and OBF will provide the meta-cognitive feedback possibilities, although it is not clear yet to which extent, and in which way the meta-cognitive feedback and the self regulated learning paths will work in DL.

The OBF compares two models, a learner and an expert model, the latter of which is used as a reference model. The comparison points out the differences between these two models, thus helping the learner to make her model more similar to the reference model.

The effects of the VC and the OBF on learning and motivation have not been evaluated by BOKU so far. Designs for an appropriate evaluation of the above mentioned issues need to be developed for the second round of evaluations.

1.6. Introducing DL and the different learning spaces into the classroom

To successfully introduce system modelling tools like DL software into the classroom, one should try to give a clear picture on what is going to happen, and why. Furthermore, it is necessary to stimulate the interest of students with regard to the modelling activity and also with regard to the topic to be explored.

During BOKU evaluations, the DL software was introduced as a tool for a better systems understanding, representing a crucial skill for dealing successfully with ecological, environmental, social and political issues. The high value of understanding the world in this way was pointed out.

Then the relation of the presented qualitative modelling approach to other approaches of representing the world (mental models, pictured or sculptural representations, verbal models (*'prosa'* models), concept maps, causal loop diagrams - with only plus and minus, typical stock flow diagrams, statistical models and equations) was shown.

Then, step by step, different kinds of system representations according to the learning spaces in DL were introduced (concept maps, simple causal loop diagrams, stock flow diagrams), and then the principle of causal qualitative reasoning was explained based on an example of showing a pot of boiling water on a stove.

Then the topic was introduced, and students were asked to build a concept map on this topic in LS 1.

Then the students had to determine a list of questions relevant for understanding systems. Answers like *how does the system work?, What are the goals of the system?, How is the system going to achieve the goals?, What are the components?, What are the connections?, How are things linked?, What is related to what?, How do things affect each other?, Which are the potential ways to influence a system?, How do affect things each other?,* were given. After this round they were prepared to move to LS2 and to build a simplified causal representation of the system. The modelling components of LS2 were presented theoretically on a PowerPoint slide. Then they had to build up a comprehensive causal representation of the system in LS2.

Finally LS4 was explored, where a specific process was taken as an example for developing a dynamic model based on typical features of system models using direct and indirect influences with the potential to apply feedback loops.

To introduce LS4, the bathtub example and a simplified population model was chosen. Then the modelling components of LS4 were presented theoretically on PowerPoint slides. Then they were asked

implement a simple population model being presented by the teacher, including rates and state variables, followed by a construction of a LS4 model related to the topic by their own.

1.7. Evaluation techniques

The evaluations of the prototype of the DL software primarily aimed at providing information on

- Usability of the software and problems learners encountered when working with the software supporting *'Basic help', 'Diagnostic feedback', 'Recommendations', ' Bug repair'*, etc.
- The appreciation of the software by students and their impressions and potential ideas for increasing usability,
- Changes in knowledge and knowledge structure influenced by the activities with DL.

Accordingly, lesson plans (Appendix, Section 10.5 and 10.6) were developed and appropriate evaluation instruments and approaches for analysing the data were chosen.

For the analysis of the pre-and post tests, quantitative text analysis (Roberts 2000) is applicable, and can be used to characterise changes in knowledge and knowledge structure in environmental sciences (Dresner & Elser 2009; Ruiz-Mallen *et al.* 2009). This evaluation strategy is usually based on coding and counting the entities and relationships used to characterize a phenomenon before and after learning activities. Furthermore the extraction of mental maps from pre- and post tests is providing additional information on how the network of knowledge changed due to the learning activity (Fellows 1994; Kinchin *et al.* 2001; Abernethy *et al.* 2005; Ruiz-Mallen *et al.* 2009).

Atlas. Ti is a software that can be used for the quantitative as well the qualitative approach (Lewis 2004), and was applied for the analysis of pre- and post-tests in the DL evaluations.

Furthermore qualitative methods like observation, also with video, and/or motivation questionnaires can be used to capture behaviour during software use and attitudes and motivations of the students towards modelling and scientific learning (Wang & Reeves 2006; Mavrou *et al.* 2007; Rich & Hannafin 2009; Zeyer 2010). Video analysis in social sciences is often performed using qualitative analysis software instruments like the *Transana* software, which was chosen for its useful features, its ability to deal with a wide variety video formats, and the relative cheapness of single user licenses.

Finally the chosen methodologies allow the application of the *'grounded theory approach'* (Strauss & Corbin 1998; Glaser & Strauss 1999). *'Grounded Theory'* (GT) thereby can be understood as a systematic qualitative research methodology in social sciences accentuating the generation of new theories from observational data in the process of analytical research. Following this methodology, the first step is data collection through a variety of methods. From these data key elements are identified and coded by key words arising from the analytical work. The codes are then tried to be unified into similar concepts, from which finally categories are formed representing the basis for the creation of a theory, or a so called *'reverse engineered hypothesis'*.

The application of the GT approach within the evaluations of the DL software allows for induction and the emergence of new theories with regard to learning with the unique and new combination of features of the DL software.

A more detailed description of how the software programs were applied can be found in sections 10.1. and 10.2. in the Appendix.

2. Participating institutions and evaluations conducted

For the 2010 evaluation period at BOKU two educational institutions were chosen to evaluate the prototype of the DL software: the International HTL Bad Radkersburg (i:HTL), an Upper Secondary Technical High School for electrical engineering in Styria, and the University of Natural Resources and Life Sciences (BOKU), Vienna.

2.1. i:HTL

The International HTL Bad Radkersburg (i:HTL) is a co-operation between the municipality (borough) of Bad Radkersburg and the BULME Graz-Göstling, one of the most renowned higher technical learning institutes (upper secondary technical colleges) in Austria. This cooperation aims to provide young people from Austria, Hungary, Slovenia and Croatia with a common training to become engineers. As a result of this the graduates should be able to establish and develop a cross-border market and help to promote the economy and culture of the Adria-Alpe-Pannonia Region. The students are trained in electrical engineering and from the third form on they are offered an in-depth consolidation course in plant management and medical technology.[2]

At the i:HTL the following evaluation was conducted:

1) Detailed assessment of the modelling behaviour and motivation of two students working with different LSs of DL software via video analysis and motivation questionnaires.

2) Assessment of the effect of the DL software on causal understanding using pre- and post-tests.

2.2. BOKU

The University of Natural Resources and Life Sciences, Vienna, the Alma Mater Viridis, sees itself as an education and research centre for renewable resources, which are a necessity for human life. With its wide range of areas of expertise it is the task of BOKU to contribute significantly to the protection of life resources for future generations. With a connection between natural sciences, engineering and economics, BOKU is trying to deepen the knowledge of an ecologically and economically sustainable use of natural resources in a cultivated landscape.

At BOKU three different evaluation activities were conducted:

1) Evaluation run with 29 students at one afternoon exploring LS1, LS2, and LS4 focusing on changes in causal understanding using the DL workbench via pre- and post-tests.

2) Continuous documentation of the modelling activity and reporting of problems encountered by two master students and a documentation of their attitudes and motivations.

3) Evaluations with regard to the OBF, run together with UMP.

The following chapters describe the individual evaluation settings, results expected, some considerations for data interpretation, data evaluation methods and final results. Additional material related to methodology and results can be found at the Appendix.

[2] International HTL Bad Radkersburg – www.ihtl.at

3. First evaluation study: i:HTL

3.1. Setup

Date:	**19.04. - 22.04.2010 (from 7:50-13:40 each day with breaks)**
Place:	**i:HTL Bad Radkersburg, AT**
Responsible person:	**Andreas Zitek**
Participating students:	**2 students, one male and one female**
Age of students:	**16 years old**
Topic:	**Does the production of wind energy influence fish populations? On the relationships between wind energy production, pump-storage hydropower plants, hydropeaking and means frequency.**
Activity:	**3 days of modelling, with LS1, LS2 and LS4 (each for one day) with a final public presentation during the event e-day at school.**
Evaluation instruments:	**Videotaping of the modelling activity and questions, pre-post test, motivation questionnaire**

<u>First day (19/04/2010):</u> LS1
After a short introduction in the DynaLearn project and an overview on fish ecological problems caused by hydropower plants the students started to work with LS1. Furthermore the relationship between wind energy production and the construction of pump-storage hydropower plants was highlighted. Aim of the session was to develop a concept map showing the relationships between alternative renewable energy production forms (focus on wind energy and hydropower) to fish ecology.

<u>Second day (20/04/2010):</u> LS2
After a short introduction to general importance of a systems understanding for making sustainable decisions, both students developed a LS2 model about energy consumption, renewable energy production and effects on water quality.

<u>Third day (21/04/2010):</u> LS4
At the third day an example of a LS4 model (population model) was introduced. As a first modelling step in this LS they were asked to re-build a simple population model which was shown on a PowerPoint slide model with birth and death as direct influences on population size and biomass using direct and indirect influences (I`s and P`s). Based on this generic pattern showing the effect of competing processes on state variables the possibility of inequality statements was introduced, in the second modelling session the students were asked to build a LS4 model of a control circuit representing the main process (means frequency regulation) in the wind energy production-hydropeaking relationship.

<u>Fourth day (22/04/2010):</u> Final presentation
The students gave a final presentation of their modelling results in front of official representatives and their parents.

The detailed lesson plan for each day of the i:HTL evaluation can be found in the Appendix (Section 10.5).

3.1.1. Expectations from this setting

- **Videotaping will provide feedback on usability and problems learners encounter with the software. This will help to focus *'Basic help'*, *'Diagnostic feedback'*, *'Recommendations'*, *'bug repair'*, etc.**

- **The pre-post test (content test) will prove if students increased their content knowledge during their modelling activities and if the structure of their knowledge was influenced by the activities with DL.**

- **A motivation questionnaire will help us knowing if students liked what they did and will collect their impressions and ideas.**

3.1.2. To be considered

The group, that participated in the evaluation was very small and consisted only of two students, one female and one male. But these students were very motivated and represented the best students of their school. Due to their education they already had experience with sustainable energy production, but they have never been informed adequately on the effect of these technologies on rivers and fish. The evaluation procedure envisaged to explore one Learning Space (LS) per day.

3.2. Data analysis i:HTL

The data gathered in the four days of evaluation at the i:HTL consisted of three components:

1. **Video recordings capturing the working activities of the two students on the computer screens, their social interactions, questions and answers, which were analyzed using *Transana* software.**

2. **Textual data, gathered by pre- and post-tests (see sections 10.3.1 and 10.3.2 in the Appendix) and analyzed with the *Atlas.ti* software.**

3. **Motivation questionnaires.**

3.2.1. Transcription and coding of video recordings

Analysed video data comprised 9 hours in total, approx. 3 hours per day and LS, 1.5 hours per person and LS per day. The *Transana* software allowed for a transcription of the video tapes and for an identification of analytically interesting clips and assignment of descriptive keywords and codes to these clips that were finally grouped into higher hierarchical concepts.

The transcript-based analysis allowed us to elaborate:

- **Conversation Analysis: about talks and questions/answers between students and between students and teacher.**
- **Action Analysis: about student modelling activities visible on their screens.**

27 main keywords concerning students' behaviour and questions with regard to the DL software and the domain knowledge (topic) during the modelling processes were identified and used as codes in the video analysis (Figure 3.1).

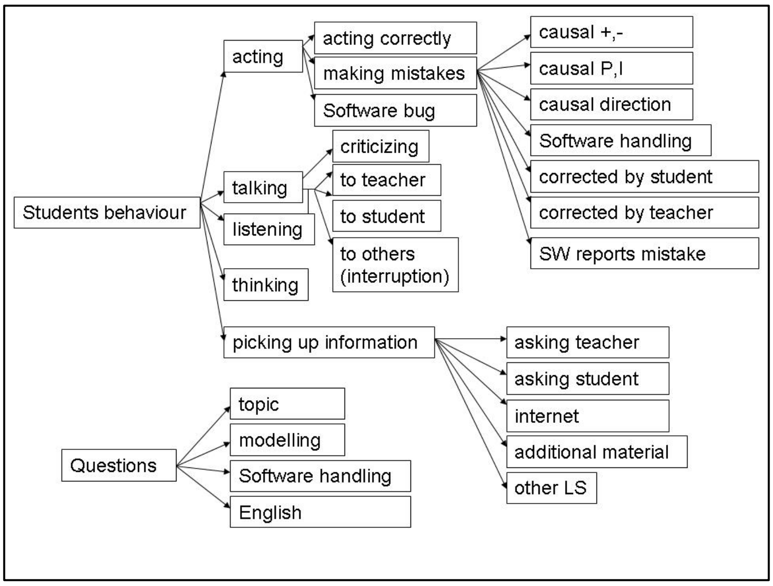

Figure 3.1: Keywords used for coding the videos of software use at the I:HTL.

By means of these keywords we wanted to focus around three main concepts:

1) **Modelling & social behaviour: *'acting'* (each type of modelling activity monitored at the screen, specified into specific sub-categories), *'talking'* and *'listening'* (to student, teacher, others, criticism), *'thinking'*, *'picking up information'* (with a description of the source of information) or *'taking a break'***
   - **How was the behaviour and social interaction during the modelling work?**
   - **Did students modelling & social behaviour differ per LS?**
2) **Detailed model building behaviour: sub-categories of *'acting'*, *'questions'* (type of question)**
   - **Which mistakes did students make at which points in software use?**
   - **Which questions were asked during modelling and when was help needed?**
   - **Were the modelling results correct?**
3) **Proposed improvements (*'criticism'*)**
   - **Which were the main critical comments made by students?**

Furthermore the export of the captured activities along a time scale allowed for temporal analyses of the data. A time sensitive transcript of the main information presented can be found in section 10.4.4 in the Appendix.

3.2.2. Transcription and coding of pre- and post tests

For the structured analysis of pre- and post-tests, they had to be scanned for allowing the import as .pdf files into *Atlas.ti.* In the tests, handled as Primary Documents, quotations were created capturing keywords (concepts) by marking the accordant word or section in the PD. Multiple mentions were also considered. Linking each quotation or concept mentioned with a code (e.g. *'demand for energy'*, *'flow velocity'*, *'wind power',…)* helped to classify the quotation information and made it possible to count

them in pre- and post test situations for comparisons, and to connect them to networks reflecting the mental model of the students. Altogether 214 quotations were marked which were connected to 108 codes.

Furthermore, the causal relations have been tagged in the PDs and classified by linking them to three codes:

- verbal causal relations
    - A list of causal verbal statements collected from pre- and post tests can be found in the Appendix (Section 10.4.5).
- graphical causal relations
- and wrong causal relations considering both, graphical and verbal expressions.

Additionally, two questions from the questionnaire were used to qualitatively judge their understanding in pre- and post-tests:

- What are the environmental effects of hydropower plants?
- Is the production of wind energy use linked to hydropower production?

For comparing the students' answers to experts' knowledge the answers to the above questions were classified into a 5-tiered-scheme - 1 (very low), 2(low), 3 (medium), 4 high) and 5 (very high) – for their convergence to experts' knowledge.

In a next step, the number of words being used to give an answer has been counted. Finally the *'degree of abstraction'* was also classified qualitatively in a 5-tiered-scheme and stored as codes in *Atlas.ti* linked to the accordant PDs (tests).

The export of the code lists into Excel allowed us to calculate sums and means of the numbers of mentioned codes sorted by pre- and post-tests and enabled the consideration of multi-mentions versus single-mentions of codes.

To visualize the students' knowledge of the treated topic and the complexity of their thinking and understanding before and after the learning activity with DL, mental/cognitive maps were created in *Atlas.ti*. The codes (concepts) were connected by so called code-code-relations, the output was a network view of nodes (codes) and links (relations) representing the mental maps of the students (see Figure 3.2).

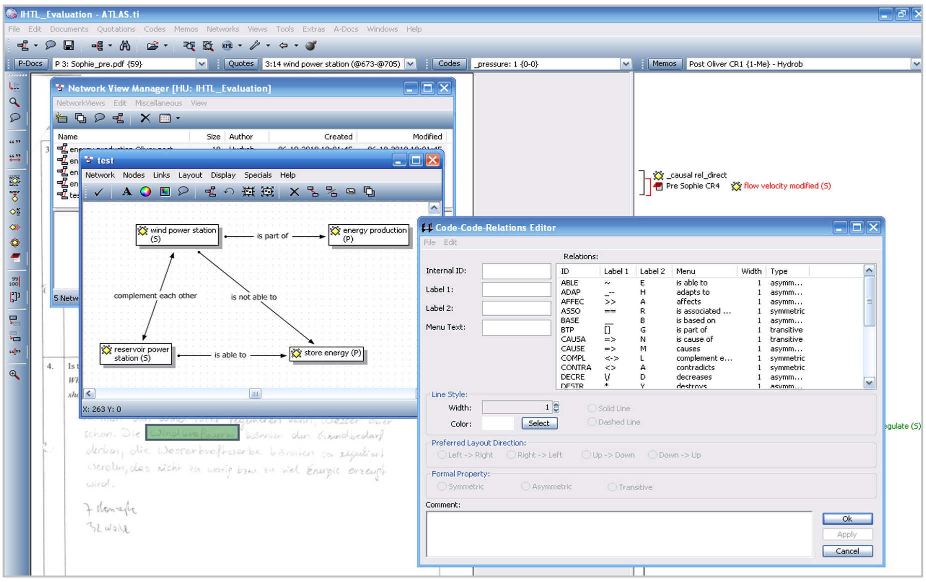

Figure 3.2: Screenshot of *Atlas.ti* network view and code-code-relations editor.

3.2.3. Motivation questionnaires

At the end of the evaluation session the students filled in motivation questionnaires (see Appendix Figure 10.12 and Figure 10.13). Twelve of the 16 questions allowed ticking applicable answers (in a 7-tiered scheme) and the remaining four had to be answered qualitatively by writing textual answers. The selected ratings per question were analysed by calculating the arithmetic means in Excel and the content of the written textual answers was extracted and collected.

3.3. Results i:HTL

3.3.1. Video analysis

3.3.1.1. Modelling and social behaviour

The following section contains the results related to the following main questions:

- How was the behaviour and social interaction during the modelling work?
- Did students modelling & social behaviour differ per LS?

Students` behaviour differed significantly between LSs. As students were not familiar with the ecological topic, they spent a lot of time in LS1 mainly for picking up information (asking teacher/student, looking in the internet, in additional material).

In LS2 students worked very self-dependent on their models which implicates more time for thinking.

Conversation increased from LS1 to LS4 and in LS4 they spent almost half of the time for picking up information, talking and listening hence discussing their modelling activities (Figure 3.3).

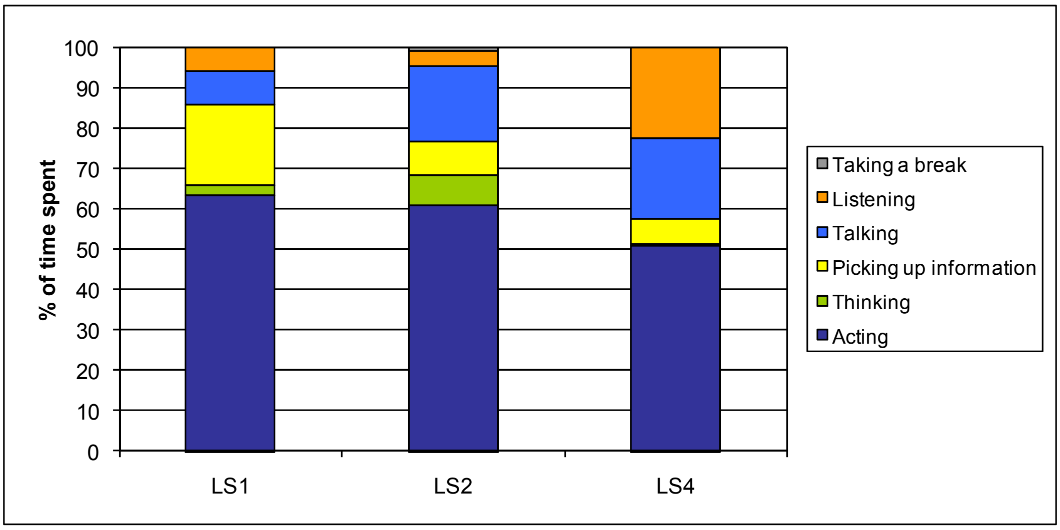

Figure 3.3: Behaviour of students at each LS expressed as percent of time spent for a specific activity.

Time spent for topic related questions was highest in LS1, when students developed their first understanding of the system using a concept map, and decreased significantly from LS2 to LS4, as LS4 activity was focused on a single process to illustrate and introduce the underlying principle of *'rates'* and *'stocks'* of typical System Dynamics models. Questions concerning Software handling (*'How to'*

questions), when the concept has been understood) or English translation arose in all LSs to a small extent.

Questions arising in LS2 and particularly in LS4 concerned increasingly the modelling parameters and features that can be used to express things in DL *('Modelling questions'*) (Figure 3.4). For questions related to '*Software handling'* (with the typical question*: 'How to implement something in the software'* once the concept has been understood) only little time was spent. This highlights the general user-friendliness of the software.

But especially the time spent for *'Modelling'* questions relating to the conceptual understanding of the available features that can be used to express certain system structures and functions, directly arising from the interaction with the software (type of questions like *'What is', 'for which purpose I can use', 'what does that mean')* significantly increased from LS1 to LS4 documenting the increasing possibilities of DL to reflect system structures in a more complex and realistic way. More detailed information on specific questions asked related to *'Software handling'* and *'Modelling'* can be found in tables in the Appendix.

<u>Main questions with regard to software handling:</u>

LS1:

- **Can I use slash or numbers for a name?**
- **How can I start to build a concept map? First "add an entity"?**
- **Name xxÜ - not allowed?**
- **How can I delete configuration?**
- **How can I save a model to a USB stick (close model and copy file from explorer or save current model to new file on USB stick)**

LS2:

- **How can I open the concept map from yesterday?**
- **How to insert a new entity between two existing ones without deleting the old ones?**

LS4:

- **How to implement the calculus?**
- **How can it be modelled that the birth rate is bigger than death rate?**

<u>Main questions with regard to modelling and modelling features (only with regard to DL features, not including topic specific questions):</u>

LS1:

- **About best structure and form of concept map.**
- **What is the function of "remarks"?**
- **What is meant by "configuration definition"?**

LS2:

- **About positive relationship in model – what does it mean?**
- **About add value function.**
- **What are attributes?**
- **About simulation start.**
- **About modelling processes.**

LS4:

- **About modelling rates (birth, death rate, growth rate).**
- **About definition of state variables example: biomass.**
- **How to inspect simulation results.**
- **Which Quantity Spaces are adequate?**

- About inequality properties and feedback loop.
- About calculus properties (the minus-calculus).
- Meaning of states in simulation.
- Is it needed to set configurations between all entities?
- About P and I – what is it – what is the difference?
- About entities and quantities.
- About calculus properties (the minus and plus calculus).
- About the possibility of introducing fluctuating simulations.

