Deliverable number:	D6.1
Deliverable title:	DynaLearn environmental science curriculum requirements

Delivery date:	2009/07/31
Submission date:	2009/08/09
Leading beneficiary:	University of Brasilia (FUB)
Status:	Version 06 (final)
Dissemination level:	PU (public)
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Project number:	231526
Project acronym:	DynaLearn
Project title:	DynaLearn - Engaging and informed tools for learning conceptual system knowledge
Starting date:	February 1st, 2009
Duration:	36 Months
Call identifier:	FP7-ICT-2007-3
Funding scheme:	Collaborative project (STREP)

Abstract

This Deliverable provides the background and planning towards the definition of the requirements for the development of an Environmental Science curriculum in which conceptual modelling and the new DynaLearn software can be used to enhance learning of secondary school and undergraduate students.

Acknowledgements

We would like to thank the University of Brasília and the partners of the project for their contributions during the discussions and preparation of this Deliverable, particularly to Bert Bredeweg, Richard Noble and Andreas Zitek.

Document History

Version	Modification(s)	Date	Author(s)
01	First version	2009/07/17	Salles, Silva and Sá
02	Second version	2009/07/27	Salles, Silva and Sá, with contributions from Noble
03	Third version	2009/07/29	Salles, Silva and Sá, with contributions from Noble and Zitek, and Noble's review
04	Forth version	2009/07/31	Salles, Silva and Sá, with contributions from Noble, Uzunov, Miouser and Zitek, and Noble's review
05	Final version	2009/08/03	Salles, Silva, Sá, with contributions from Noble, Zitek, Uzunov, Mioduser and Bredeweg's review
06	Layout optimisation	2009/08/09	Bredeweg

Contents

1. Introduction

This Deliverable presents a set of themes for the development of curricula and contents on Environmental science, to be used as a test bed for the software produced in the DynaLearn project. In fact, education in the concepts of Environmental science shapes students' capacity for understanding the interactions between humans and the natural world. This domain of knowledge explores ecosystems, communities, and populations living in a range of environments (water, land and atmosphere) and the physical and chemical factors that influence them. In addition to these natural phenomena, Environmental science and management disciplines consider the influence on the living world of man-made abstract systems, embedded in things such as society, institutions, legislation, governance, public policies, economy, religion, science and technology and art amongst others.

The Environmental science curriculum created for the DynaLearn project is based on seven main themes: Earth systems and resources, The living world, Human population, Land and water Use, Energy resources and consumption, Pollution, and Global changes. This document describes key content and objectives of Environmental science curricula implemented in institutions of the five project partner countries. From this the topics to be explored in DynaLearn curricula were selected. More than 600 topics related to the main themes mentioned above were identified during this initial phase, after which the topics were filtered to 70 core topics, with ten topics per main theme.

The topics were selected in order to fulfil the following requirements: the relevance for Environmental science curricula, providing a comprehensive coverage of interesting issues; the adequacy to each partner's educational context, in which specific interests and peculiarities should be considered in order to frame the educational activities developed by the project; the potential to create opportunities for learning enhancement using the DynaLearn software tools. Accordingly, preliminary educational goals were defined along with the themes in order to characterise the set of themes as possible pieces of curricula.

To be effective Environmental science education should focus on certain points: understanding scientific concepts and innovations; the application of scientific knowledge to everyday life; the development of problem solving skills; the capacity for decision-making and argumentation-building; and strengthening the capacity for elaborating proposals for creating a sustainable world. These aspects could be better developed by adopting a view on the curriculum as if it is organised in a web of themes, so that multiple learning routes may be followed, according to the learner's needs and interests [21].

From this perspective, the Environmental science curriculum may be broken into multiple short curricula that may be explored with the support of qualitative models with increasing complexity [32]. Given the evaluation results obtained in the NaturNet-Redime (STREP project co-funded by the European Commission within the Sixth Framework Programme (2002-2006), contract no. 004074), about using qualitative reasoning models for communicating scientific concepts in educational contexts [6], it is expected that this approach will enhance self-regulation and stimulate learners' participation on the decision making about their own learning process. The next phases of the project (Tasks 6.2, 7.1 and 7.2) will integrate these features into the learning-by-modelling approach adopted in DynaLearn project.

2. DynaLearn software implementation

The DynaLearn software is designed to support learners in different ways, exploring opportunities during educational activities guided by a teacher or for learners to work on their own. The DynaLearn software consists of three integrated facilities: the conceptual modelling (CM) environment, the pedagogical agents ("Virtual Characters", VC) and the semantic technology (ST). Technical aspects of the software are described in deliverable D2.1, and will be only summarised here.

The DynaLearn modelling software is built around the Garp3 software [5]. The technical terminology used in this section is explained in these key references. The Garp3 software includes entities, quantity, magnitudes, derivatives, quantity space, model fragment and others. These modelling primitives are used to explain how the new use-levels proposed for the DynaLearn software will work. Detailed examples of how to build qualitative models, and therefore how to use these modelling primitives, are discussed in [4].