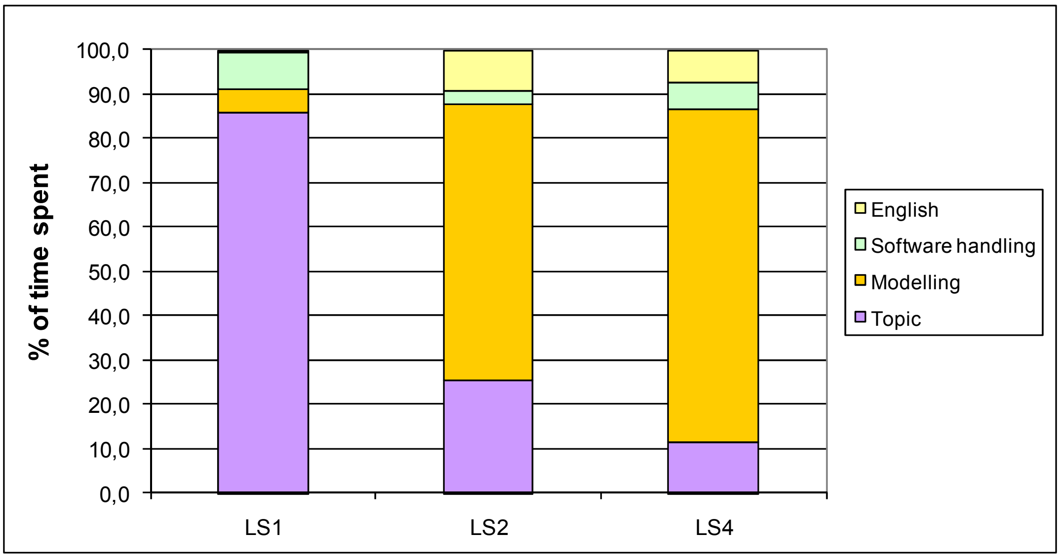

Figure 3.4: Questions of students at each LS expressed as percent of time spent for a specific type question.

In LS1, students improved their ecological knowledge mainly by using the additional materials provided (slides of introductory talk, publications, newspaper articles provided as pdf-files to students) (Figure 3.5.). Students interacted in all LSs mainly with the teacher, but also amongst them. Especially in LS1 and LS2, where students build their first dynamic models, they cooperated more. During LS2 activities, students also switched to LS1 to see the ideas and thoughts from the concept map, which points out the importance of developing abroad picture of the system under study before stepping into causal modelling. In LS4, the interaction is dominated by questions and talks to the teacher.

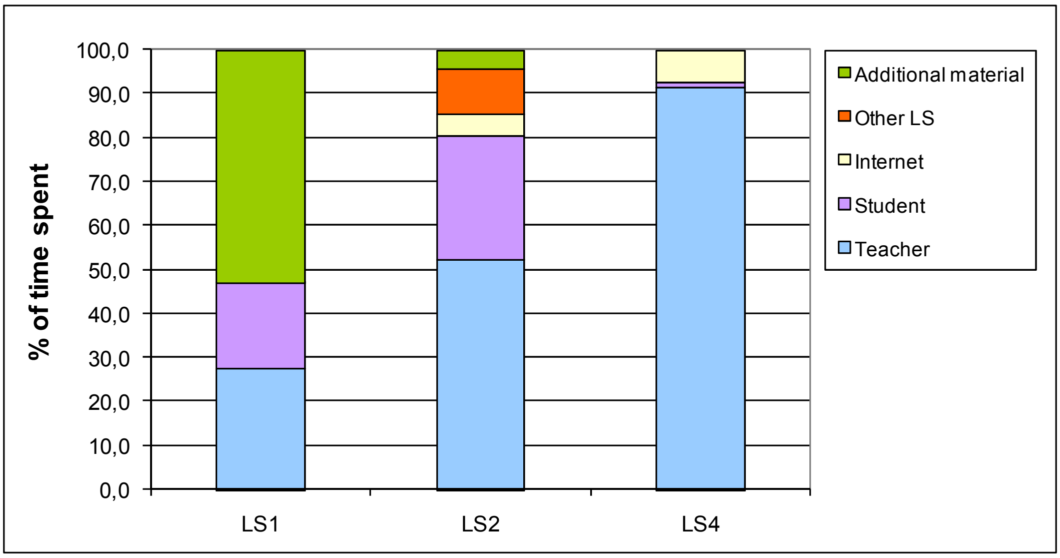

Figure 3.5: Sources of information used by students at each LS expressed as percent of time spent.

3.3.1.2. Detailed modelling behaviour and criticism

Which main mistakes did students make at which points and when was help needed

In all LSs was help needed for explaining modelling terms (e.g., entity, configuration, quantity space, etc.).

LS1: particularly software handling mistakes like:

- **Proper selection of entities to add configurations between them**
  - **Example: the student selects 2 entities by pressing leftclick on the mouse and trying to catch the certain entities within a window, therefore he has to arrange all entities to catch the right ones. The better way would be: selecting the first entity, then holding down shift key and selecting the second one, and then adding the configuration.**
- **Adding new configurations**
  - **Student changed the name of old configuration unintentionally during adding a new one.**
  - **Configuration properties: adding arrow direction**
- **Changing an already existing configuration unintentionally:**
  - **Student adds new entity - selecting second entity – and adding configuration – when not saving a new configuration name, and just overwriting the old one with a new one pushing the save button causes the change of all of the other configurations in the model to the new one.**

LS2: also Software handling mistakes like:

- **Setting of wrong causal relationships and directions avoided correct simulation results.**
- **Add a new configuration between 2 entities with wrong arrow direction (multiple times)**
- **Problem to select entities - student rearranged the chain several times to capture the right entities in a window, also deletion of causal relations, just to select quantities. (The better way would be: selecting the first entity, then holding down shift key and selecting the second one).**
- **Student added starting values at more than one quantity, the question mark showed up.**
- **Student is deleting configuration by pressing del - SW crashes**
- **Student is deleting entity in the simulation window - SW crashes**

LS4:

- **Students interacted strongly with the teacher, they asked whenever questions arose.**
  - **To introduce the features available at LS4 is a task that requires time.**
- **Help was needed for setting the minus calculus function correctly to create a rate.**
- **Help was needed for model debugging when incomplete simulation results occurred.**
- **How to establish the feedback loop from the state variable to the rate?**

Proposed improvements and main critical comments by students

LS1:

- **Complex concept maps are confusing (colours, different forms and size would help) and the handling in LS1 is not user-friendly.**
- **Names of configurations are often the same (e.g. 10 times the same configuration name has to be set in the concept map).**
  - **Student cannot unite the same configurations to one – thy overlaid the same configurations to reduce complexity of the concept map).**
- **Student cannot add a name with two capital letters.**
- **"Lettering also vertical possible?**

- Remarks window is cut off by display.

LS4:

- Numbers are not permitted in quantity spaces for setting benchmarks.
- Better ways for inspecting simulation results.
- Better possibilities for arranging the value histories.

3.3.2. Results of pre- and post-tests

Comparing pre- and post-tests (see Table 3.1) an increase of identified concepts of over 40% considering multiple mentions of individual concepts, and of nearly 30% considering only single mentions of concepts could be documented. The used of verbal causal relations increased by 91 %, whereas wrong causal relations did not occur in post tests.

The degree of causal understanding of the effects of hydropower plants and of the link between wind and hydropower production as judged by a comparison to an expert model significantly increased from low understanding to very high understanding by 100% and 150%.

The final analysis of the gathered data by creating networks in *Atlas.ti* (which can be found in the Appendix) displays the change of students' thinking after the learning activity with DL. Figure 10.20 and Figure 10.22 show the cognitive maps of both students in the pre-test and Figure 10.21 and Figure 10.23 show the cognitive maps post-tests documenting the significant increase of causal understanding of how things are related and influence each other.

Table 3.1: Chart with comparison of pre- and post-tests results of i:HTL evaluation.

Comparison pre- and post-tests							
		(multiple mentions)			(single mentions)		
Parameter	unit	prest-tests	post-tests	*change (in %)*	prest-tests	post-tests	*change (in %)*
concepts, total	[n]	43,5	62,5	*43,7*	36,5	46,5	*27,4*
causal rel_verbal	[n]	5,5	10,5	*90,9*	5,5	10,5	*90,9*
causal rel_graphic	[n]	0	1	*100,0*	0	1	*100,0*
causal rel_wrong	[n]	1	0	*-100,0*	1	0	*-100,0*
number of words	[n]	157,5	183	*16,2*	157,5	183	*16,2*
degree of abstraction	rated from 1 (very low), 2 (low), 3 (medium), 4 (high) to 5 (very high)	2,5	3,5	*40,0*	2,5	3,5	*40,0*
degree of understanding effects of hydropower plants	rated from 1 (very low), 2 (low), 3 (medium), 4 (high) to 5 (very high)	2	5	*150,0*	2	5	*150,0*
degree of understanding the link wind / hydropower	rated from 1 (very low), 2 (low), 3 (medium), 4 (high) to 5 (very high)	2,5	5	*100,0*	2,5	5	*100,0*

3.3.3. Results of motivation questionnaires

The motivation questionnaires yielded in general only positive feedback to all questions asked.

In detail, they very much liked the lesson and learning activity we had together, they understood much better the relationship between wind energy, hydropower and fish after having explored the topic with DL, modelling with the software enabled them to better understand the human-energy-environment system, and they highly agreed that modelling with the software could be also used in other learning topics (Figure 3.6).

They less agreed that the software provides a very comfortable way of learning (modelling with DL was experienced as being challenging), that the exploration of the topic at different use levels is important for their understanding, and that the modelling approach is very easy.

They both answered that LS4 contributed most to their understanding of the concepts represented in the models, as it allows for the most realistic representation of reality; one of the students also mentioned that LS2 contributed significantly to the understanding of the system. For detailed results of the questionnaire see Figures 10.28 – 10.38 in the Appendix.

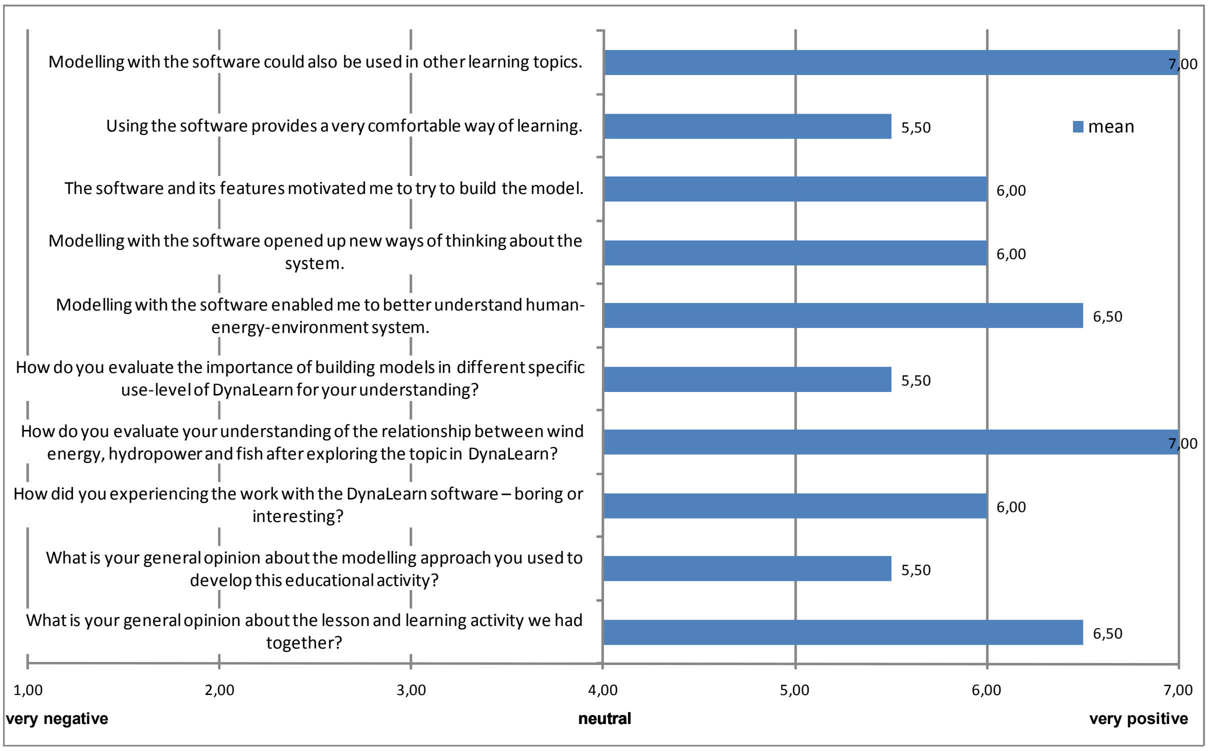

Figure 3.6: Mean rating value per question of the evaluation questionnaire at the i:HTL evaluation (1=very negative, 4=neutral, 7=very positive), for a detailed description of the rating scheme see Figures 10.28-10.38 in the Appendix.

3.3.4. Personal impressions as evaluator

First day

They had the first contact with me and the DL software on April 19th 2010. LS1 was easy for them, but they complained about that it is necessary to redo the same connector again and again and that it is hard to keep the overview. They asked for a possibility to combine many arrows to one connector expression which would make the concept map less confusing

Second day

At the second day they got very interested in what I have studied, and which environmental studies are available at BOKU. I had the impression that they got very excited with environmental issues. The male student has put information on the negative effects of hydropower turbines on fish at his Skype communication (“turbines kill nase”).

Third day

The female student communicated from herself that in her opinion the software can be used for every topic. She considered the software especially as useful at the beginning of a topic, where a student is able to explore a topic starting from his/her point of view (one can also develop a very personal viewpoint on the system, and sees easily the consequences of his/her assumptions), which is considered to be motivating for students. At LS4 they complained that the way to inspect the simulation results (value history) is not very insightful. The ordering possibilities of the value history was not really clear and they claimed more possibilities for arranging it.

Fourth day

They worked on the final presentation of this evaluation project. First they developed a text, based on some information on the basic structure that the presentation should follow given by the teacher. They produced a very well structured presentation and were able to present the central issues very clear and structured. We all were very excited about our working experience with DynaLearn.

3.3.5. Personal impressions as a teacher

Preparing for the lessons for different LSs was an interesting task, and required deep thinking on HOW to introduce each LS with its specific features and possibilities. It was easy for LS1, where I 'only' had to provide the typical PowerPoint slides describing an issue, which I gave to them in digital form, to do their LS1 work. LS1 only presented challenges with the insightful organization of the entities and relationships. So they asked for colours and instruments to better group things visually. When using LS2, they went back to LS1 to prove, if their model is complete. So LS 1 seemed to serve as a reference for developing models at LS2.

Then, at LS2, I introduced the concept of causal relations, which enabled them to develop a dynamic view of their thoughts, with an end result that could not be simply foreseen because of the complexity of their relationships. So here LS2 helped to overcome typical limitations of human brains, enabling the development of a model of relatively high complexity with many interactions. Also both of them developed a very personal viewpoint on the problem. LS2 seems to me well suited to allow the inclusion and development of own viewpoints, which turned out to be very engaging and was forming an interesting basis for further discussions. LS2 seems to represent the first opportunity in DL to include own ideas and viewpoints into existing causal relationships stimulating both, questions and answers.

On LS4, I first had to decide, which process is the most important process, that, when understood deeply, would form a central basis for including other (similar) processes that could be added using the same modelling pattern to build up a bigger systems view. So, identifying the most important process(es) within a topic seems to me THE pre-requisite to build models in LS4.

At LS4, to make things easier for them, I first introduced the System Dynamics view of the world using the bathtub example. Then I introduced the concept of I`s and P`s to describe the world in this manner – as flows = rates (I`s) and stock variables = state variables (P`s). After that, I showed a PowerPoint slide with a simple population model containing birth, death, population size and biomass, letting them re-build this system on their own computers. Then they had to decide where to put an I and where to put a P. This was relatively simple. Then I gave the example to do the control circuit, and again, after some first trials, I gave the structure of the entities and quantities on a PowerPoint slide, and we together developed the system. They got the idea of calculations, rates and state variables relatively fast, and started to expand the modelling pattern to describe other system elements in the same way (creating rates, that triggered the whole system more realistic They both were of the opinion that LS4 contributed most to their understanding of the concepts represented in the models allowing for the most realistic representation of reality; one student also mentioned that LS2 contributed significantly to the understanding of the system.

They really liked the presentations and the way we were discussing the topic.

The feedback of this modelling sessions in the i:HTL was very positive. Other teachers that joined these sessions were very interested and got very excited on the potential of the software for expressing own thoughts for e.g. stimulating discussions.

The students had the impression that the software could be easily implemented in other topics, especially at the beginning of the topic, to get an overview, and to make your own viewpoint explicit as a basis for collaborative learning and discussion. They really enjoyed the three days.

4. Second evaluation study: BOKU I

At BOKU University we had the possibility to implement DL during one lesson within the course "Selected Topics of aquatic ecology and river management" as one of 5 afternoons in total. The lesson for the whole course as well as for the afternoon with DL can be found at the Appendix (Section 10.6). The rest of the course was held as PowerPoint presentations. This course provides comprehensive information about river management, river landscapes and their fluctuations and large river systems as well as benthic invertebrate ecology, water quality assessment, EU Water Framework Directive or classification and modelling of river systems.

4.1. Setup

Date:	**19.05.2010 (12:00-17:00)**
Place:	**BOKU, Vienna, AT**
Responsible person:	**Andreas Zitek, Michaela Poppe, Michael Stelzhammer, Susanne Muhar**
Participating students:	**29 students (12 female, 17 male)**
Age of students:	**22-39 years old**
Educational level of students:	**mainly master students**
Topic:	**River channelization: background and physical and biological effects.**
Activity:	**one afternoon introducing DL, and modelling with LS1, LS2 and LS4 (from 13:00-17:00, starting at 12:00 with software installation)**
Evaluation instruments:	**Videotaping of the modelling activity on the screen of the software, of social interactions, questions and answers; pre- and post-test, motivation questionnaire, final exam**

4.1.1. Expectations from this setting

- **Feedback on usability and problems learners encounter with the software. This will help to focus *'Basic help', 'Diagnostic feedback', 'Recommendations', 'bug repair'* etc.**
- **The pre- and post-test will help us in knowing if they learned something, and if the structure of their knowledge is influenced by the activities with DL.**
- **The final exam will show, how students perform with regard to content delivered within the modelling session in comparison to content delivered by the other lessons (held as PowerPoint presentations with discussion)**
- **A motivation questionnaire will help us knowing if they liked what they did and collect impressions and ideas.**

4.1.2. To be considered

The group of participants consisted mainly of very experienced students that were already well informed in the treated topics. Most of them were master students (n=21), five of them PhD students and only three were Bachelor students. The detailed age distribution and distribution of educational degrees can be found in the Appendix (Figure 10.14. and Figure 10.15). As the group had a very good knowledge of the topic beforehand, we did not expect great increase in factual knowledge but more a structural change of knowledge representation. The evaluation time was relatively short to treat all the planned items in detail. Only 20 out of 29 delivered pre- and post tests, of which seven did not fill consequently the post test. Finally 13 students delivered a pre- and post test that could be used for analysis. Some of them were in a hurry during post test.

4.2. Data analysis BOKU I

For the analysis of the BOKU I evaluation session the following components were available:

- **pre- and post-tests,**
- **motivation questionnaires and**
- **final exams of the course with written answers.**

The analytical process of the pre- and post-tests was similar to the one used for the i:HTL evaluation described above: scanning the tests, importing them into *Atlas.ti*, marking quotations, linking them with codes and memos, categorization of causal relations and determination of the degree of abstraction.

From the evaluation session we got 20 completed pre- and post-tests from the students, but for the final interpretation only 13 could be used. Seven post-tests were not filled or commented like *'see pre-test', 'point of view didn't change'*, etc. which made them useless to analyse.

The motivation questionnaire (see Figure 10.17 and Figure 10.18 in the Appendix) was completed by 27 students after the evaluation lesson. The structure of this questionnaire is similar to the one used at i:HTL. 11 of the 15 questions allowed ticking applicable answers (in a 7-tiered scheme) and the remaining four had to be answered qualitatively by writing textual answers. The data were processed with Excel by calculating arithmetic means and medians of the single ratings.

The third component of the BOKU evaluation was the assessment of the performance with regard to a question within the final exam of the course, which offered us the possibility to verify how much the students learned about the topic explored with the help of the DL software in comparison to content delivered as PowerPoint presentations. Here, every single question was graded separately by the lectors of the course (1=very good, 2=good, 3=medium, 4=poor, 5=bad), allowing for the calculation of mean values per question in an Excel matrix. Here all 29 students delivered a test.

4.3. Results BOKU I

4.3.1. Results pre-and post tests BOKU I

In contrast to the analysis chart of i:HTL data, the BOKU results (see Table 4.1) show a different trend. Whereas verbal or wrong causal relations decrease, graphical relations increase significantly. This can be assigned to the students' advancement in structural knowledge in the discussed topic. On the other hand the significantly increasing degree of abstraction (from low to high) leads to a significantly lower number of words used and a decreased number of concepts (keywords) mentioned.

The structuring of the pre- and post-test data by creating networks of the codes in *Atlas.ti* showed an expected result: the difference between pre- and post-test networks were not as remarkable compared to those at the i:HTL. Examples illustrating the changes in the mental models from pre- to post test situation of two students are displayed in Figures 10.24 – 10.27 in the Appendix.

Table 4.1: Chart with comparison of pre- and post-tests results at BOKU I evaluation.

Comparison pre- and post-tests							
		multiple mentions			single mentions		
Parameter	unit	pre-tests	post-tests	change (in %)	pre-tests	post-tests	change (in %)
concepts, total	[n]	27,31	21,23	-22,3	21,77	17,46	-19,8
causal rel_verbal	[n]	1,38	1,23	-11,1	1,38	1,23	-11,1
causal rel_graphic	[n]	0,77	2,54	230,0	0,77	2,54	230,0
causal rel_wrong	[n]	0,23	0,08	-66,7	0,23	0,08	-66,7
number of words	[n]	101,46	54,38	-46,4	101,46	54,38	-46,4
degree of abstraction	rated from 1 (very low), 2 (low), 3 (medium), 4 (high) to 5 (very high)	2,08	3,62	74,1	2,08	3,62	74,1

4.3.2. Results of motivation questionnaires BOKU I

The analysis of the motivation questionnaires collected at the BOKU I evaluation involving more experienced students shows a more heterogenic result compared to the i:HTL. (see Fehler! Verweisquelle konnte nicht gefunden werden.). The highest agreement was documented for the applicability of the software to other learning topics. Furthermore they liked the lesson and learning activity supported by DL and they found it very interesting to work with DL. Also the importance of building models in different LSs was ranked as high. As the students were already well informed about the issue that was explored by DL, the activity did not much contribute to a new understanding of the system. For detailed results of the several questions see Figure in the Appendix.

4.3.3. Results of final exam BOKU I

The analysis of the test results of the final exam showed, that the topic explored with DL (question 5, red bar in Figure 4.2) was amongst the best graded questions, indicating the highly satisfying and 'very good' understanding of the topic explored with DL in comparison to other comparable questions (blue bars).

As for the questions indicated by the grey bars only some single facts had to be memorized, they are considered as not being directly comparable to the other questions requiring a deeper and broader understanding of the involved entities and processes.

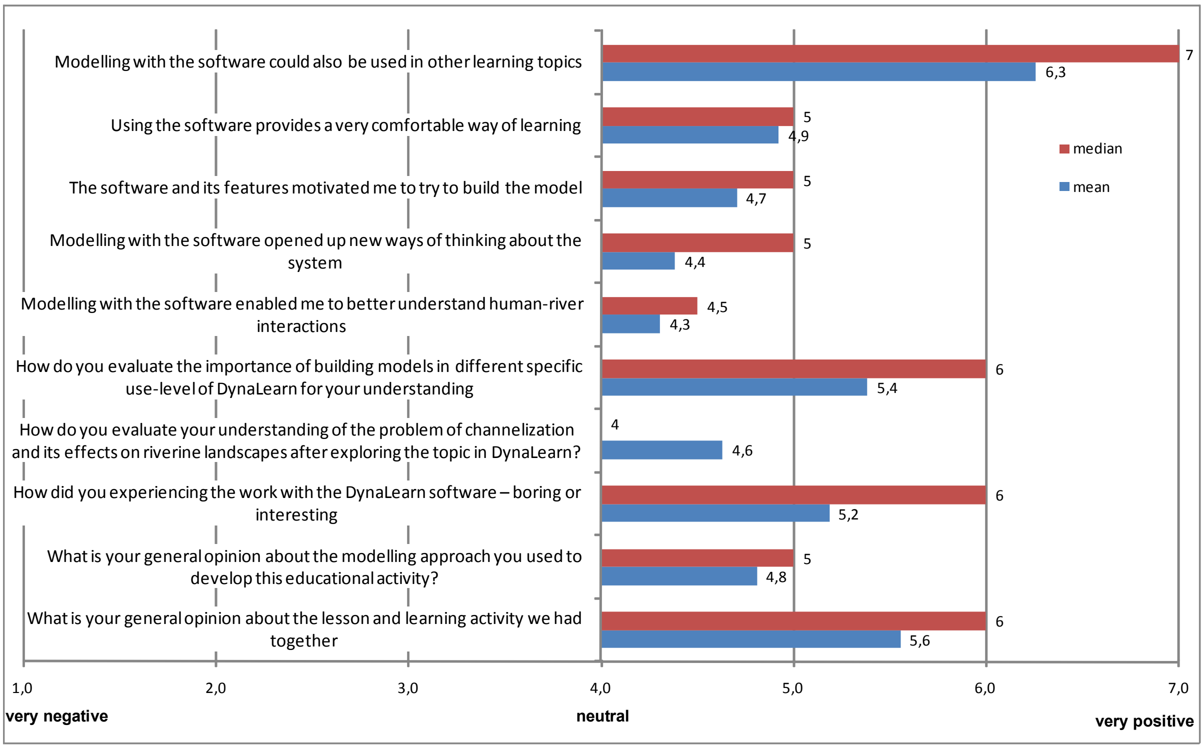

Figure 4.1.: Mean and median rating values per question of the evaluation questionnaire at the BOKU I evaluation (1=very negative, 4=neutral, 7=very positive), for a detailed description of the rating scheme see Figures 10.39-10.49 in the Appendix.

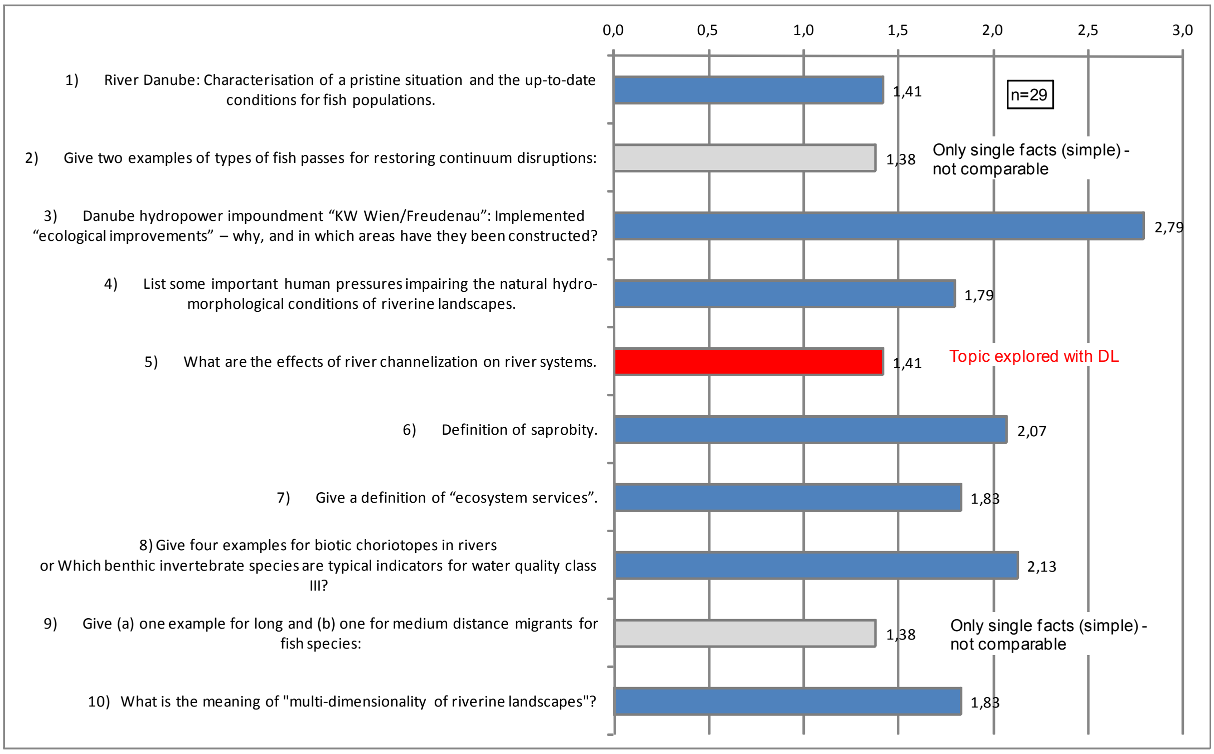

Figure 4.2.: Mean grades (1=very good, 2=good, 3=medium, 4=poor, 5=bad) achieved per question at the final exam at the BOKU I evaluation; the red bar represents the topic explored by DL, the blue bars represent comparable questions of similar complexity, the grey bars represent questions that are not comparable because the were asking only for some memorized single facts).

4.3.4. Impressions as evaluator and teacher

- **They liked the presentation and the way things were introduced very much.**
- **Very heterogeneous engagement of the students (some only did what was shown, others started to extend the models by their own), maybe because of the size of the group.**
- **In principle they liked modelling, although some asked why it should be useful to learn another software.**
- **High interest of students to learn something new, to look at a topic in a different way, to highlight causal relationships.**
- **One afternoon is far too short to really work through different LS.**
- **Modelling initiated profound discussions with professor.**
- **Some were hard to motivate to develop models by themselves, they simply rebuilt what was shown on the screen and stopped then doing other things.**
- **Most interested in the approach seemed people that already had modelling experience and a profound knowledge on the topic (PhD students) – they really had fun with finding ways to express their knowledge.**
- **The + and − notation in causal diagrams and at P`s and I`s were sometimes not intuitively understood. Here further clear support should be provided by the software.**

4.3.5. Typical modelling mistakes and questions by students

- **Accidental re-naming of the quantity or configuration definition because the „add new“ button was not hit.**
- **Why different entities or quantities cannot be linked?**
    - **Answer: In most cases only one, or more than one was selected**
- **Some did not find the button for creating a new model.**
- **Some liked to change colours or sizes of the representation for a better overview.**
- **How big should the modelled system be?**

4.3.6. What did they like (results of the questionnaire)

- **Support**
- **The SW shows, that the system is like a net**
- **Individual and cooperative working possible, better understanding of system parameters**
- **Visualisation of interactions**
- **Easy way to think how system works**
- **Structure/composition of lesson**
- **Layout, virtual brainstorming**
- **SW forces to think about the relationships of a system**

- **SW easy, user-friendly**
- **You can use your own knowledge for modeling and creation of ones own knowledge model**
- **Better understanding of relationships in a system**
- **Interactive lecture**
- **Visualisation of interactions, easy use, overview of a system**

4.3.7. What did they dislike (results of the questionnaire)

- **No understanding about cause of the program**
- **Handling of SW**
- **LS4 (time constraints)**
- **Handling SW, layout possibilities SW**
- **Installation**
- **No overview in a complex model**
- **Color-style**
- **No new insights**
- **Target of the lesson was not explained**
- **LS1 becomes confusing if system is complex**
- **Spent too much time in LS 1,2 - UL4 most interesting**
- **Time constraints for LS 4**
- **Not enough time for the whole SW**
- **Confusing if model is complex**

4.3.8. Ideas for improving the software (results of the questionnaire)

- **P+I better buttons, better overview of the SW**
- **More symbols available**
- **Questions mark button to hover over tool buttons activates help**
- **Handling of DL software**
- **Arrows in both directions LS1**
- **Expert mode for more attributes and differentiations**
- **Include shortcut "strg + z" for one step backwards**
- **Adjustment of entities and quantities in a grid**
- **Visual differentiation between +,- or P and I**
- **Symbols SW, ok, delete buttons are at unusual position**

4.3.9. Further comments (results of the questionnaire)

- **One might need a lot of exercise for the DL software**
- **Make it more usable**
- **Not enough time, but excellent for DPSIR analyses**
- **Start with a collaborative model together with all students**
- **I know VENSIM, but DL is better**
- **DL cannot replace conventional learning, but can be an additional tool**
- **Good tool fur simulations and overview of a system, knowledge of the system must exist before modeling**
- **I would use DL if it fully developed**
- **It would be good to have expert models behind the system, as students learn from both, their own model building activity and expert models.**

5. Third evaluation study: BOKU II

For collecting further information on the usability of the DL software evaluating at BOKU two students conducting their master theses within the DL project at the Institute of Hydrobiology and Aquatic Ecosystem Management were asked to keep records of their modelling activities as part of their master thesis.

Date:	**May 2010 – November 2010**
Place:	**BOKU, Vienna**
Responsible persons:	**Andreas Zitek, Michaela Poppe**
Participating students:	**2 students, both female**
Age of students:	**24 years old**
Educational level of students:	**master students**
Topic:	**River Continuum Concept and Global change effects on river catchments**
Activity:	**model building with DL, as part of their master thesis**
Evaluation instruments:	**Continuous documentation of their modelling activity and reporting of problems they encounter at different LS, documentation of their attitudes and motivations**

5.1. Expectations from this setting

- **Feedback on usability and problems learners encounter with the software. This will help to focus *'Basic help'*, *'Diagnostic feedback'*, *'Recommendations'*, *'bug repair'*, etc.**
- **A collection of their attitudes and motivation will help us knowing if the liked what they did and collect impressions and ideas.**

5.2. Impressions and motivation

5.2.1. What did they like?

- **Learning by doing!**
- **It is interesting to see how much and how detailed information you need for the different LSs.**
- **You need to understand the processes before you can model, thus you have to understand the causal relations.**
- **As you don`t need to focus on numbers, you can purely focus on concepts and their relations, which itself represents a very complex task, to understand how different factors interact. In comparison to the DL approach looking only for some statistics and correlations in your numerical data is quite simple.**

5.2.2. What did they dislike?

- **It takes some time to understand the different LSs.**
- **Lack of a description/manual of the different LSs and their features.**
- **To understand how modelling is done in different LSs is complicated.**
- **To understand which information can be presented with which feature at the different LSs is complicated.**
- **To get a satisfying simulation results is quite challenging at LS4, LS5 and LS6.**
- **Low speed of the software, particularly when simulating at LS2, and when removing elements.**
- **Software bugs.**

5.3. Comments on Learning spaces

LS2:

- **Problem: It is not possible to say, which influence is bigger.**
    - o **Solution: Could it be an option to have the inequality statements also available at LS2 – because otherwise you always get all opportunities, which cannot be resolved at this LS. No feedback loop on the starting variable possible.**
- **Problem: No feedback loop possible at LS2**

  - **Solution: Feedback loops should be available so the initial value could be changed during the simulation which would include more specifically a time & typical systems effect in the simulation.**

LS3:

- **It is not possible to say, which influence is bigger.**
  - **Could it be an option to have the inequality statements also available at LS3– because otherwise you always get all three opportunities, which cannot be resolved at this LS.**
- **Modelling preferences not available, model cannot go to zero. There is not the opportunity to change model preferences, so you often cannot reach zero – this has to be well explained how to reach zero in LS3 conditions.**
  - **Wee need a clear statement why the model cannot go to zero. It should go to zero and automatically stabilize there – as it makes no sense to decrease in zero, but the software should recognize that be itself.**

LS4:

- **Why are the assumption and agent buttons appearing, how can you set up an assumption? Can you make it active? This problem also relates to other LSs – where buttons are available, but it is not clear if they contribute actively or if they are just there as additional features without effect on the simulation.**
  - **Solution: remove superfluous buttons as they seem to irritate the modeller.**

LS5:

- **Here we need a clear information on how conditions have to be expressed….(e.g. always define two model fragments – one for the specific behaviour you want to have, and one for the others…), as this is often being forgot.**

LS6:

- **At least this learning space should contain a the sketch environment for developing causal models, as one gets easily lost when implementing models following the compositional approach implemented in LS6.**

All LSs:

- **Quantities and expressions already defined in other models in different LS HAVE to be available for import at all other UL as this is one of the most annoying things for beginners – who always have to start from a blank window!**
- **Would be nice to have the possibility to confirm modelling steps & choices with hitting the “enter” key.**
- **For saving a new quantity, the quantity definition editor has always to be closed. There should be the possibility to define more quantities at once.**
- **No possibility to go a step back in modelling!**
- **No possibility to cancel the last step!**
- **Does not safe the model automatically, when quitted!**
- **No reconstruction of model, when it shuts down!**
- **Also it would be good to see, which models were opened and changed the last session!**

- **It would be better to have the possibility to change things in the simulation of the scenario, too! Would allow you to work much faster! This is a typical mistake that you start doing things in the scenario…this should be possible…as a basis for changes you see the results…**
- **What about adding the existing sketch environment of GARP 3 to all LS at least the possibility to do causal I- and P diagrams?**
- **Be careful which buttons appear on the left side, and what they mean for modelling – in LS4 e.g. it is not possible to set an assumption that really affects the simulation – so why it is there?**
- **There is a need for explaining the use of the + and – button, as the possibilities for using these features is not clear to modellers.**
- **Would be nice to have an opportunity to export entities and related quantities with Q-space names into an excel table for creating model documentations.**

5.4. Ideas for improving the software

- **Import of entities and quantities from other LSs.**
- **Add possibility to go step by step back in modelling (Back button) linked to the possibility to cancel the last step.**
- **Safe the model automatically when the software is shut down (now there is no reconstruction of model, when started again).**
- **It would be good to see which models were opened and changed the last session.**
- **It would be helpful to have an overview of the models already done.**

6. Fourth evaluation study: BOKU III

Finally, BOKU was involved into several activities related to the development of the grounding and OBF features of DL guided by UPM. BOKU contributed several times with evaluations of the DBpedia grounding experiments, to prove the scientific reliability of DBpedia groundings.

Furthermore BOKU participated in a guided distance experiment with collaboration via Skype to test the OBF functionality of DL. The hypothesis is that Ontology Matching techniques can be applied to DL models to find equivalences (or mappings) between terms. Therefore, it is needed to test the correctness of those mappings and the general contribution of the type of feedback generated to learning.

Date:	**24.08.2009, 10:00 and 14:00**
Place:	**BOKU, Vienna**
Responsible person:	**Andreas Zitek (also participating the evaluation)**
Participating students:	**2 students, both female;**
Age of students:	**24 years old**
Educational level of students:	**master students**
Activity:	**Ontology based feedback based on pre-prepared models provided by UPM**
Evaluation instruments:	**Continuous documentation of the activity by log files, collection of ideas; communication via Skype**

The OBF evaluation at 24.08.2009 was run during a Skype conference for direct instruction and feedback and consisted of two phases:

- **During the first evaluation phase the learner models consisted of different versions of the reference model, created by making specific modifications over some terms to cover all the types of feedback. Given the high similarity between the two models to compare, they should be easy to understand and should thus be easy to evaluate as well. This part of the experiment allowed evaluators to familiarize themselves with the tool and the evaluation procedure.**

- **In the second evaluation phase the learner models differed in more details from the reference model, it was expected, that more differences will be generated and evaluation will take more time and effort.**

6.1. Expectations from this setting

The setup of the test situation was supposed to allow for

- **Testing the correctness of the results of the OBF.**

- **Evaluating how useful the OBF is during the learning process and how it can help the students to improve the quality of their models .**

- **The collection of ideas to improve usefulness of the OBF.**

6.2. Data analysis BOKU III

UPM provided lists with scientific terms that were grounded by DBpedia to the partners, to evaluate the reliability of the DBpedia groundings. The files with the expert evaluations of the DBpedia groundings were sent back to UPM for further analysis.

Furthermore the log files of the OBF distance experiment were sent to UPM for further analysis and a list of ideas for improving the OBF from an educational point of view was put together and directly sent to UPM.

6.3. Results BOKU III

The quantitative results collected by the log files during the evaluations were delivered to UPM. Here we present the ideas for improving the OBF identified and collected during the evaluation.

1) **Currently the OBF window does not offer a clear guidance, of what a learner can expect from this tool. As the representation of differences and similarities is still not sufficient, its hard for the learner to see the benefit of using this tool. Therefore, we suggest, that having a better guidance and more structured window with clear headers, what a learner can get when working with the OBF function would be very helpful (e.g. *'look for similarities by clicking this and this' – 'look at the groundings'*; *'look at entities and quantities - what is different to your model*?', etc.)**
2) **Groundings should be better represented as a text not only as url.**
3) **The model description taken from the metadata of the model could be also very useful to see how the models relate**
4) **Better feedback on similarities in structure and vocabulary in addition to mappings of terminology.**
5) **Full list of model compartments of both models as option (because of potentially large lists, there should be a possibility to hide-standard should be only different, which could be enrolled).**
6) **Configurations and their related entities would give a very important info on the general structure.**
7) **It is very important to know how to judge sentences like: *'The Quantity Women_access_to_job_rate in the reference model is equivalent to the Quantity Women_access_to_education_rate in the user model. The elements differ on label.'* What does that mean for the learner? A well developed guidance gives at the first glance understanding what is meant by each option to be clicked. Here is some potential to be clearer.**
8) **Finally this means a clear and insightful guidance trough the whole process of model comparison would be really helpful. By now the learner cannot learn very much from the feedback – a more advanced and learner oriented feedback window is needed.**

7. Summary, conclusion and future prospects

The evaluations of the prototype of the DL software primarily aimed at providing information on

- **Usability of the software and problems learners encountered when working with the software supporting *'Basic help', 'Diagnostic feedback', 'Recommendations', ' Bug repair'*, etc.**
- **The appreciation of the software by students and their impressions and potential ideas for increasing usability,**
- **Changes in knowledge and knowledge structure influenced by the activities with DL.**

In the following section the main results of the evaluation of the prototype of the DL software are summarized.

7.1. Main Results

7.1.1. The behaviour of students differed per LS at i:HTL evaluation

- **As students were not familiar with the ecological topic, they spent a lot of time in LS1 for picking up information (asking teacher/student, looking in the internet, in additional material).**
- **Conversation (with student especially in LS2 and with teacher especially in LS4) increased from LS1 to LS4.**
- **In LS2 students worked very self-dependent on their models which implicated more time for thinking.**
- **LS 2 also allowed students easily to translate their mental model into a dynamic model instead of having to invest too much effort in identifying relevant variables and relationships between them.**
    - ***It can be considered as being very important to free up capacity for mastering modelling techniques during early stages of learning to model (Hogan & Thomas 2001), which is supported by the finding of Sins et al. (2005) that students had difficulties with comprehending a system dynamics modelling formalism (in this case PowerSim), even after they received an instruction.***
- **In LS4 they spent almost half of the time for discussing their modelling activities, mainly with the teacher.**
    - ***This can be seen as an effect of the advanced possibilities available in LS4 to build models.***

7.1.2. Motivation questionnaires

In general the feedback to the DL approach was rated from neutral to very positive, very interesting and very easy etc. and never negative which indicates the general acceptance of the whole DL approach by students. The selected answers shown below should highlight the most positive and most critical ratings.

7.1.2.1 Selected answers at i:HTL and BOKU

- **Very high agreement, that the software could be applied to other fields of science –** ***this indicates that they grabbed the modelling principles and were able to apply them mentally to other fields of science.***
- **Students liked the model based learning activity as a whole very much –** ***indicating that learning with DL differs from common ways of learning activities in school and represents an engaging and motivating way of learning.***
- **Using the software was not experienced as providing a very comfortable way of learning –** ***this indicates, that modelling is a challenging task, and modelling comfort can be increased e.g. by help functions and other motivating features.***
- **Using the software was experienced as not very motivating, especially at BOKU –** ***indicating the need for the planned motivating features like teachable agents, grounding by DBpedia or OBF.***
- **The whole modelling approach was not considered as being very easy –** ***indicating the need to make it more self explaining e.g. by help functions.***
- **Students at iHTL rated their understanding of the system after the activities with DL as very high –** ***this can be assigned to the lack of knowledge about the topic the students had before*****.**
- **The statement** ***„modelling with the software allowed me to understand the complexity of the human-environment system“*** **was rated as being ‚very correct‘ by i:HTL students –** ***which can be also assigned to the lack of knowledge about the topic the students had before*****.**
- **In contrast, at BOKU, the answers indicated that using the DL software did not increase the understanding of the system much, as the students were already very well informed on the topic before.**

7.1.3. Pre-and post-tests

In general the use of DL in classrooms has led to significant change in factual knowledge and knowledge structure even after short contact with the software (e.g. one afternoon at BOKU I evaluation). Below the main findings of the pre-and post test analyses are summarized.

- **A significant decrease in words and concepts when students were experienced and a significant increase in words and concepts used when students were less informed**
    - ***Conclusions:***
        - ***Already informed students get more focused, the others significantly learn.***
        - ***"If factual knowledge increases, number of words and concepts used to describe a phenomenon might increase (new factual learning) - if causality, structure and focus increase words and concepts used to describe a phenomenon might decrease (structural and causal learning) but the use of causal notations (graphical and verbal) might increase.***
- **Significant increase in the use of causal relations, especially graphical ones at BOKU and verbal expressions at i:HTL**
    - ***Conclusions:***
        - ***It might be that more experienced students at university level are more likely to use graphical representations, and younger students at a secondary high school level rely still more on using causal vocabulary.***

    - ***The increased use of written causal words instead of using graphical means at younger students might be a result of their prior learning, why learning to use graphical and more abstracted representations to communicate knowledge might be a mid- to long term goal of education***
    - ***In short term an increased use of causal verbal expressions and increased knowledge on concepts can be expected at younger/inexperienced students***

- **Significant increase of the abstraction level of representing knowledge at i:HTL and BOKU**
  - ***Conclusion:***
    - ***Abstraction allows for integrating more knowledge in a more structured way why it is considered to be a valuable result***

- **Wrong causal notations were less abundant in post tests**
  - ***Conclusion:***
    - ***This can be interpreted as sign that students pay more attention to causal expressions after using DL.***

7.2. Plans for the evaluation of the final software

Future evaluations will additionally focus on the effects of the VC and the OBF on learning and motivation. Designs for an appropriate evaluation of the directed and guided meta-cognitive feedback provided by DL and the development of self regulated learning paths need to be developed for the evaluation of the final software release.

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9. Online Sources

http://www.ihtl.at (International HTL Bad Radkersburg, Austria)

http://www.transana.org (Transana, Qualitative analysis software for video and audio data)

http://www.atlasti.com (ATLAS.ti, The Knowledge Workbench)

10. Appendix

10.1. Evaluation methods

The analysis of the video-monitoring files gathered during the detailed evaluation of the modelling activity at the i:HTL, and the evaluation of the pre- and post tests in both evaluation situations required specific methods and tools for a structured analysis and interpretation. Basically the videos were transcribed and qualitatively coded and analysed with regard to the modelling activity, the social behaviour and the questions of the students and answers provided by the evaluator with the aim to identify possibilities to improve the *'Basic help'*, *'Diagnostic feedback'*, *'Recommendations'*, *'Bug repair'* and related features.

The pre-post test evaluations were coded and analysed with regard to the changes in the structure and content of the cognitive maps of the students after having worked with the DL software following the *'Grounded Theory'* approach.

10.2. Analysis tools

For the analyses of the evaluation material mainly two software programs were used. *Atlas.ti*® was a useful help for structuring and organising data from pre- and post-tests of the two evaluation sessions at the i:HTL and at BOKU university. For analysing the video documentation of the i:HTL session *Transana*™ was used, another qualitative analysing software. The data gathered were further processed using *Microsoft Excel*. For the statistical analysis, the *SPSS 18* package was used.

10.2.1. Atlas.ti

Atlas.ti (version 6.0) is a workbench for qualitative analysis of textual, graphical, audio or video data (Muhr 2004). With its variety of tools it can help to organise unstructured data, especially those, that can not be analyzed easily and directly by formal statistical methods. It helps to detect complex coherences, structures or connexions hidden in the data.

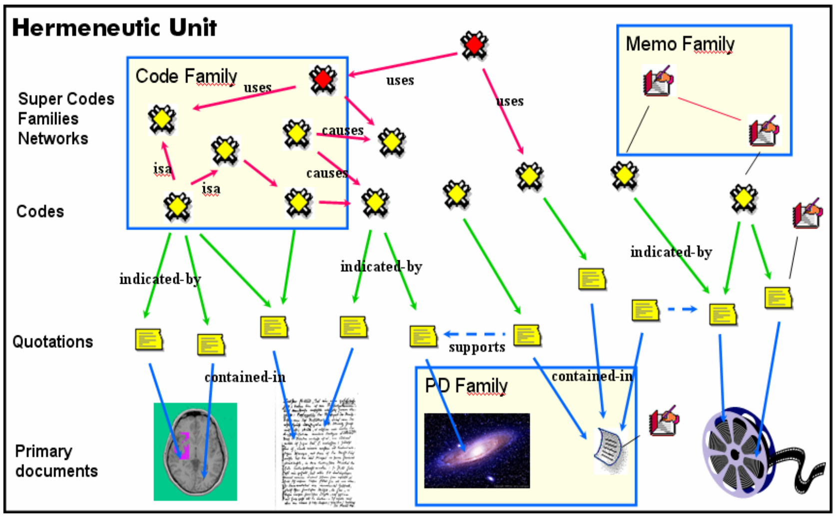

Figure 10.1: The hierarchy of objects inside a Heuristic Unit in Atlas.ti. (Muhr 2004).

Using the software, firstly you create a so called *'Hermeneutic Unit'* (HU), which provides the data structures for each *Atlas.ti* project.

All relevant data you need for a project is part of the HU and its paths and sources are stored in the HU. So the user has to handle just a single entity which bundles the whole network of data and links.

The lowest level of the HU contains the *'Primary Documents'* (PD) that represent the textual, graphical, audio, and/or video materials that you wish to interpret (see Figure Fehler! Verweisquelle konnte nicht gefunden werden.). The content of PDs is usually stored in data files on your computer so the HU only stores the paths to these files.

In a next step, the user marks segments from a PD which are interesting or important for the analysis. These quotations can again be linked with *'Codes'* or *'Memos'*.

'Codes' are used as classification devices at different levels of abstraction in order to create sets of related information units for the purpose of comparison by classifying an often large number of data units.

A *'Memo'* is similar to a *'Code'*, but here it is possible to record longer passages of text to capture thoughts, ideas or data units. *'Memos'* can be linked with each element of the Heuristic Unit.

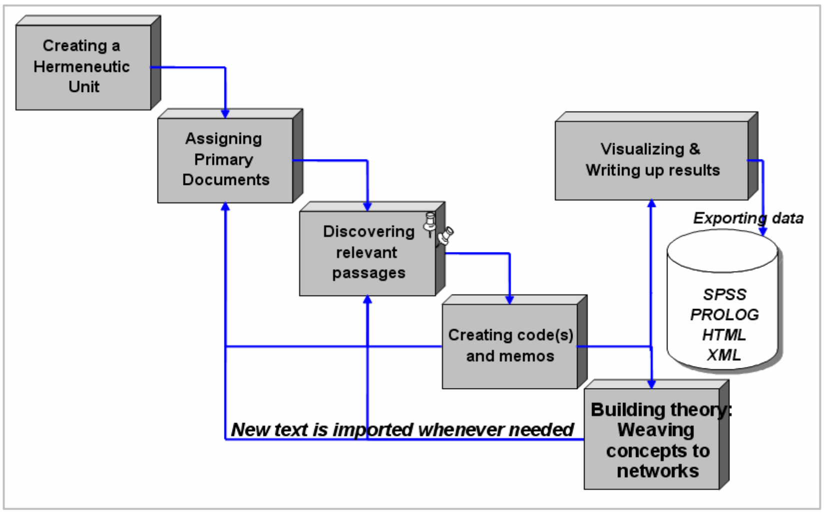

Figure 10.2: The Atlas.ti workflow (Muhr, 2004).

Furthermore, *PDs*, *'Memos'* or 'Codes' can be connected to clusters, so called families, for easier handling the groups of data. Using the *'Network View'* it is possible to visualize the complex structure of links and relations between the data elements and to create a visual diagram, which can be put out as a graphic file.

Finally, the results can be exported, visualized and are written up, and based on the gathered data and understanding following the GT approach, a theory about the issue monitored can be developed (Figure 10.2.)

10.2.2. Transana

For the qualitative analysis of the video tapes, the free and open source Software *Transana 2.42* released on September 2, 2010 was used. *Transana* is a computer program that allows researchers transcribing and analysing large collections of video and audio data.

The transcription in *Transana* is a facilitated manual process, where you can identify and easily access the analytically significant portions of the video data. You can manage large video collections by organising shorter video clips into meaningful categories, as a mechanism for developing and expanding the theoretical understanding of what the video shows.

First of all, a database has to be created, where all content (video clips, wave-files, transcriptions, codes, memos etc.) is stored.

Then the video has to be imported, and a wave file has to be created. The wave file represents the basis for a time sensitive coding of aspects. The output then allows analysis of the temporal aspects of the coded activities (Figure 10.3).

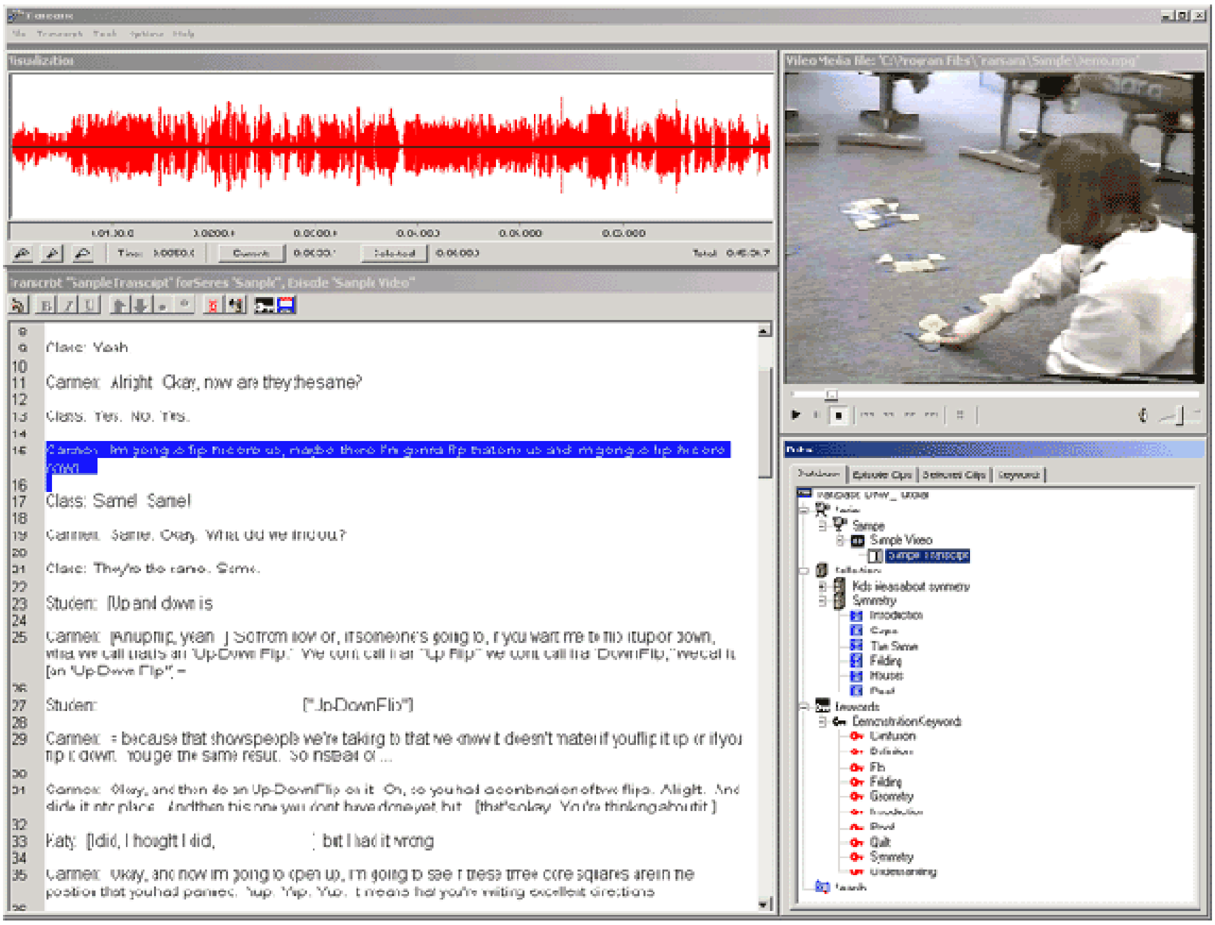

Figure 10.3: Screenshot of a transcript using *Transana.*

10.3. Questionnaires

10.3.1. I:HTL Pre-test questionnaire

Evaluation of DynaLearn Beta 6.02 Software
Date: 19.04.-22.04.2010
Place: IHTL Bad Radkersburg, AT
Dynalearn partner: BOKU
Responsible person: Andreas Zitek

Test questionnaire

Please describe all questions in as much detail as possible!

1.	Have you ever used modelling software before? If yes, which one and for which purpose?

2.	Do you know any environmental problems caused by energy consumption? *Please provide a written text or some graphical representation e.g. a concept map.*

Figure 10.4: Page 1 of the i:HTL pre-test questionnaire.

Evaluation of DynaLearn Beta 6.02 Software
Date: 19.04.-22.04.2010
Place: IHTL Bad Radkersburg, AT
Dynalearn partner: BOKU
Responsible person: Andreas Zitek

3.	What are the environmental effects of a hydropower plant? *Please provide a text and one diagram showing one or some causal relationships between some variables.*
4.	Is the production of wind energy use linked to hydropower production, if yes please describe how? *What are the effects of increased production of wind energy on hydropower use? Please provide a short text or graphical representation e.g. small concept map or causal diagram.*

Figure 10.5: Page 2 of the i:HTL pre-test questionnaire.

Evaluation of DynaLearn Beta 6.02 Software
Date: 19.04.-22.04.2010
Place: IHTL Bad Radkersburg, AT
Dynalearn partner: BOKU
Responsible person: Andreas Zitek

5.	What is the principle of a so called "Pumpspeicherkraftwerk"? Why are they increasingly built? *What are the causes for their increased need and construction? Please provide a short text or drawing e.g. a concept map or causal diagram.*
6.	How are fish populations affected by hydropower plants? *What are the main causes and effects and how do they act on fish populations? Please provide some small examples, written text or a type of graphical representation. Additionally please give a simple (causal and graphical) representation of which general factors drive a population.*

Figure 10.6: Page 3 of the i:HTL pre-test questionnaire.

Evaluation of DynaLearn Beta 6.02 Software
Date: 19.04.-22.04.2010
Place: IHTL Bad Radkersburg, AT
Dynalearn partner: BOKU
Responsible person: Andreas Zitek

7.	What are potential ways to reduce energy consumption and therefore the negative effects on the environment? *Please provide two scenarios of different ways of reaching this target and show it in a concept map or causal diagram.*

THANK YOU!!!

Figure 10.7: Page 4 of the i:HTL pre-test questionnaire.

10.3.2. i:HTL Post-test questionnaire

Evaluation of DynaLearn Beta 6.02 Software
Date: 19.04.-22.04.2010
Place: IHTL Bad Radkersburg, AT
Dynalearn partner: BOKU
Responsible person: Andreas Zitek

Test questionnaire

Please describe all questions in as much detail as possible!

1.	Do you know any environmental problems caused by energy consumption? *Please provide a written text or some graphical representation e.g. a concept map.*

Figure 10.8: Page 1 of the i:HTL post-test questionnaire.

Evaluation of DynaLearn Beta 6.02 Software
Date: 19.04.-22.04.2010
Place: IHTL Bad Radkersburg, AT
Dynalearn partner: BOKU
Responsible person: Andreas Zitek

2.	What are the environmental effects of a hydropower plant? *Please provide a text and one diagram showing one or some causal relationships between some variables.*
3.	Is the production of wind energy use linked to hydropower production, if yes please describe how? *What are the effects of increased production of wind energy on hydropower use? Please provide a short text or graphical representation e.g. small concept map or causal diagram.*

Figure 10.9: Page 2 of the i:HTL post-test questionnaire.

Evaluation of DynaLearn Beta 6.02 Software
Date: 19.04.-22.04.2010
Place: IHTL Bad Radkersburg, AT
Dynalearn partner: BOKU
Responsible person: Andreas Zitek

4.	What is the principle of a so called "Pumpspeicherkraftwerk"? Why are they increasingly built? *What are the causes for their increased need and construction? Please provide a short text or drawing e.g. a concept map or causal diagram.*
5.	How are fish populations affected by hydropower plants? *What are the main causes and effects and how do they act on fish populations? Please provide some small examples, written text or a type of graphical representation. Additionally please give a simple (causal and graphical) representation of which general factors drive a population.*

Figure 10.10: Page 3 of the i:HTL post-test questionnaire.

Evaluation of DynaLearn Beta 6.02 Software
Date: 19.04.-22.04.2010
Place: IHTL Bad Radkersburg, AT
Dynalearn partner: BOKU
Responsible person: Andreas Zitek

6.	What are potential ways to reduce energy consumption and therefore the negative effects on the environment? *Please provide two scenarios of different ways of reaching this target and show it in a concept map or causal diagram.*

THANK YOU!!!

Figure 10.11: Page 4 of the i:HTL post-test questionnaire.

10.3.3. i:HTL Motivation questionnaire

Evaluation of DynaLearn Beta 6.04 Software
Date: 19.04. - 22.04.2010
Place: IHTL Bad Radkersburg, AT
Dynalearn partner: BOKU
Responsible persons: Andreas Zitek

Attitudes/motivation questionnaire

1.	What is your **general opinion about the course and learning activity** we had together? **Very bad** 1 2 3 4 5 6 7 **Very good**
2.	What is your general **opinion about the modelling approach** you used during this learning activity? **Very difficult** 1 2 3 4 5 6 7 **Very easy**
3.	How did you experiencing the work with the DynaLearn software – boring or interesting? **Very boring** 1 2 3 4 5 6 7 **Very interesting**
4.	How do you evaluate your understanding of the problem between wind energy, hydropower and fish after exploring the topic in DynaLearn? **Now I am very much confused** 1 2 3 4 5 6 7 **I understand much better now**
5.	How do you evaluate the importance of building models in different specific use-levels of DynaLearn for your understanding? **Very little importance** 1 2 3 4 5 6 7 **Very important**
6.	Which use level did contribute most your understanding of the concepts represented in the model? **Concept map (UL 1)** □ **Basic causal model (UL 2)** □ **Causal differentiation model (UL 4)** □
7.	Which use level did you like most? **Concept map (UL 1)** □ **Basic causal model (UL 2)** □ **Causal differentiation model (UL 4)** □ Why?
8.	Modelling with the software enabled me to better understand the complexity of the human-energy-environment system. **Incorrect** 1 2 3 4 5 6 7 **Correct**
9.	Modelling with the software opened up new ways of thinking about the system. **Incorrect** 1 2 3 4 5 6 7 **Correct**
10.	The software and its features motivated me to try to build the model. **Did not motivate** 1 2 3 4 5 6 7 **Motivated very much**
11.	Using the software provides a very comfortable way of learning. **I fully disagree** 1 2 3 4 5 6 7 **I fully agree**

Questionnaire developed by BOKU, FUB, TAU & UVA

Figure 10.12: Page 1 of the i:HTL motivation questionnaire.

Evaluation of DynaLearn Beta 6.04 Software
Date: 19.04. - 22.04.2010
Place: IHTL Bad Radkersburg, AT
Dynalearn partner: BOKU
Responsible persons: Andreas Zitek

12.	Modelling with the software could also be used in other learning topics. **No** 1 2 3 4 5 6 7 **Yes**
13.	What did you like?
14.	What did you dislike?
15.	Any ideas for improving the software?
16.	Further (general) comments?

THANK YOU VERY MUCH!!!

Questionnaire developed by BOKU, FUB, TAU & UVA

Figure 10.13: Page 2 of the i:HTL motivation questionnaire.

10.3.4. Age distribution and distribution of educational degrees at BOKU I evaluation

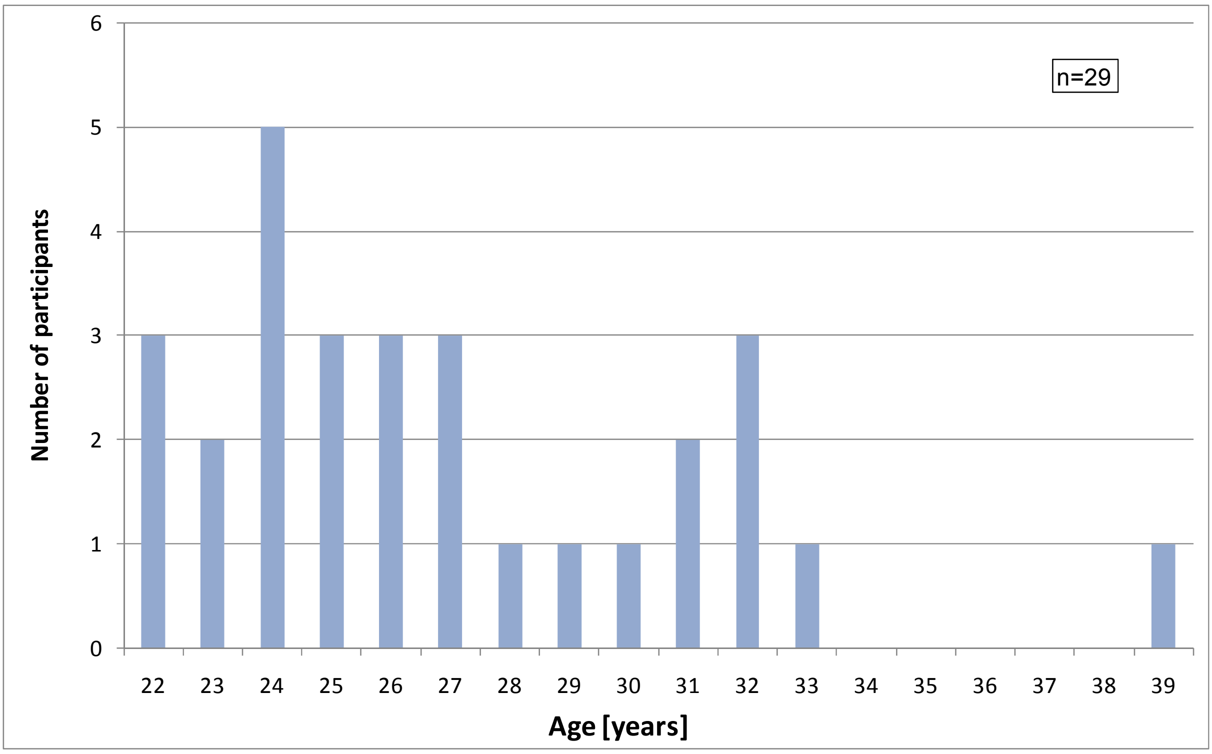

Figure 10.14: Age distribution of students at the BOKU I university evaluation.

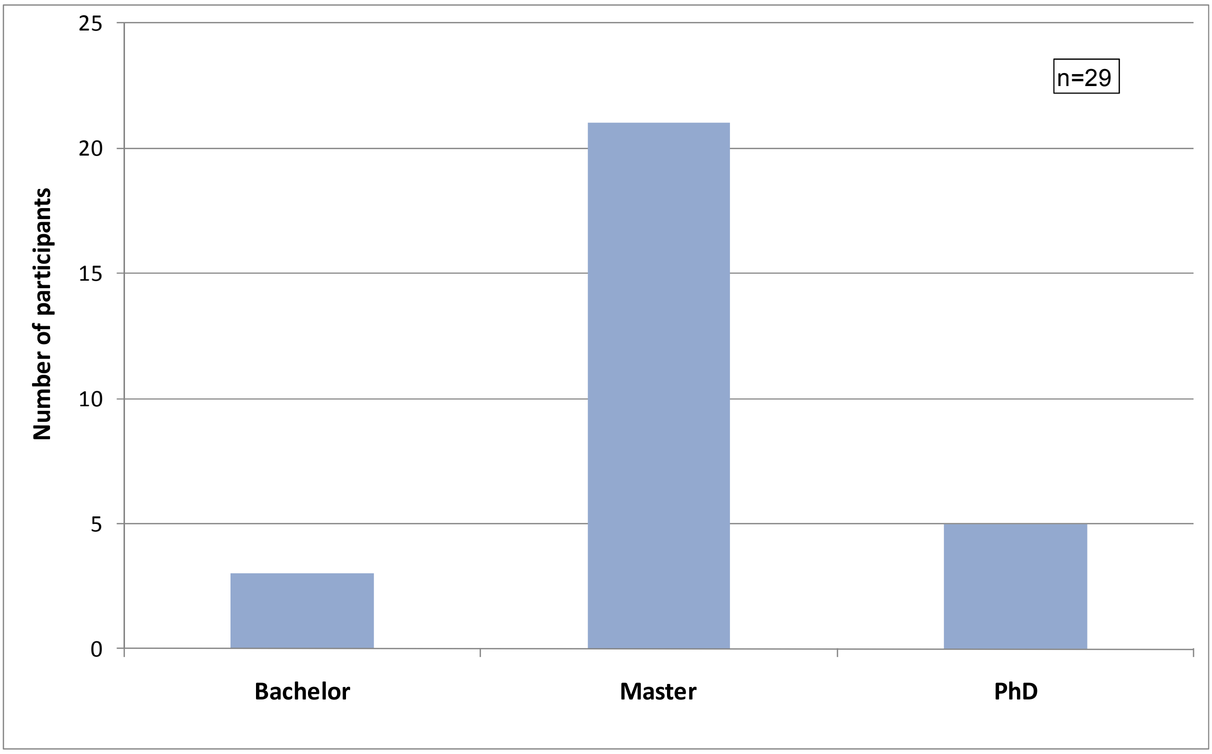

Figure 10.15: Distribution of educational degrees at the BOKU I university evaluation.

10.3.5. BOKU I Pre- and post-test

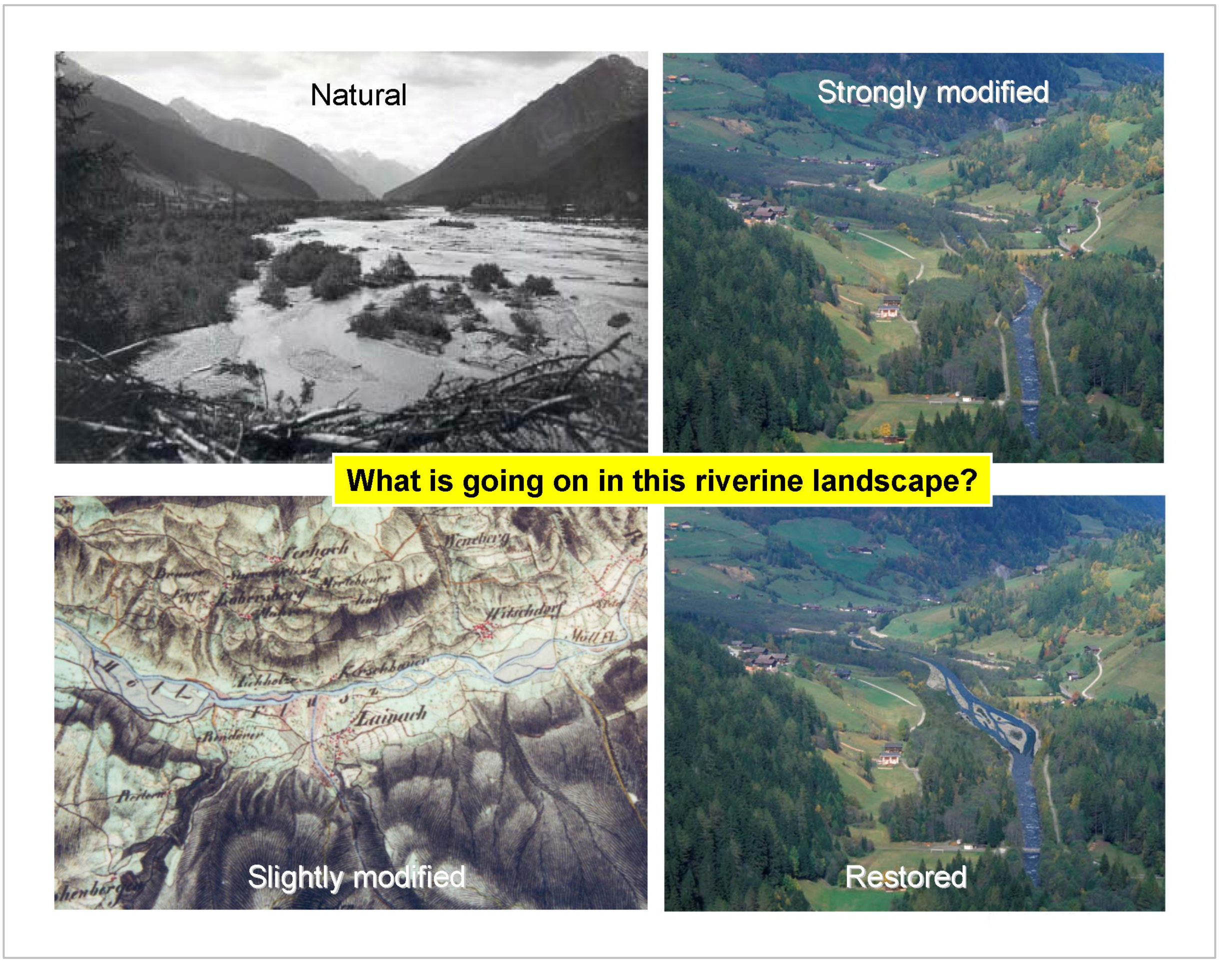

Figure 10.16: Pre- and post-test of the BOKU evaluation lessons.

10.3.6. BOKU I motivation questionnaire

Evaluation of DynaLearn Beta 6.04 Software
Date: 19.5.2010
Place: BOKU, Hydrobiology
Dynalearn partner: BOKU
Responsible person: Susanne Muhar, Andreas Zitek

Attitudes/motivation questionnaire

1.	What is your general opinion about the lesson and learning activity we had together? (Very bad) **1 2 3 4 5 6 7** (Very good)
2.	What is your general opinion about the modelling approach you used to develop this educational activity? (Very difficult) **1 2 3 4 5 6 7** (Very easy)
3.	How did you experiencing the work with the DynaLearn software – boring or interesting? (Very boring) **1 2 3 4 5 6 7** (Very interesting)
4.	How do you evaluate your understanding of the problem of channelization and its effects on riverine landscapes after exploring the topic in DynaLearn? (Now I am very much confused) **1 2 3 4 5 6 7** (I understand much better now)
5.	How do you evaluate the importance of building models in different specific use-level of DynaLearn for your understanding? (Very little importance) **1 2 3 4 5 6 7** (Very important)
6.	Which use level did contribute most to your understanding of the concepts represented in the model? **Concept map (UL 1)** □ **Basic causal model (UL 2)** □ **Causal differentiation model (UL 4)** □
7.	Modelling with the software enabled me to better understand human-river interactions. (Incorrect) **1 2 3 4 5 6 7** (Correct)
8.	Modelling with the software opened up new ways of thinking about the system. (Incorrect) **1 2 3 4 5 6 7** (Correct)
9.	The software and its features motivated me to try to build the model. (Did not motivate) **1 2 3 4 5 6 7** (Motivated very much)
10.	Using the software provides a very comfortable way of learning. (I fully disagree) **1 2 3 4 5 6 7** (I fully agree)
11.	Modelling with the software could also be used in other learning topics. (No) **1 2 3 4 5 6 7** (Yes)

Questionnaire developed by BOKU, FUB, TAU & UVA Page 1 of 2

Figure 10.17: Page 1 of the BOKU I motivation questionnaire.

Evaluation of DynaLearn Beta 6.04 Software
Date: 19.5.2010
Place: BOKU, Hydrobiology
Dynalearn partner: BOKU
Responsible person: Susanne Muhar, Andreas Zitek

12.	What did you like?
13.	What did you dislike?
14.	Any ideas for improving the software?
15.	Further comments?

THANK YOU VERY MUCH!!!

Questionnaire developed by BOKU, FUB, TAU & UVA Page 2 of 2

Figure 10.18: Page 2 of the BOKU I motivation questionnaire.

10.3.7. BOKU I exam questionnaire

EXAM:

812.330 Selected Topics of aquatic ecology and river management

Name:

Studienkennzahl:	Matrikelnummer:

1) River Danube: Characterisation of a pristine situation and the up-to-date conditions for fish populations.
2) Give two examples of types of fish passes for restoring continuum disruptions:
3) Danube hydropower impoundment “KW Wien/Freudenau”: Implemented “ecological improvements” – why, and in which areas have they been constructed?
4) List some important human pressures impairing the natural hydro-morphological conditions of riverine landscapes.
5) **What are the effects of river channelization*? (Question related to the topic explored with DL).***
6) Definition of saprobity.
7) Give a definition of “ecosystem services”.
8) Give four examples for biotic choriotopes in rivers
9) Give (a) one example for long and (b) one for medium distance migrants for fish species:
10) What is the meaning of "multi-dimensionality of riverine landscapes"?

Figure 10.19: BOKU I final exam questionnaire.

10.4. Results

10.4.1. Results of i:HTL *Atlas.ti* analysis

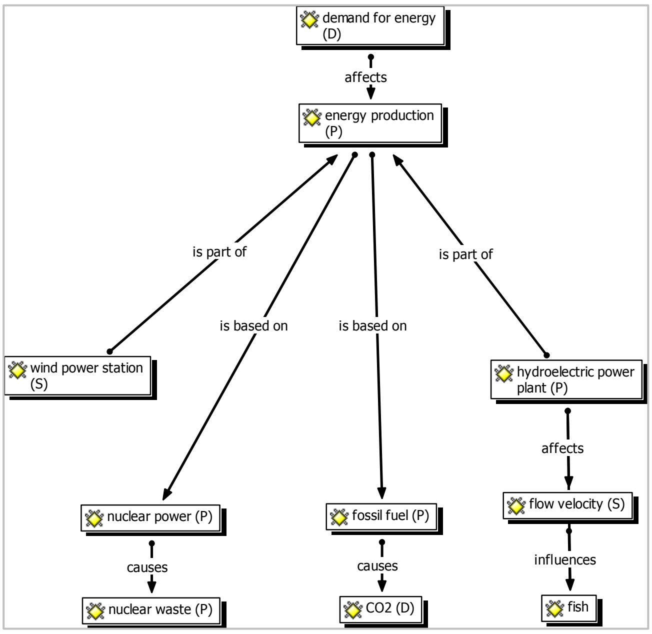

Figure 10.20: Network View of the linked keywords in the pre-test of i:HTL student 1.

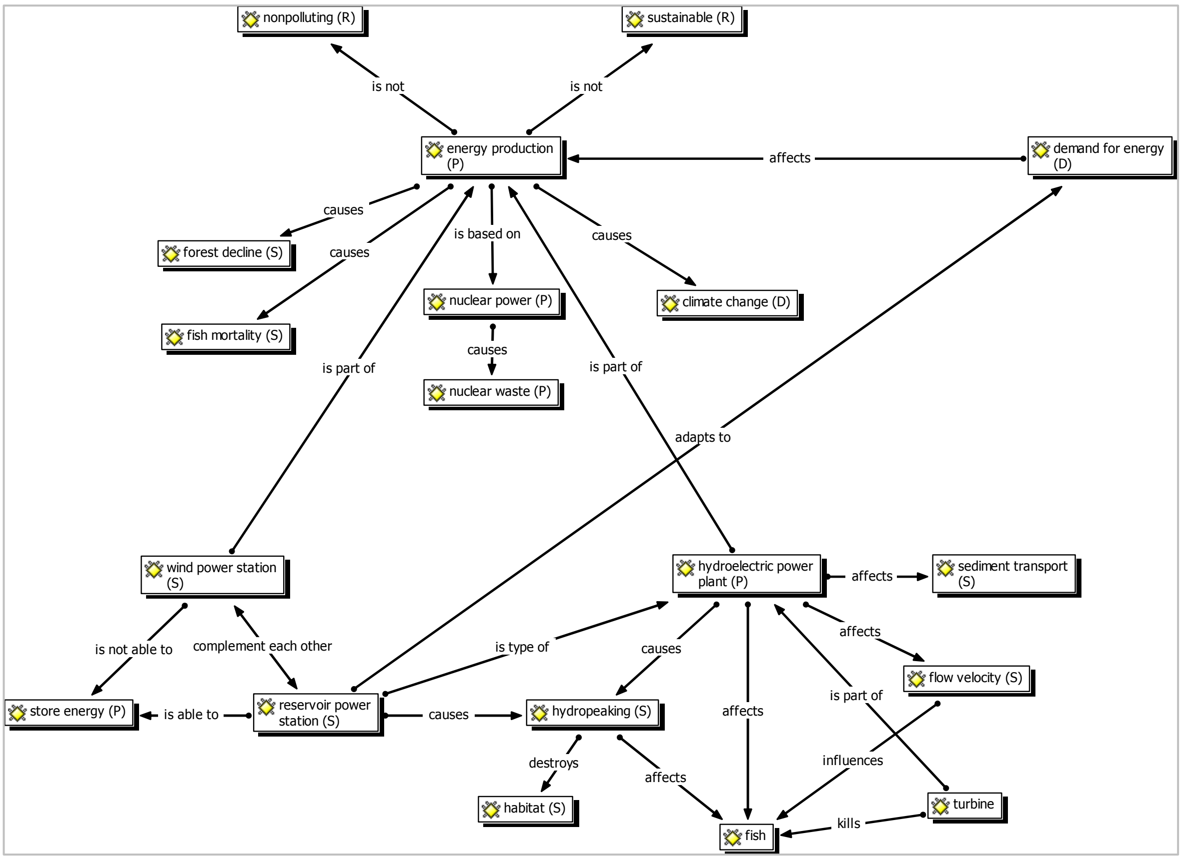

Figure 10.21: Network View of the linked keywords in the post-test of i:HTL student 1.

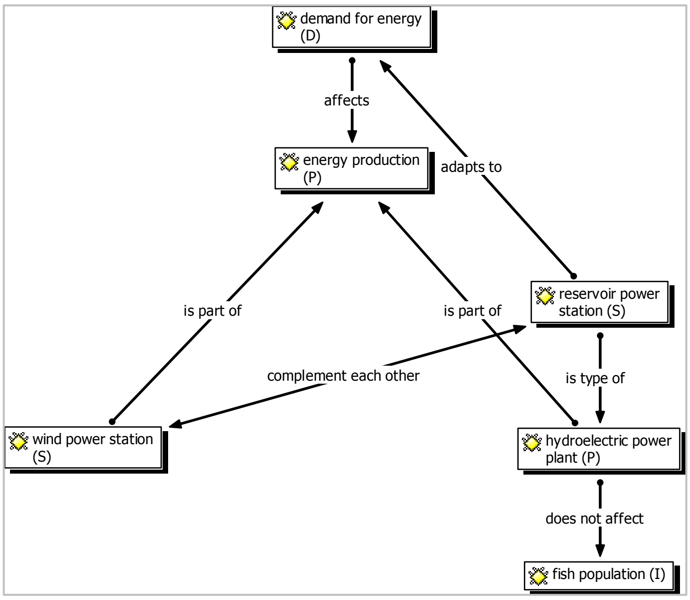

Figure 10.22: Network View of the linked keywords in the pre-test of i:HTL student 2.

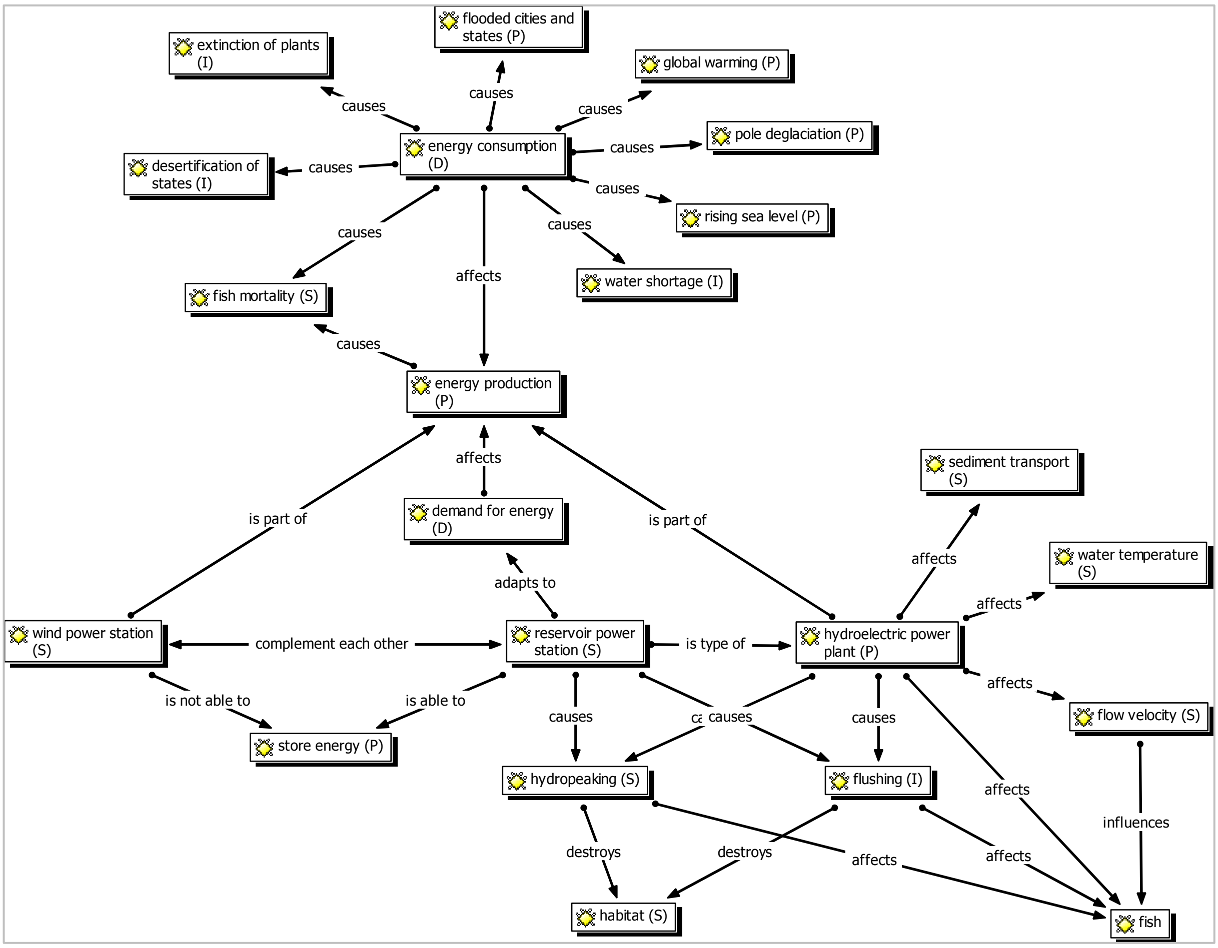

Figure 10.23: Network View of the linked keywords in the post-test of i:HTL student 2.

10.4.2. Selected results of BOKU I *Atlas.ti* analysis

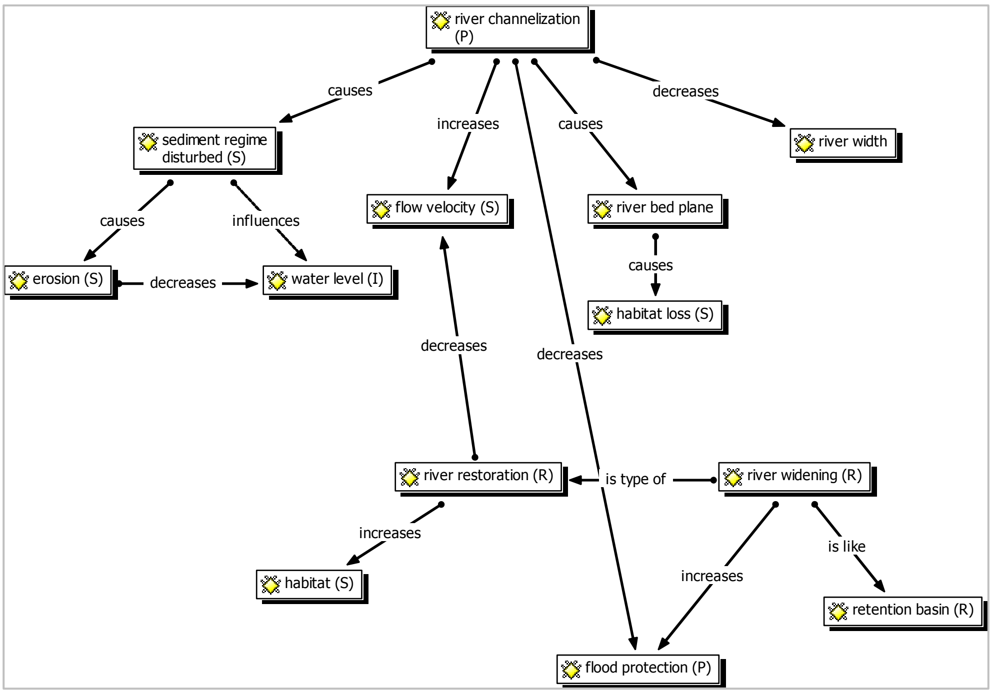

Figure 10.24: Network View of the linked keywords in the pre-test of BOKU I student 1.

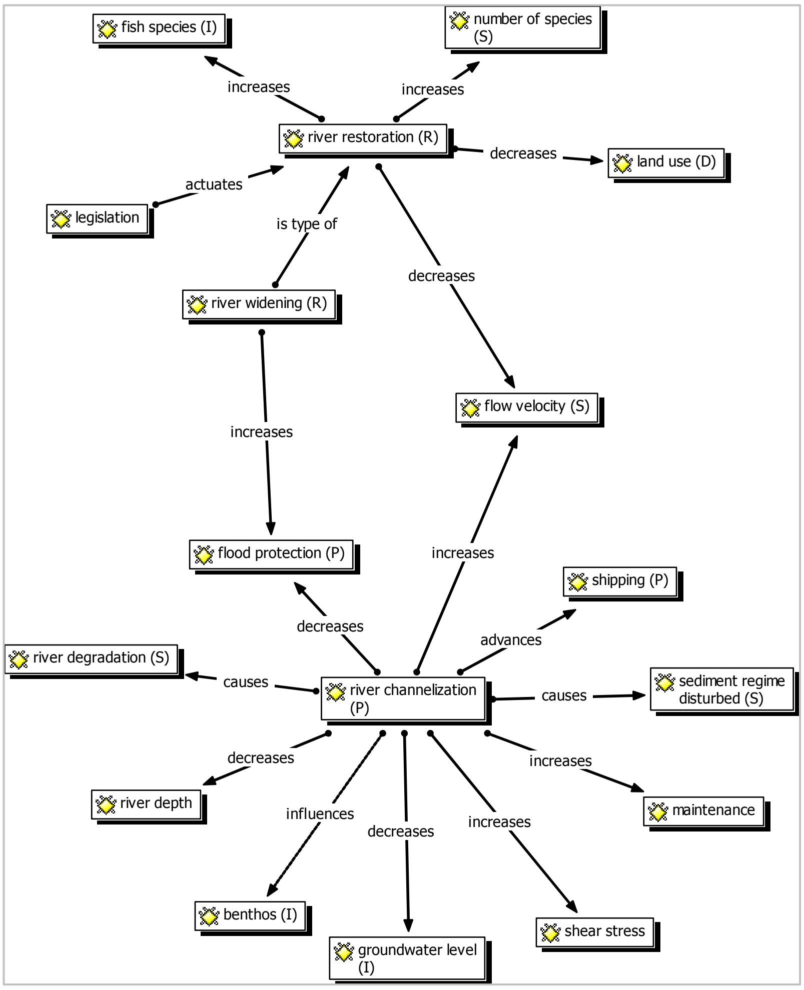

Figure 10.25: Network View of the linked keywords in the post-test of BOKU I student 1.

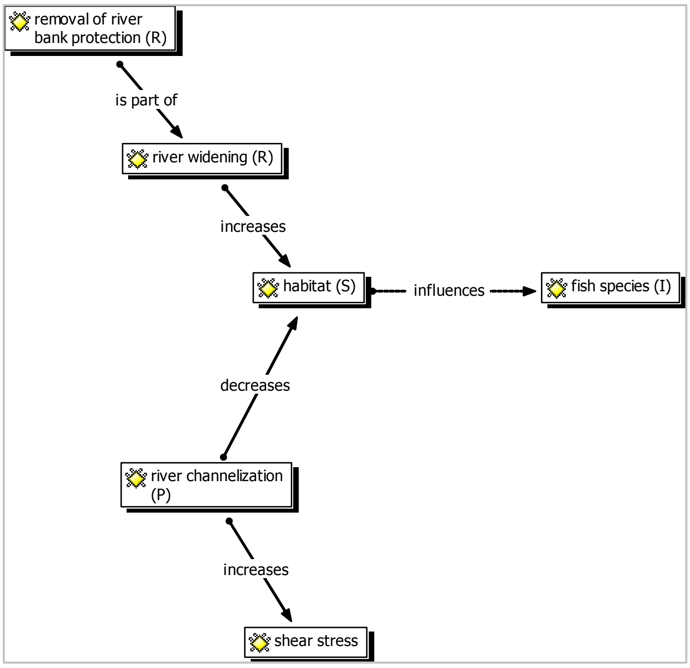

Figure 10.26: Network View of the linked keywords in the pre-test of BOKU I student 2.

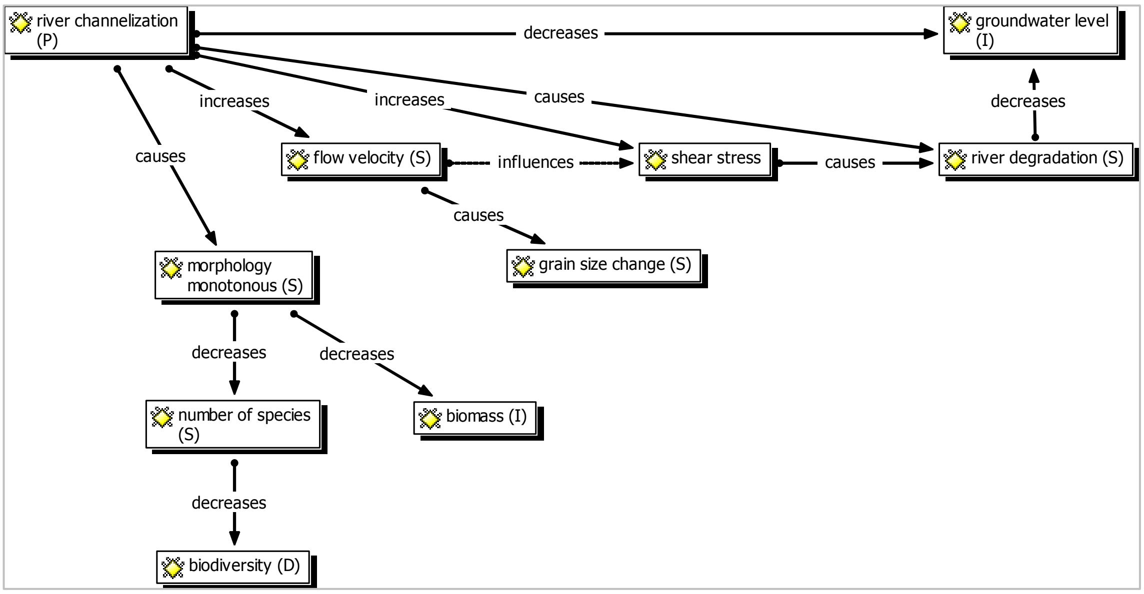

Figure 10.27: Network View of the linked keywords in the post-test of BOKU I student 2.

10.4.3. Results of the motivation questionnaire

10.4.3.1. Results of the i:HTL motivation questionnaire

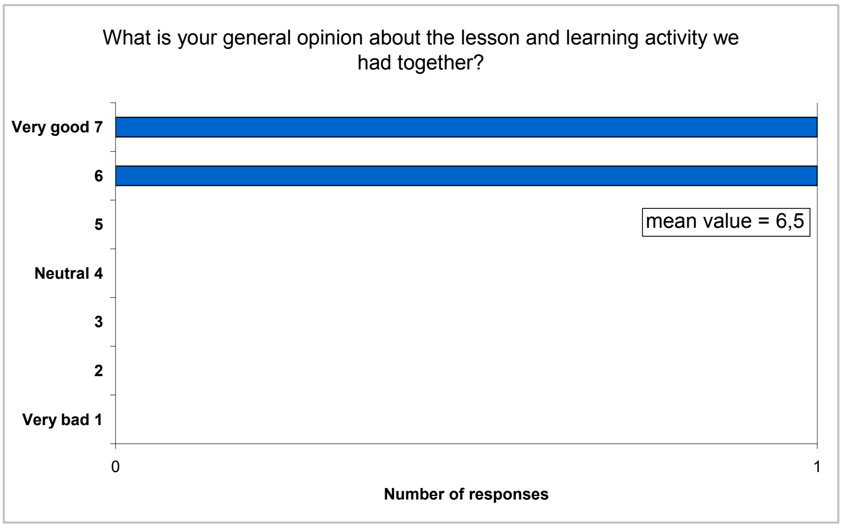

Figure 10.28: Results of question 1 of the i:HTL motivation questionnaire.

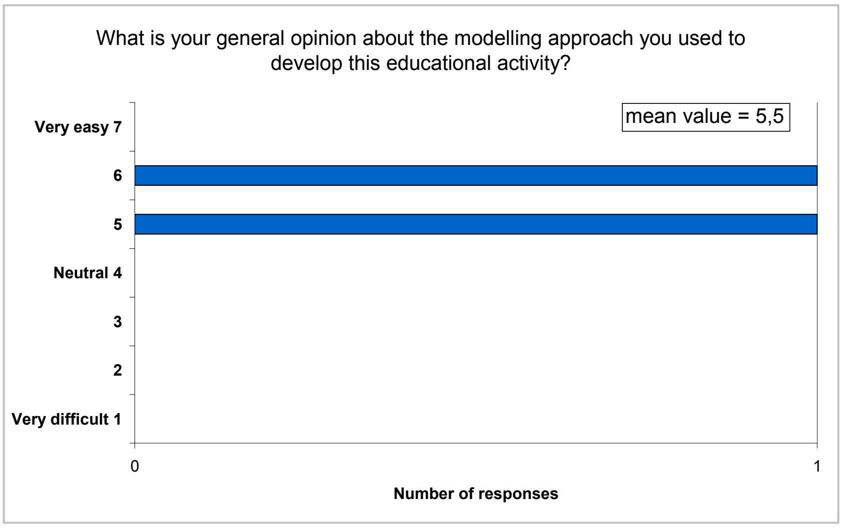

Figure 10.29: Results of question 2 of the i:HTL motivation questionnaire.

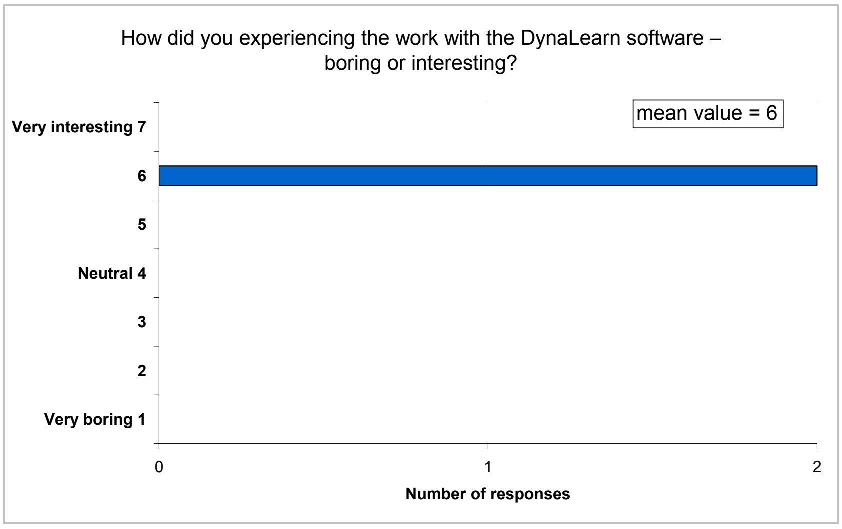

Figure 10.30: Results of question 3 of the i:HTL motivation questionnaire.

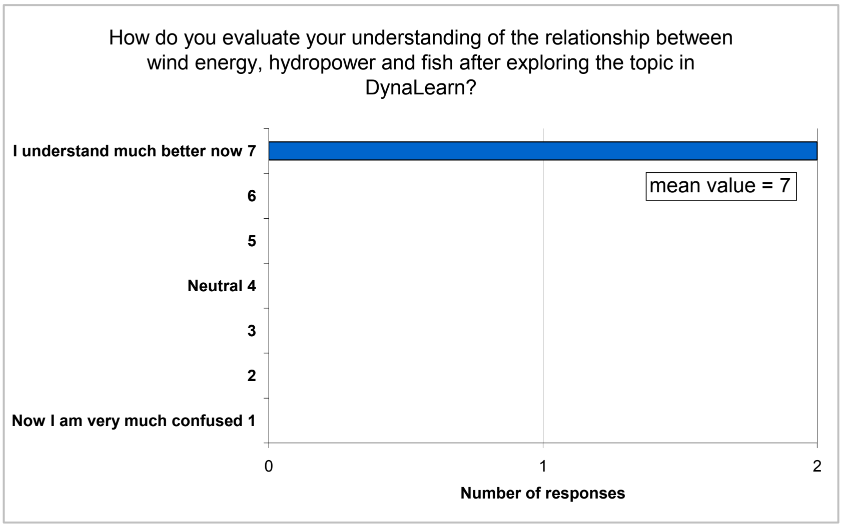

Figure 10.31: Results of question 4 of the i:HTL motivation questionnaire.

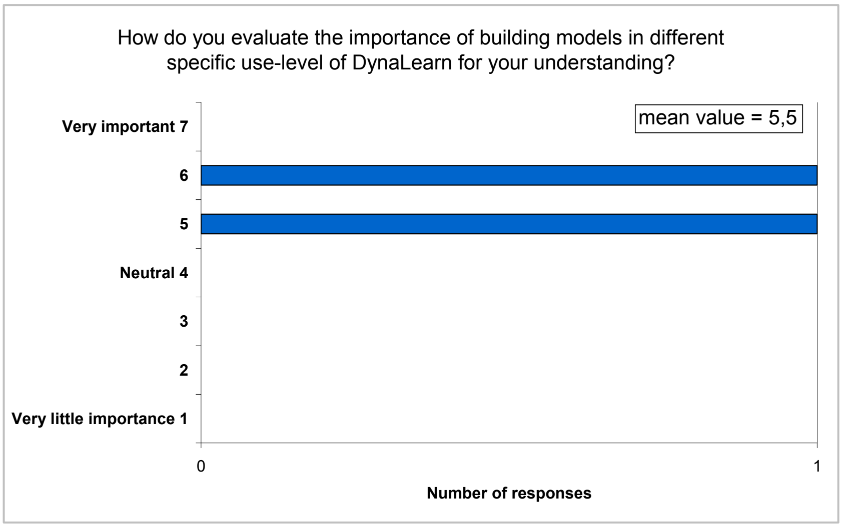

Figure 10.32: Results of question 5 of the i:HTL motivation questionnaire.

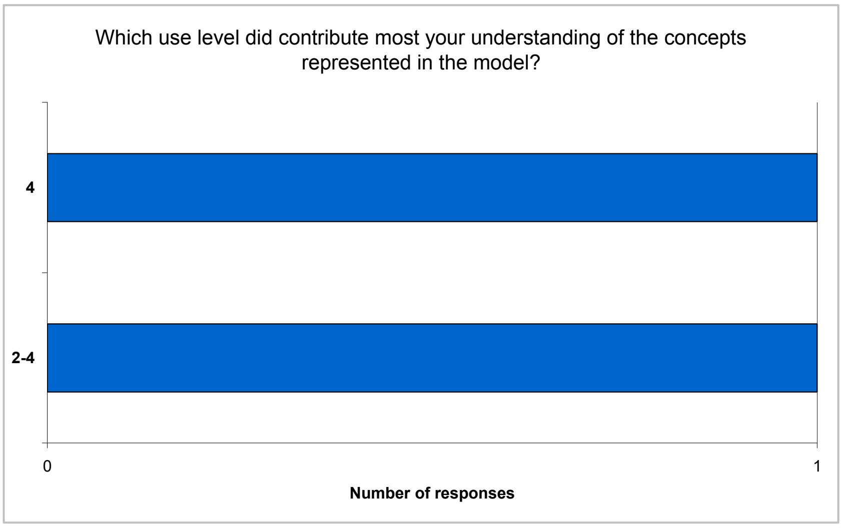

Figure 10.33: Results of question 6 of the i:HTL motivation questionnaire.

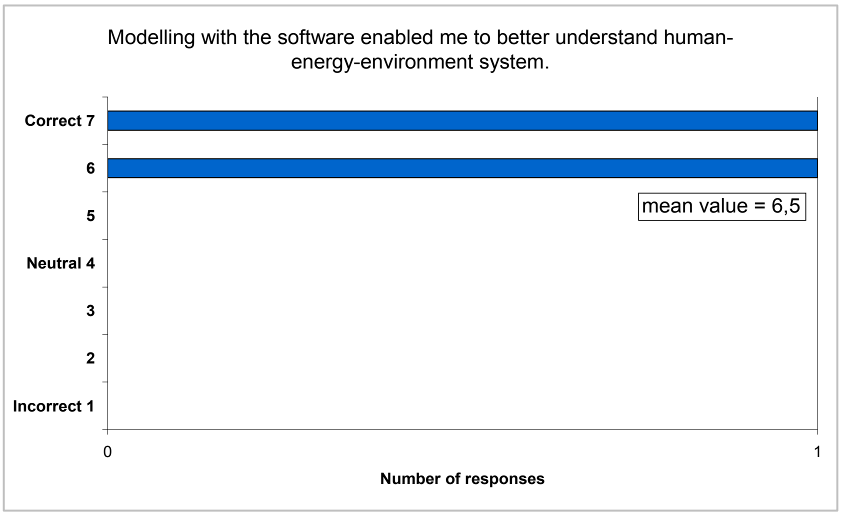

Figure 10.34: Results of question 8 of the i:HTL motivation questionnaire.

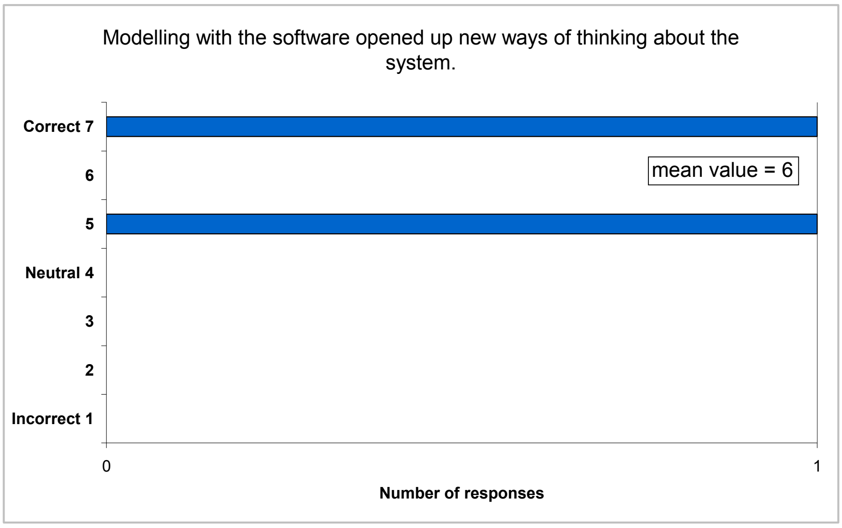

Figure 10.35: Results of question 9 of the i:HTL motivation questionnaire.

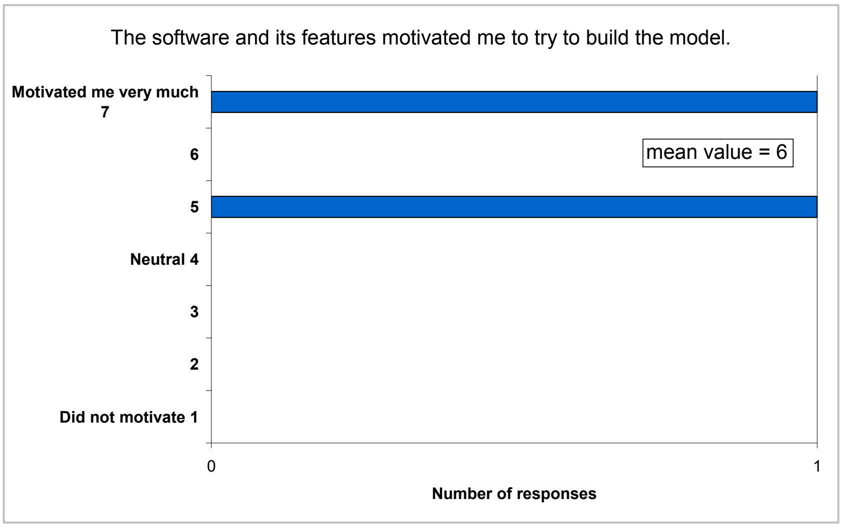

Figure 10.36: Results of question 10 of the i:HTL motivation questionnaire.

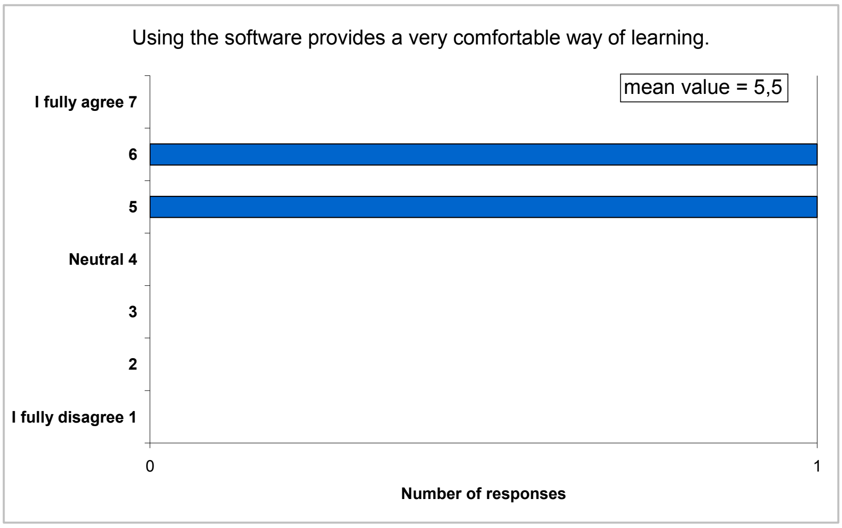

Figure 10.37: Results of question 11 of the i:HTL motivation questionnaire.

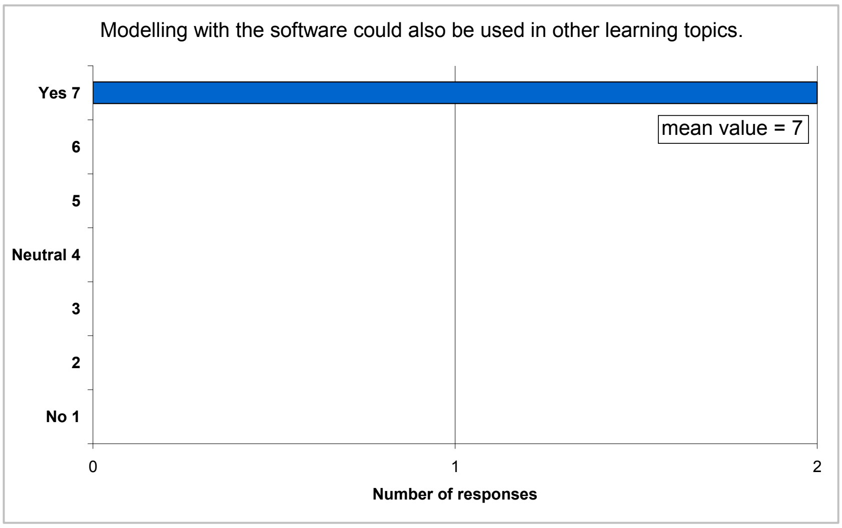

Figure 10.38: Results of question 12 of the i:HTL motivation questionnaire.

10.4.3.2. Results of the BOKU I motivation questionnaire

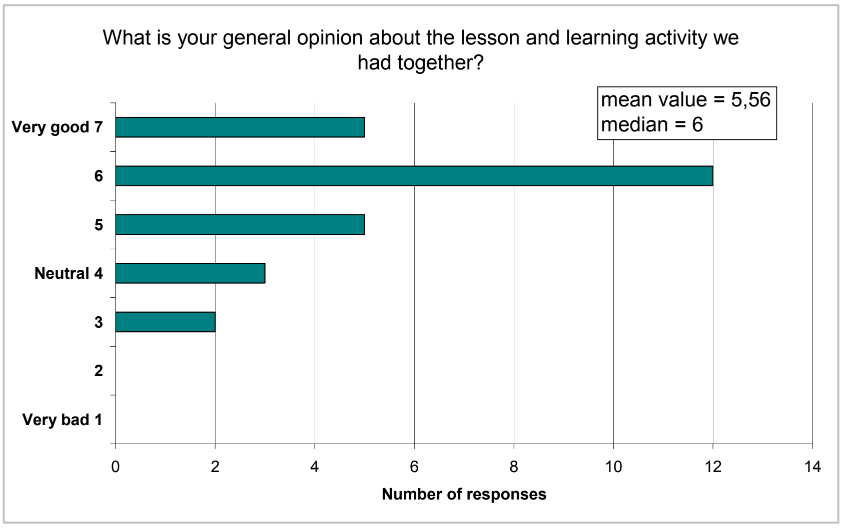

Figure 10.39: Results of question 1 of the BOKU motivation questionnaire.

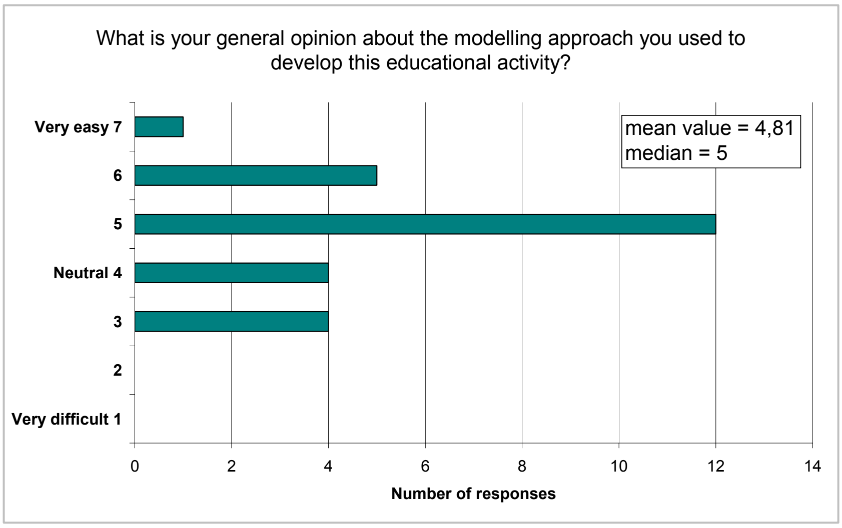

Figure 10.40: Results of question 2 of the BOKU motivation questionnaire.

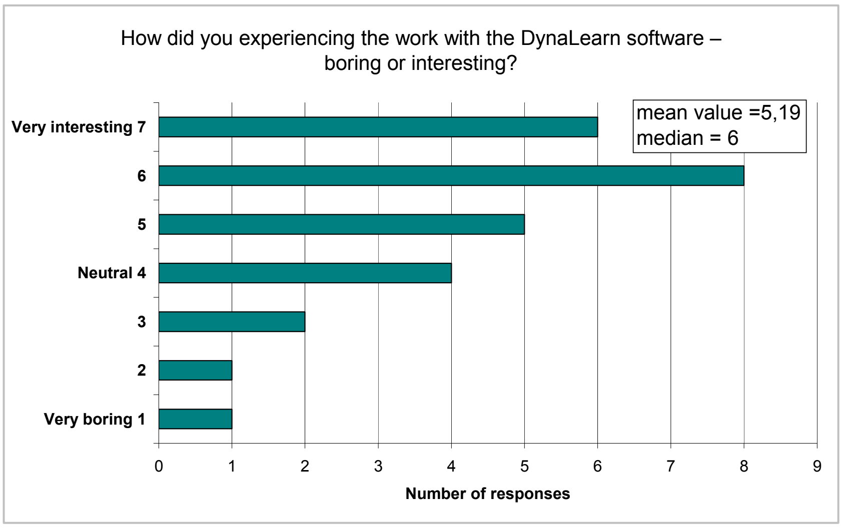

Figure 10.41: Results of question 3 of the BOKU motivation questionnaire.

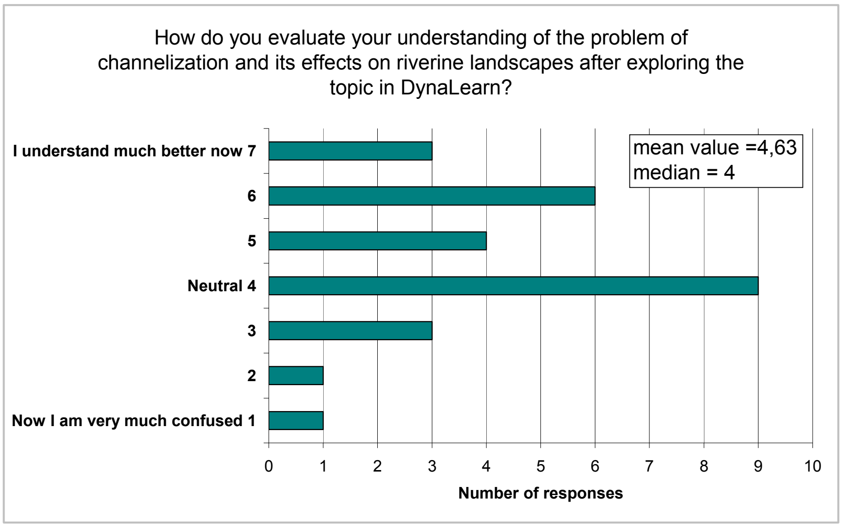

Figure 10.42: Results of question 4 of the BOKU motivation questionnaire.

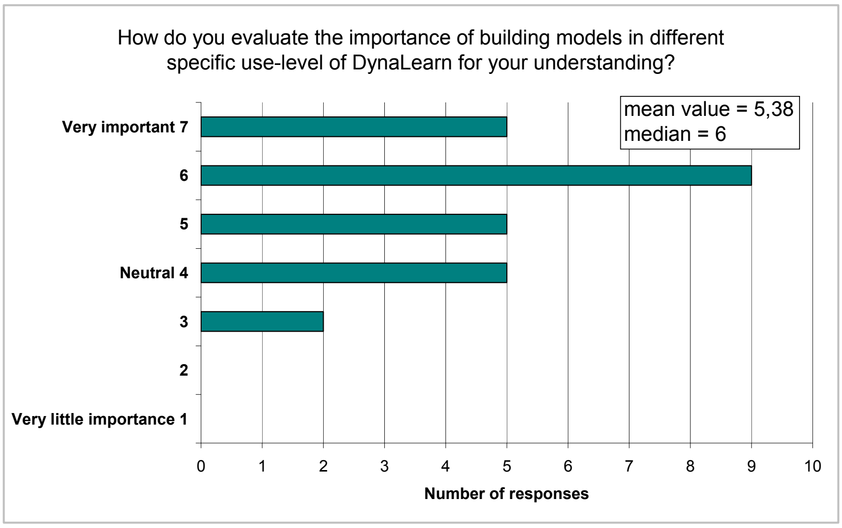

Figure 10.43: Results of question 5 of the BOKU motivation questionnaire.

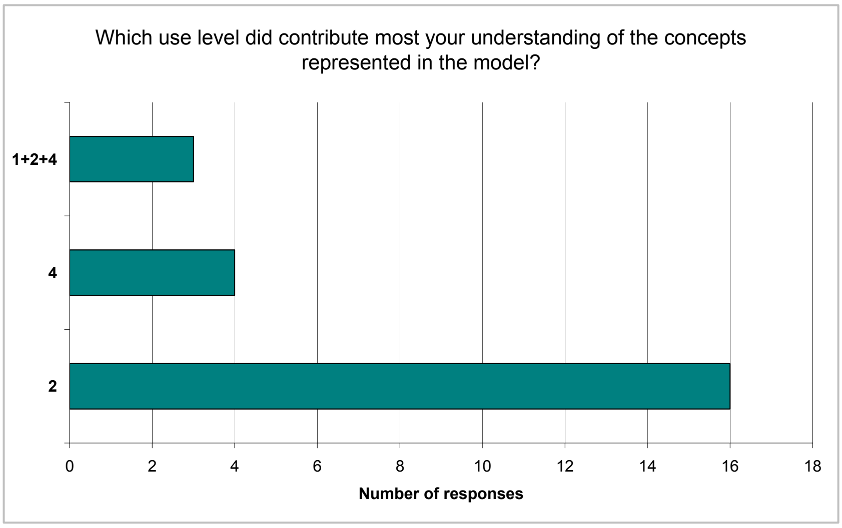

Figure 10.44: Results of question 6 of the BOKU motivation questionnaire.

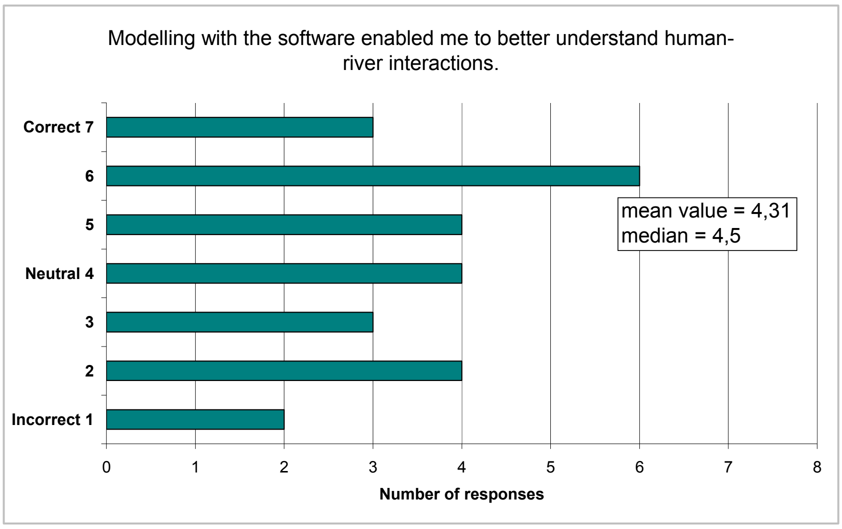

Figure 10.45: Results of question 7 of the BOKU motivation questionnaire.

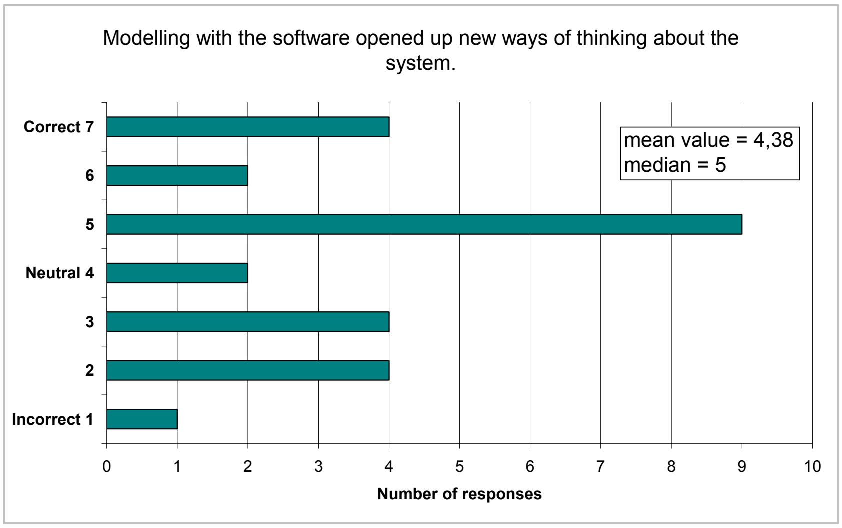

Figure 10.46: Results of question 8 of the BOKU motivation questionnaire.

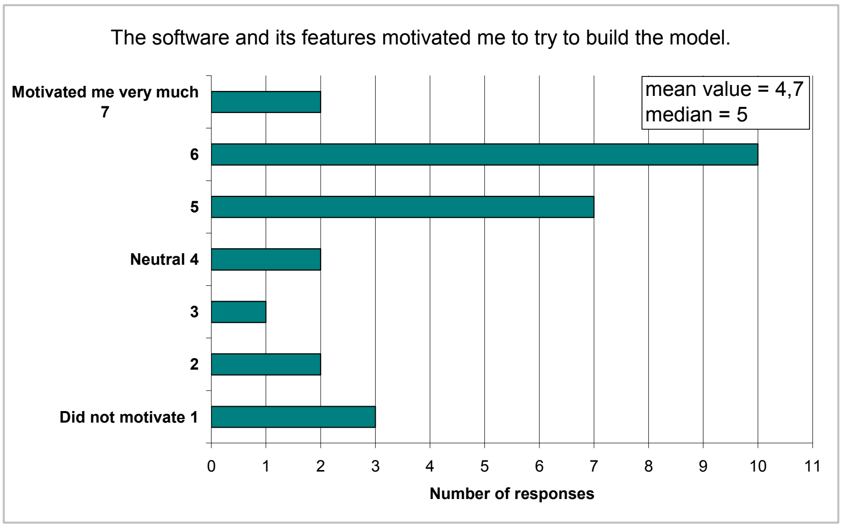

Figure 10.47: Results of question 9 of the BOKU motivation questionnaire.

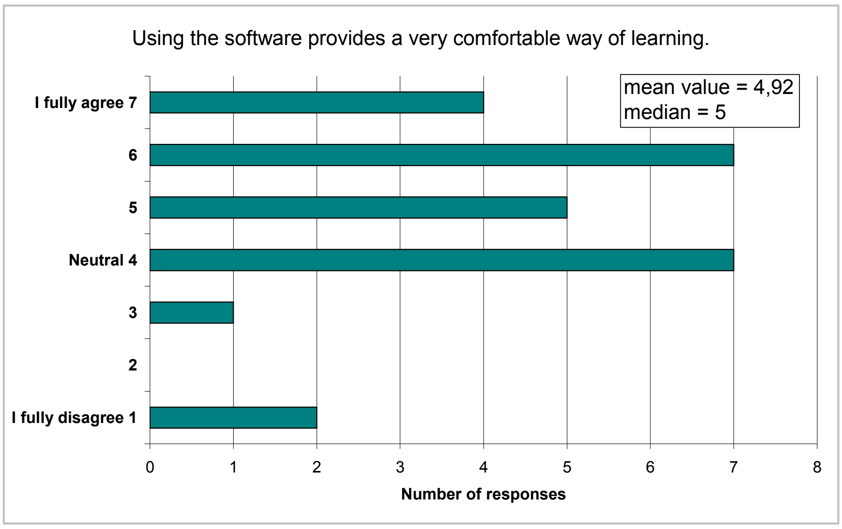

Figure 10.48: Results of question 10 of the BOKU motivation questionnaire.

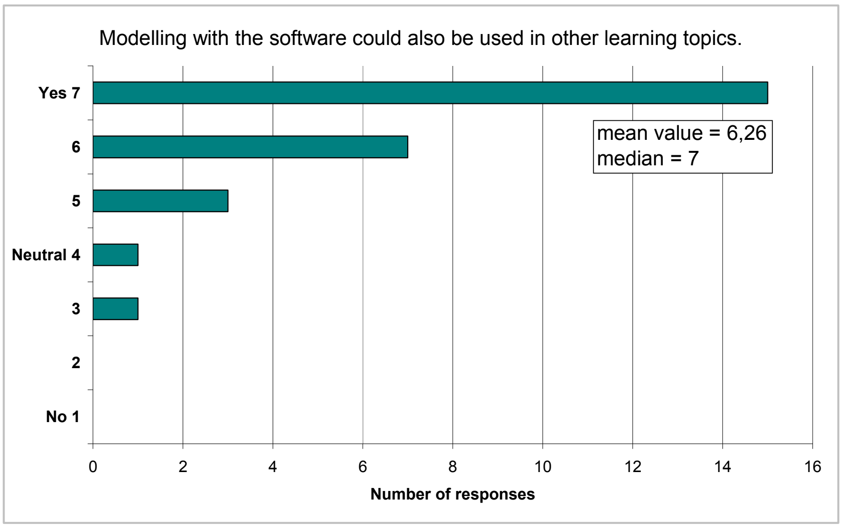

Figure 10.49: Results of question 11 of the BOKU motivation questionnaire.

10.4.4. Results of the I:HTL video analysis

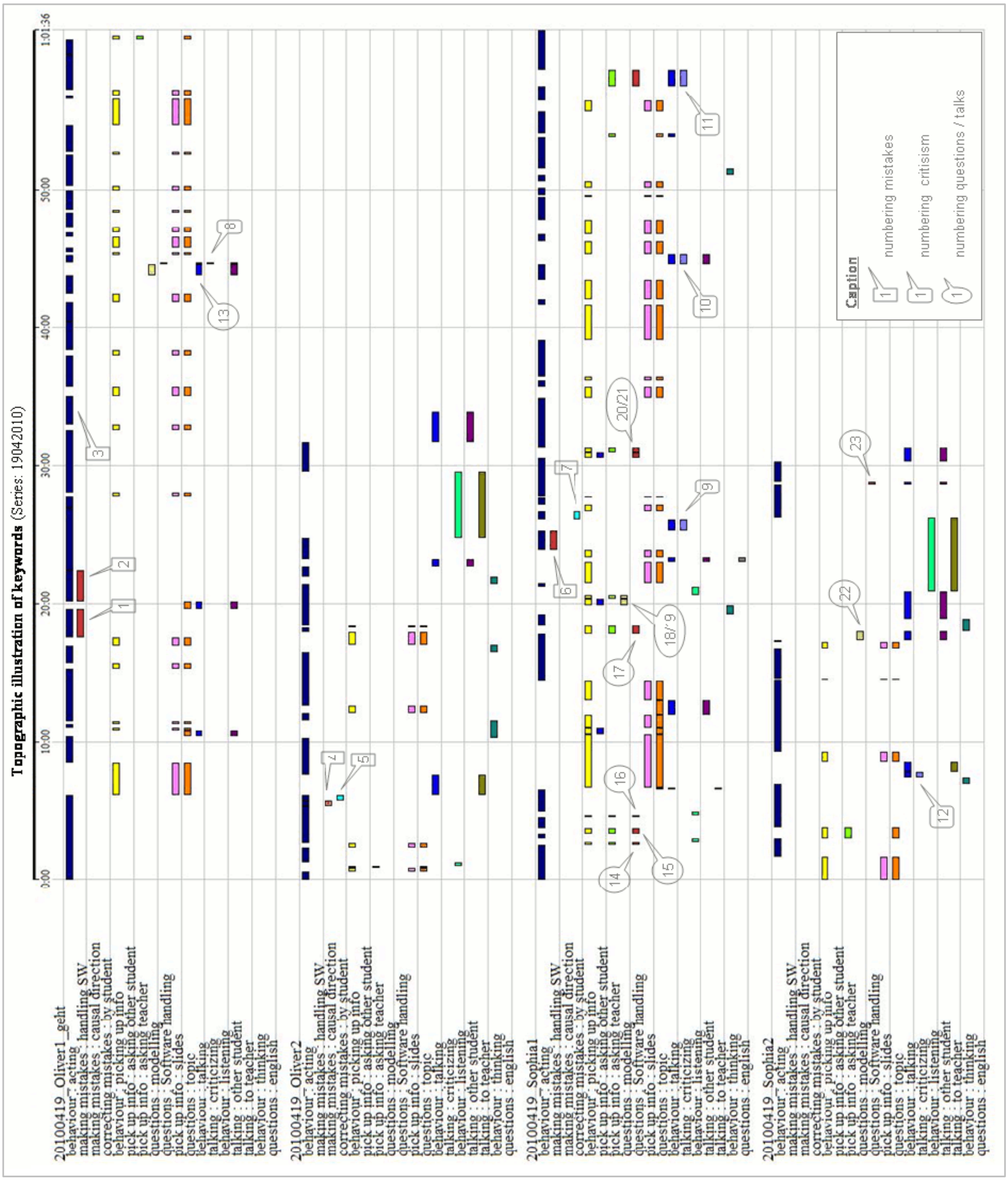

Figure 10.50: Topographic illustration of the i:HTL video analysis (first evaluation day 2010-04-19). For details of the numbered time items see Table 10.1, Table 10.2 and Table 10.3.

Table 10.1: List of mistakes captured by video analysis of the first i:HTL evaluation day 2010-04-19 (see Figure 10.50).

MISTAKES LS1						
No.	**Transana QuickClip**	**Time**	**Mistake**	**Action**	**correction**	**need for**
1	35 (O1_19042010)	00:17:33 - 00:19:37	SW handling	student changes name of old configuration unintentionally during adding a new one; selects 2 entities by pressing leftclick on the mouse and trying to catch the certain entitites in a w indow , therefore he has to arrange all entities to catch the right ones..(better: holding dow n shift key and selecting first one, then w hile still holding dow n that button, clicking the second one)		basic help
2	37 (O1_19042010)	00:20:13 - 00:22:34	SW handling	student changes name of old configuration unintentionally during adding a new one		basic help
3	43 (O1_19042010)	00:32:57 - 00:35:01			student creates a new model w ith new entities and configurations - adding new configurations correctly	
4	140 (O2_19042010)	00:05:18 - 00:05:43	causal direction	add a new configuration; configuration properties: (w indKW erzeugen Energie) mistake: arrow direction		
5	141 (O2_19042010)	00:05:43 - 00:06:06			student corrects his mistake by sw itching arguments	
6	98 (S1_19042010)	00:23:52 - 00:25:17	SW handling	student adds new entity - selecting 2 - add configuration - SW handling mistake: she doesn`t select a new configuration ..so she changes also the old "causes" to the new one		basic help
7	100 (S1_190402010)	00:26:03 - 00:26:39			correcting her mistake: add new configuration - add causes	

Table 10.2: List of critical remarks captured by video analysis of the first i:HTL evaluation day 2010-04-19 (see Figure 10.50).

CRITICALS STATEMENTS LS1			
No.	**Transana QuickClip**	**Criticism**	**problem**
30	52 (O1_19042010)	student cannot unite the same configurations	complex concept maps are confusing
31	99 (S1_19042010)	student cannot add a name w ith tw o capital letters	problem for several german nouns
32	116 (S1_19042010)	names of configurations are often the same - 10 times the same configurations in the concept map	complex concept maps are confusing
33	131 (S1_19042010)	lettering also vertical possible? handling of concept map	handling of concept map is not user-friendly
34	165 (S2_19042010)	remarks w indow is cut off by display	handling of concept map is not user-friendly

Table 10.3: List of talks and questions between students and/or with teacher captured by video analysis of the first i:HTL evaluation day 2010-04-19 (see Figure 10.50).

TALKS/QUESTIONS about modelling or SW in LS1					
No.	**Transana QuickClip**	**talking to**	**keyword**	**talk/question content**	**need for**
1	51 (O1_19042010)	student	modelling	about the structure of her model	
2	73 (S1_19042010)	teacher	SW handling	can I use slash or numbers for a name?	
3	76 (S1_19042010)	teacher	SW handling	how can I start to build a concept map? First "add an entity" ?	help - No. It w as her first step intuitional
4	78 (S1_19042010)	teacher	SW handling	w hat is the function of "remarks"?	optional
5	88 (S1_19042010)	teacher	SW handling	name xxÜ - not allow ed?	
6	91 (S1_19042010)	student	SW handling	w hat is meant by "configuration definition"?	help
7	92 (S1_190402010)	teacher	SW handling	w hat is meant by "configuration definition"?	help
8	105 (S1_190402010)	student	SW handling	how can you delete a configuration?	help - No. It should be clear (mouse info over button)
9	106 (S1_190402010)	teacher	SW handling	how can you delete a configuration?	help - No. It should be clear (mouse info over button)
10	173 (S2_190402010)	student	modelling	talking about the form of their concept maps	
11	178 (S2_190402010)	student	SW handling	about saving (close model and copy file from explorer or save current model to new file on USB stick?)	

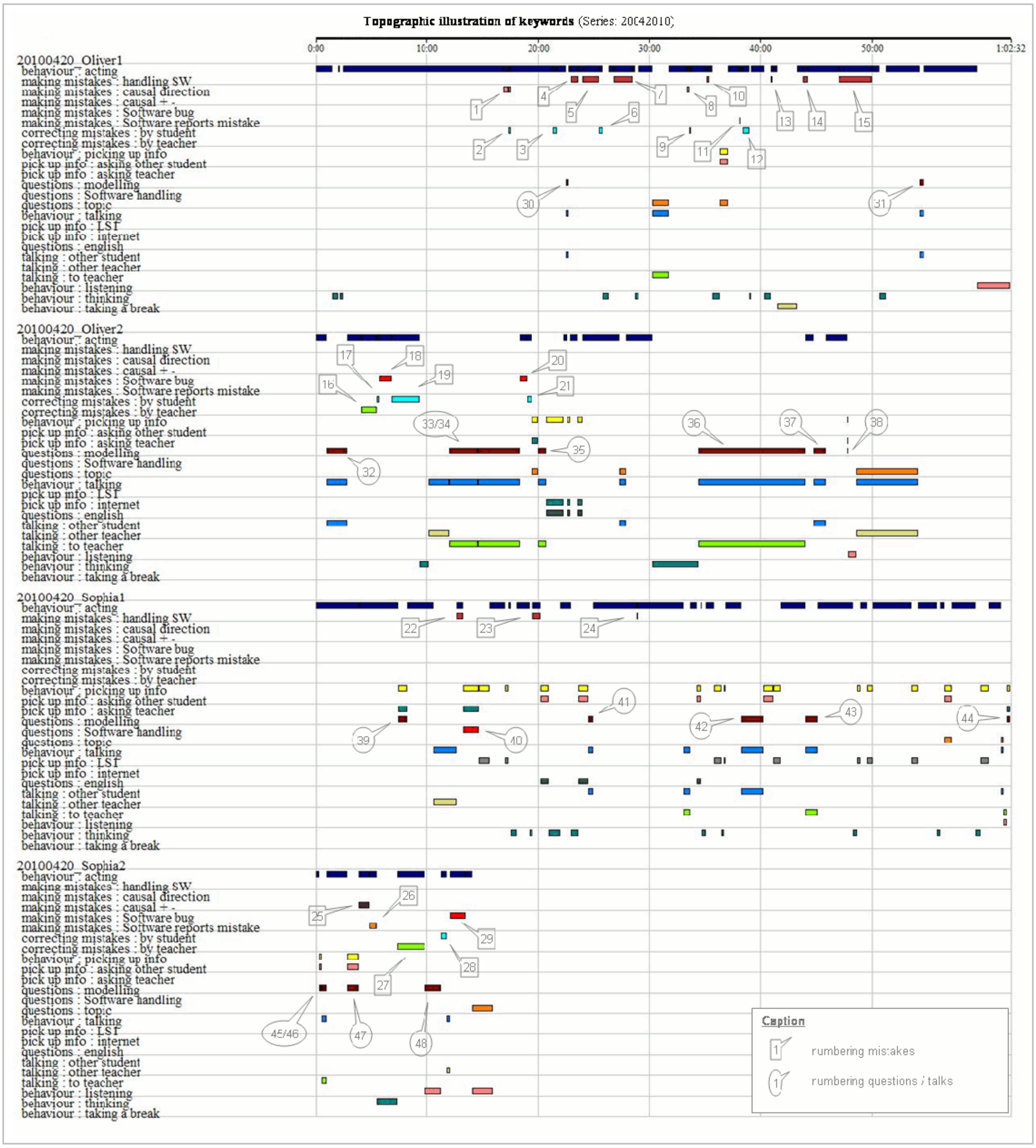

Figure 10.51: Topographic illustration of the i:HTL video analysis (second evaluation day 2010-04-20). For details of the numbered time items see Table 10.4 and Table 10.5.

Table 10.4: List of mistakes captured by video analysis of the second i:HTL evaluation day 2010-04-20 (see Figure 10.51).

MISTAKES LS2						
No.	Transana QuickCli	Time	Mistake	action - mistake	correction	need for
1	290 (O1_20042010)	00:16:54 - 00:17:22	causal direction	add a new configuration betw een 2 entities - mistake: arrow direction (multiple mistakes)		help
2	291 (O1_20042010)	00:17:22 - 00:17:36			student corrects his mistake by sw itching arguments	
3	293 (O1_20042010)	00:21:18 - 00:21:41			student corrects his mistake by sw itching arguments	
4	297 (O1_20042010)	00:23:00 - 00:23:37	SW handling	problem to select entities - student has to rearrange the chain several times to catch the right entities. Better solution: holding dow n shift key and selecting first one, then w hile still holding dow n that button, clicking the second one		help
5	299 (O1_20042010)	00:24:00 - 00:25:28	SW handling and causal direction	re-arranging because of problem to select quantities (0:25:00.0) deletes positive causal relation from consumption and population only because of selecting problem - selecting - and re-adding positive causal relation from consumption and population - add negative causal relationship:consumption (energy) to level (human inteligence) mistake direction		
6	300 (O1_20042010)	00:25:28 - 00:25:58			student corrects his mistake by sw itching arguments	
7	303 (O1_20042010)	00:26:48 - 00:28:30	SW handling	problem to select…(see above)		help
8	309 (O1_20042010)	00:33:24 - 00:33:47	causal direction	production (energy produce) to number (w ind energy)		
9	310 (O1_20042010)	00:33:47 - 00:35:06			student corrects his mistake by sw itching arguments	
10	312 (O1_20042010)	00:35:06 - 00:35:21	SW handling	problem to select…(see above)		help
11	317 (O1_20042010)	00:38:04 - 00:38:11		student added values at various derivatives	simulation: question mark pops up	
12	319 (O1_20042010)	00:38:23 - 00:39:00			student is deleting values add value: up human intelligence	
13	323 (O1_20042010)	00:40:54 - 00:41:05	SW handling	problem to select…(see above)		help
14	327 (O1_20042010)	00:43:47 - 00:44:14	SW handling	problem to select…(see above)		help
15	329 (O1_20042010)	00:47:04 - 00:50:01	SW handling	problem to select…(see above)		help
16	242 (O2_20042010)	00:04:10 - 00:05:32			student and teacher are looking for mistakes in the simulation (student notices how the teacher selects the entities)	
17	243 (O2_20042010)	00:05:32 - 00:05:41			student is looking for mistakes in the simulation	
18	244 (O2_20042010)	00:05:41 - 00:06:54	SW bug	student is deleting configuration by pressing del - SW bug		
19	245 (O2_20042010)	00:06:54 - 00:09:18			start - open model student is looking for mistakes by himself - starts simulation - runs correctly	
20	250 (O2_20042010)	00:18:24 - 00:19:00	SW handling	student is deleting entity in the simulation w indow - SW bug		
21	251 (O2_20042010)	00:19:00 - 00:19:26			student corrects his mistake	
22	187 (S1_20042010)	00:12:410 - 00:13:19	SW handling	problem to select…(see above)		help
23	196 (S1_20042010)	00:19:32 - 00:20:14	SW handling	problem to select…(see above)		help
24	197 (S1_20042010)	00:28:49 - 00:29:00	SW handling	problem to select…(see above)		help
25	275 (S2_20042010)	00:03:54 - 00:04:53	causal +,-	student is setting w rong causal relationships		
26	276 (S2_20042010)	00:04:53 - 00:05:31			simulation: question mark pops up	
27	278 (S2_20042010)	00:07:25 - 00:09:52			looking for mistakes - correction by teacher	
28	280 (S2_20042010)	00:11:19 - 00:11:48			looking for mistakes - correction by student	
29	282 (S2_20042010)	00:12:03 - 00:13:33	SW bug	Softw are bug because of changes in the simulation w indow		

Table 10.5: List of talks and questions between students and/or with teacher captured by video analysis of the second i:HTL evaluation day 2010-04-20 (see Figure 10.51).

TALKS/QUESTIONS about modelling or SW in LS 2					
No.	Transana QuickClip	talking to	keyword	talk/question content	need for
1	295 (O1_20042010)	student	modelling	about positive relationship in students model	
2	333 (O1_20042010)	student	modelling	student asks about the quantities of hydropeaking,..	
3	240 (O2_20042010)	student	modelling	talking to sophia (she is asking about add value function)... he answ ers: w here is the starting point of your model? they talk about her model entities,..	
4	248 (O2_20042010)	teacher	modelling	student explains his model und the simulation results	
5	249 (O2_20042010)	teacher	modelling	about next modelling steps	
6	253 (O2_20042010)	teacher	modelling	about modelling complexity and the need of focusing on details	
7	263 (O2_20042010)	teacher	modelling	about further simulation results	
8	265 (O2_20042010)	student	modelling	about her model	
9	267 (O2_20042010)	teacher	modelling	about next LS	
10	184 (S1_20042010)	teacher	modelling	w hat are attributes?	help
11	188 (S1_20042010)	teacher	SW handling	how can I open the concept map from yesterday?	? optional help
12	202 (S1_20042010)	student	modelling	about students model	
13	216 (S1_20042010)	student	modelling	about students LS1 models	
14	220 (S1_20042010)	teacher	modelling	about next modelling steps	
15	238 (S1_20042010)	teacher	modelling	student w ants to insert a new entity betw een tw o existing ones w ithout deleting the old ones	
16	271 (S2_20042010)	student	modelling	about add value function	
17	272 (S2_20042010)	teacher	modelling	about add value and simulation start	
18	274 (S2_20042010)	student	modelling	about add value function	
19	279 (S2_20042010)	teacher	modelling	about modelling processes	

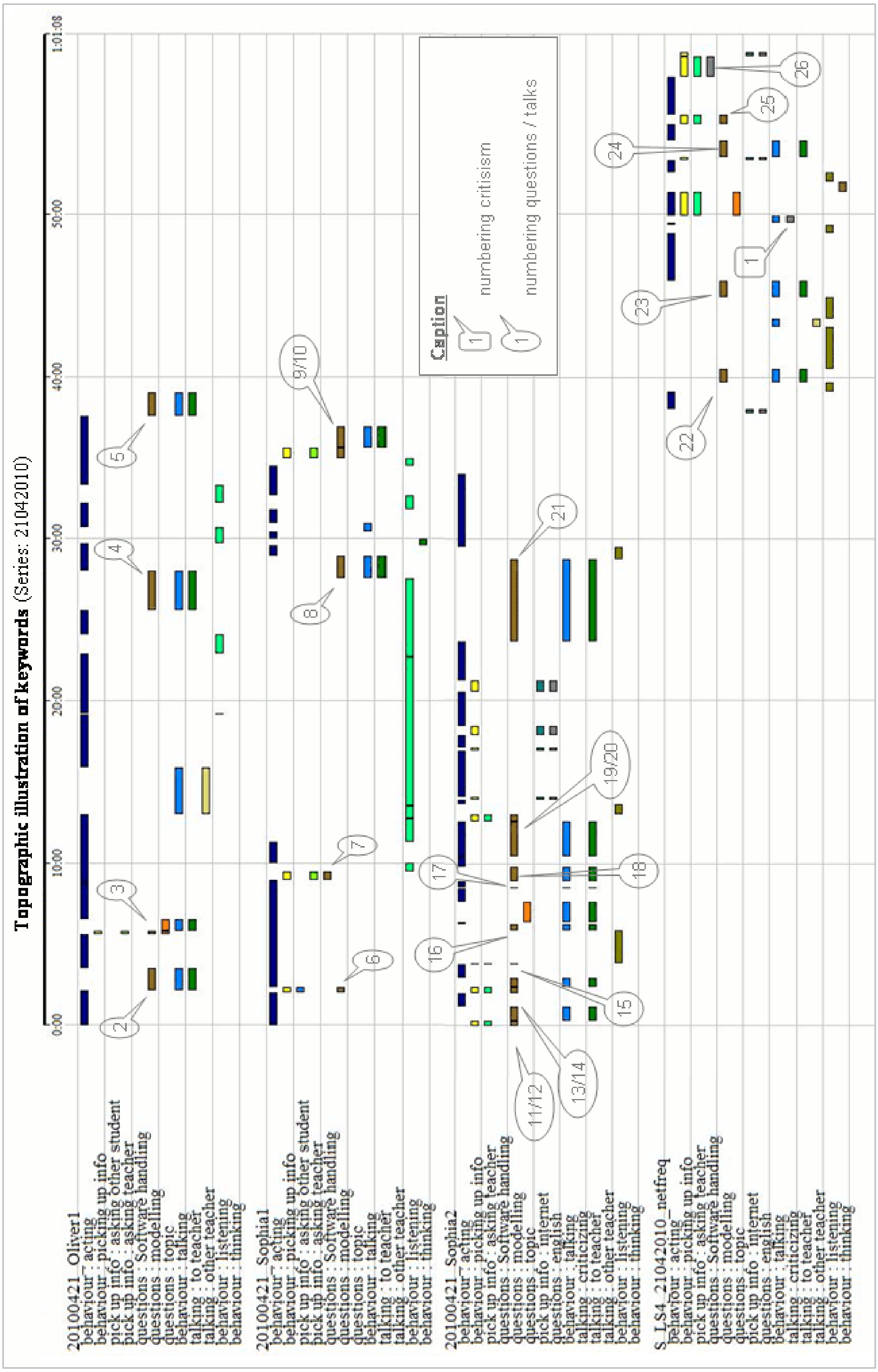

Figure 10.52: Topographic illustration of the i:HTL video analysis (third evaluation day 2010-04-21). (for details of the numbered time items see Table 10.6. and Table 10.7.

Table 10.6: List of critical remarks captured by video analysis of the third i:HTL evaluation day 2010-04-21 (see Figure 10.52).

No.	Transana QuickClip	Criticism	problem
1	12 (S2_21042010netfre	numbers are not permitted in names	student w anted to set a benchmark (50Hz net frequency)

Table 10.7: List of talks and questions between students and/or with teacher captured by video analysis of the third i:HTL evaluation day 2010-04-21 (see Figure 10.52).

TALKS/QUESTIONS about modelling or SW LS4					
No.	**Transana QuickClip**	**talking to**	**keyword**	**talk/question content**	**need for**
2	2 (O1_21042010)	teacher	modelling	about modeling- teacher asks about rates (birth, death rate, grow th rate)	
3	4 (O1_21042010)	teacher	modelling	topic definition: biomass	
4	14 (O1_21042010)	teacher	modelling	about simulation results; how can w e model that the birthrate is bigger than deathrate	help
5	20 (O1_21042010)	teacher	modelling	about his model results	
6	22 (S1_21042010)	student	modelling	w hich Quantity Spaces are adequate	
7	24 (S1_21042010)	teacher	modelling	about tw o kinds of simulation..	help - No. It should be clear (mouse info over button)
8	30 (S1_21042010)	teacher	modelling	about inequality properties and feedback loop	
9	39 (S1_21042010)	student	modelling	about the next steps: LS4 for w indenergy - hydropeaking model	
10	40 (S1_21042010)	teacher	modelling	about next steps	
11	41 (S2_2104210)	teacher	modelling	about calculus	help
12	42 (S2_2104210)	teacher	modelling	about calculus	help
13	44 (S2_2104210)	teacher	modelling	about calculus	help
14	45 (S2_2104210)	teacher	modelling	about calculus	help
15	47 (S2_2104210)	teacher	modelling	meaning of states in simulation	
16	49 (S2_2104210)	teacher	modelling	about calculus	help
17	53 (S2_2104210)	teacher	modelling	about simulation results	
18	55 (S2_2104210)	teacher	modelling	about simulation results	
19	57 (S2_2104210)	teacher	modelling	about frequencies and next modelling steps	
20	58 (S2_2104210)	teacher	modelling	is it needed to set configurations betw een all entities?	help
21	69 (S2_2104210)	teacher	modelling	about model features - only 1 state in simulation - w hy?	help
22	4 (S_2104210_netfreq)	teacher	modelling	about P, I	
23	8 (S_2104210_netfreq)	teacher	modelling	about entities and quantities..	
24	18 (S_2104210_netfreq)	teacher	modelling	calculus properities	help
25	20 (S_2104210_netfreq)	teacher	modelling	modelling SW oportunities (fluctuating simulation)	
26	22 (S_2104210_netfreq)	teacher	SW handling	how to implement the calculus?	help

10.4.5. A list of selected causal verbal expressions

To do something to achieve something; cause; if you change something, something else will change; influence; to do something to achieve something; increases, decreases or goes down because; due to; because; hence; something leads to something; something happens due to; depends on; something rises/increases/decreases and therefore something other happens; something leads to a loss, increase, decrease; something produces something; something has an effect on something; without an effect on; something is done to achieve; if-then; something influences something; something is the cause for something;, something is followed by something because of; something takes place because of; something is done because of; something is regulated by; something changes another thing; the more-the more; something happens due to, something is changed due to; something depends on; change of, lack of; changes or effects occur due to.

10.5. Lesson plans i:HTL

Day 1 19.04.	Activity	Learning target	Modus	Learning teaching resources/ material	Evaluation activity	Evaluation resources	Potential problems and solutions
7:50 – 8:40	7:50 -8:15 Personal introduction short Intro of the Dynalearn project with its aim of producing a modelling software – to support conceptual understanding in environmental science. They are involved as active participants contributing to the software development. **08:15-9:00: Pre-test – how are rivers – humans – fish – energy production and consumption – wind energy related**	They are part of the project, and their work contributes to software development	Personal communication, some slides by AZ, then each of the pupils tries to represent in a way he wants the problem (prosa, sketch ….) in pre-test	Ppt slides, beamer, pencil and paper	They get a questionnaire with a free sketching part and some detailed questions **on the system -** gathering their first descriptions of an environmental/social system – looking of **what** they already know and **how** they represent the system	Questionnaire, pencils	
9:10- 9:40	**Time plan for the next days.** Each day is dedicated to a specific aspect (type of model + content): - Day 1: Concept map (UL1) - Day 2: Global causal model (UL2 – UL 3) - Day 3: Processes (a couple of small models) (UL4) Types of models existing by an example on an environment (concept map, from concepts to causal diagrams to specific system dynamics to equations…), basic idea of a system **Introduction of general topic to be explored within the next days: sustainable energy production and use**	Overview over the topic, some known ways to represent things in models, introduction of the general problem	Ppt presentation students listening, feedback on what system description tools they know	Ppt slides, computer beamer			
9:50- 10:35	**Content related slides introducing the topic in a more specific way.** Provision of **additional material** to students. If they want, they also can go to the internet or use other resources. Software installation. Introduction of UL 1.	Content related knowledge, software installation	Ppt presentation, questions, Software presentation	Ppt slides for a short intro, **digital and/or printed information material**, computer, beamer, DL software Prolog on USB stick			
10:50- 11:40	**Start of modelling – building a concept map in UL 1** capturing the important concepts related to the topic. Exploration of the given material, probably own resources. Important: as the software is still BETA please always save your models.	Learning how to create a concept map, and organize things in UL 1	Everybody works on his/her own computer	Computer DL software, written content material	Videotaping of their model building activities	Videocamera, batteries, mini dv tapes,	
11:50- 12:40 12:50- 13:40	Continuing modelling Preparation and presentation of the results of the first day, feedback round	See above **What did they learn today - content**	See above Feedback round, all	See above	See above Taping of discussion, motivational aspects will be discovered face to face	See above Videocamera, batteries, mini dv tapes,	

Day 2 20.04.	Activity	Learning target	Modus	Learning teaching resources/ material	Evaluation activity	Evaluation resources	Potential problems and solutions
7:50 – 8:40	Starting with a ppt presentation on **a causal issue of human-energy-environment relationship,** mainly focusing on demand, different types of energy, and their relation to each other and the environment **Short Intro of the use level 2**	Content related knowledge	Ppt presentation, questions, discussion	Ppt slides for a short intro, printed information material, computer, beamer, DL software	Videotaping of their behaviour when introducing the software	Videocamera, batteries, mini dv tapes	
8:50-9:40	**Development of a global causal model in UL 2**. Focus will be on causality and expression of alternative ideas and simulation results (each saved as a single model). Alternative means two things: different causal details + different simulation results. Wrt the latter, to show a particular result the idea of setting the change of quantities at the beginning of the causal chain to zero and have only one driving quantity cause an increase or decrease etc. Fine tuning the model in this respect, will take time and provides many opportunities to articulate different details and/or views, Probably, if there is time: UL3 will be shown and one scenario with 2 qtt and a qtty space for the second one will show the sequence of states. Next, a scenario with a chain with 3 quantities - being the first with just {p} and the other two with similar / related qtty spaces will be created. All the possible combinations of values will be shown, and the different notions of time explored. (correspondence between the quattes 2 and 3, time and simultaneity…)	Model development, structuring the knowledge along causal relationships	Everyone on his own, with possibility to ask, collaborate and give feedback,	printed material computer DL software, pencil paper	Videotaping of their model building activities	Videocamera, batteries, mini dv tapes	
9:50-10:35	Model development	See above	See above	See above	See above	See above	
10:50-11:40	Model development	See above	See above	See above	See above	See above	
11:50-12:40	Model development	See above	See above	See above	See above	See above	
12:50-13:40	Preparation and presentation of the results of the second day, feedback round	**What did they learn today - content**	Feedback round, all		Taping of discussion, motivational aspects will be discovered face to face		

Day 3 21.04.	**Activity**	**Learning target**	**Modus**	**Learning teaching resources/ material**	**Evaluation activity**	**Evaluation resources**	**Potential problems and solutions**
7:50 – 8:40	Starting with a ppt presentation of an specific issues on human-energy-environment relationships, mainly focusing on the effect of increased hydropower production on rivers and fish, Provision of material to the students. Introduction of UL 4 and its conceptual content	Content related knowledge	Ppt presentation, questions, discussion	Ppt slides for a short intro, **printed information material**, computer, beamer			
8:50-9:40	**Exploration of UL 4 with an existing model.** Four things are of interest here: (1) the difference between a rate (rates) and a propagation thereof, and (2) the quantities involved, (3) the proper causal dependencies, and (4) the trigger for the process to happen. (e.g. liquid flow process as included in the Utube).	Learning how to build a model in UL 4	Collaborative exploration of a model in UL 4	As here we need to make clear the differences between I`s and P`s, some extra material – a model for a common exploration - will be used.	Videotaping of their model building activities		
9:50-10:35	Model development in UL 4	Model development, structuring the knowledge along a specific process	Everyone on his own, with possibility to ask, collaborate and give feedack	printed material Computer DL software, pencil paper	Videotaping of their model building activities	Videocamera, batteries, mini dv tapes,	
10:50-11:40	Model development in UL 4	See above	See above	See above	See above	See above	
11:50-12:10	Model development in UL 4	See above	See above	See above	See above	See above	
12:15-13:40	**12:15-13:00 Post-test content** **13:10-13:30 Motivation questionnaire** **13:30-13:50 Final feedback round**	What did they learn? Do they like the approach? Which additional ideas do the have?			Post test questionnaire – the same s provided at the pre-est– looking of **what** they have learned and **how** they represent the system **after three days of DL.** They get a motivation questionnaire of how they liked the approach, their feelings, final face to face feedback round	Questionnaire, motivation questionnaire	

Day 4 22.04.	Activity	Learning target	Modus	Learning teaching resources/ material	Evaluation activity	Evaluation resources	Potential problems and solutions
7:50 – 8:40	Preparation of presentation for the e-day		Collaborative mode, feedback, support, discussion				
8:50-9:40	Preparation of presentation for the e-day		Collaborative mode, feedback, support, discussion				
9:50-10:35	Preparation of presentation for the e-day		Collaborative mode, feedback, support, discussion				
10:50-11:40	Preparation of presentation for the e-day		Collaborative mode, feedback, support, discussion				
11:50-12:40	Preparation of presentation for the e-day		Collaborative mode, feedback, support, discussion				
12:50-13:40	Preparation of presentation for the e-day		Collaborative mode, feedback, support, discussion				
15:00	**Presentations at e-day, end of activities**				Videotaping of their presentation	Videocamera, batteries, mini dv tapes	

10.6. Lesson plans BOKU I

The main focus of the activities at the BOKU is on the following main objectives:

1. **Serve as a pilot to test the use of DL software within existing lectures as a basis to develop a curriculum allowing students to move along their interests in an individualized learning mode.**
2. **Exploring the attitudes of students towards the learning by modeling approach delivered by the DL software.**
3. **Testing the potential of DL to support understanding of science concepts and systems understanding related to river management.**

In the interdisciplinary lecture "Selected topics of aquatic ecology and river management" four main topics will be presented without DynaLearn software, each in one afternoon lasting for about 4 hours using a traditional power point teaching approach.

Course Plan ID: Lecture Selected Topics of aquatic ecology and river management 2SWS – 3 ECTS May and June 2010	
Topic:	4 main topics: 1. Basics of river landscapes and river management 2. Large river systems - examples from the Danube 3. Benthic invertebrate ecology and water quality assessment 4. Fish as Indicators for Ecological integrity of running waters
General Objectives:	Developing and improving students understanding of processes in aquatic ecology and river management. The selected topics should cover the range of aquatic ecology and river management. A variety of examples will be presented.
Target population:	~20-30 Bachelor, Master PhD students
Procedure	
Duration:	5 lessons with duration of about 4h
Implementation plan and schedule:	**Demonstration and investigation mode** Each of the 4 topics will be presented without Dynalearn software, each in one afternoon lasting for about 4h using a traditional power point teaching approach. In the fifth lesson (workshop - duration 5h) an applied example in river management (effects of river channelization) will be explored and discussed supported by the DynaLearn software.
Teaching/Learning organization:	BOKU - Institute of Hydrobiology and Aquatic Ecosystem Management
Assessment:	**Summative** 1) Pre-post test at the DL event. 2) At the end of the full course there is a written assignment, with relatively open questions, allowing comparing the answers related to the content delivered by the support of the DL software with answers related to content delivered in form of PowerPoint presentations. **Formative** Interviews & questionnaires, observational notes
Resources	
Dynalearn resources:	Simple DL test models in each LS presented by PowerPoint slides as starting point for modeling, related to System Dynamics vocabulary
Learning materials:	Power point presentation as a basis to formulate models, Textbook "Angewandte Fischökologie an Fließgewässern" Jungwirth et al. 2003 Facultas UTB 2113 ISBN 3-8252-2113, Pictures as starting points for discussions and the pre- and post test.

In the fifth lesson (workshop - duration 5 hours) an applied example in river management will be demonstrated by means of the DynaLearn software, followed by a collaborative model building approach.

The summative assessment will include a pre- and post test at the DL lesson allowing to identify the effect of the DL software on learning/understanding and a written fin al assignment about the content of all five lectures allowing a comparison of the knowledge gained during DL activities with knowledge gained during PowerPoint presentations. Formative assessments will be conducted during the DL event by motivation/attitude questionnaires and observational notes.

10.6.1. Introductory slides for the BOKU I evaluation

Time plan

12:00-13:00 Software Installation
- 13:00-13:10 Introduction to the project
- 13:10-13:30 Pre-test
- 13:30-13:45 Introductory lecture on river channelization
- 13:45-14:05 Concept map UL 1

10 min Break
- 14:15-14:45 Causal modelling UL 2
- 14:55-15:45 Causal differentiation UL 4

10 min Break
- 15:45-16:10 Post test
- 16:10-16:30 Motivation questionnaire

End

Aims of the project

- Development of a software to support student`s in learning about systems allowing
  - To Articulate one`s own ideas about systems
  - Simulate scenarios and viewpoints
  - To confront one`s ideas with expert models
- The software
  - is based on qualitative reasoning (area of AI)
  - Is still under development
  - Will have several interesting and engaging features (links to wikipedia terminology, automated feedback via animated characters)

Aims of the session

- Part of the software development process – still Beta
- To collect your ideas and problems when working with the software (modelling exercises, videotaping of questions and answers)
- To collect your impressions when working with the software (videotaping of questions and answers, motivation questioannaire)
- To get an idea if the software supports learning in the way it is planned (pre-test, post test)

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