2.1. Conceptual modelling environment

The CM environment is the workbench in which the learner will develop qualitative reasoning models. The DynaLearn software will have six use levels as follows:

1. Concept map
2. Basic causal model
3. Basic causal model with state-graph
4. Causal differentiation
5. Conditional knowledge
6. Generic and reusable knowledge

Meta model information

These use-levels allow learners to build models at different levels of complexity, using a progressively increasing number of modelling primitives in each new use-level. Any use-level may be either the starting point for more complex models, to be built progressively in higher use-levels, or it may also be the final goal of the modelling/educational activity. In this way, educational activities within the DynaLearn software may address concepts and topics at different levels of complexity, depending on the educational goals or settings. A teacher has a great deal of flexibility, as the software may be regulated for the whole group to use just one level during specific activities, or change between levels in other activities. In some cases, learners may be stimulated to explore different levels, expressing ideas with increasing amounts of detail and complexity.

2.1.1. Concept map

Concept maps are widely recognised in many domains as a valuable tool for communication of ideas, creating consensus or planning models or essays. This use-level can be seen as the simplest entry level for modelling activities, as suggested in the current framework for building QR models [7].

2.1.2. Basic causal model

This is also a very simple use-level, useful in the initial stages of the learning process. It deals with entities and quantities; these have only derivative values, and the influences are identified only by an arrow and the signs + and –. There is no such a notion of (physical, biological or social) process [14]. Simulations in this level typically show information such as that if quantity A is increasing, then quantity B is increasing, C is decreasing and so on. This use-level may be very valuable from the educational perspective. Of course, for beginners, it may be the starting point for any modelling activity as this use-level would make it clear what should be expected in every possible behaviour path, including possible ambiguity in potential behaviours. Ambiguity is also an important issue in qualitative models, a critical thing to learn at an early stage in conceptual modelling. This use-level may also be used as the final goal of the modelling activity. For example, dealing with very complex problems this might be the unique approach to study the dynamics of complex systems.

2.1.3. Basic causal model with state-graph

As in previous use-levels, entities and quantities are included in the modelling space; all the quantities have values for derivatives (*increasing*, *stable* or *decreasing*) but one or more quantities have values for the qualitative magnitudes (e.g. concepts such as *small*, *below the normal*, *greater than the threshold*, etc.). The notion of quantity space, an ordered set of magnitudes with all the possible qualitative values a quantity may assume, is introduced. With the quantities having different magnitude values, simulations in this use-level produce behaviours with sequential states and state transitions where quantities change magnitude. Only arrows with the signs + and – indicate the type of influence. The simulation typically shows information such as that if quantity A is increasing, then quantity B is increasing, and the value of C is changing from *small* to *medium*, from *medium* to *large* and so on.

This use-level may be used for valuable educational activities exploring the dynamics of the system. It provides more semantics to the model for describing the system behaviour by combining changes in magnitudes and derivatives. From previous studies it is known that identification of possible (or important) qualitative values for each quantity, which means also to identify qualitative states for the variables and, by extension, for the whole system, is not an easy task [33]. In fact, the definition of quantity spaces is one of the most important aspects of qualitative reasoning modelling. This is because the vocabulary required to express qualitative states and to describe the system behaviour heavily depends on the quantity space definition. Also the notions of state and state transition (and the conditions for transitions to occur) are important aspects for understanding the system behaviour. It is expected that this use-level will become one of the most used by teachers and students in the DynaLearn software.

2.1.4. Causal differentiation

In this use-level even more tools and definitions are added to the model-building environment, particularly to express the notion of process. Among them, *direct influences* (I+ and I–) and *qualitative proportionalities* (P+ and P–), modelling primitives that express causal relations and mathematical functions required to calculate the values of the quantities during simulations, are added. In fact, mathematical interactions between magnitudes and derivatives of the quantities (such as A + B = C) become possible in this use-level. Educational activities in this level typically explore the notion of process, as a mechanism that causes the system to change. The concept of "rates" as measures of change within a period of time is the basis for understanding dynamics, and there is a great opportunity to explore this concept after the progression from the second use-level (expanding processes from the basic causal model).

2.1.5. Conditional knowledge

In this use-level, models can be read as "IF – THEN" statements, and it is possible to represent the conditions and consequences in dynamic systems. Conditions for processes to start and to stop, and for changes to propagate throughout the system, via causal chains, are at the centre of the learning issues explored at this use-level. Though some statements may be always true, without any condition to be satisfied, it may well happen that during the simulation, some statements that were true will no longer apply, whereas others may become applicable and specific processes or proportionalities will become active. The idea of representing conditions and consequences is very rich, and provides reality to the model. From the educational point of view, this is an important step towards understanding the functioning of complex systems. In fact, conditional relations explore integration between system elements, and expand the notion that even things that are not causally related may have important role on the dynamics of the system.

2.1.6. Generic and reusable knowledge

Here the conceptual modelling environment has the same facilities as the current version of Garp3 [5]. Models consist of a library of model fragments and a set of scenarios from which simulation starts. Combinations of reusable knowledge contained in the model fragments are used to create each state of behaviour during the simulation, an approach known as compositional modelling [14]. In this way, different, and even opposite, views on the same topic may coexist in the library of model fragments, and the knowledge captured can be reused to create more complex representations of the system. This use-level differs in many aspects compared to the previous use-levels. The use of generic and reusable knowledge allows for working with towards higher-level educational goals, such as formulating and representing hypotheses to explain how a system works, and providing representations for alternative hypotheses and comparing them. This use-level will probably only be used by advanced learners, users that are able to make the required abstractions in order to create complex qualitative models, using the previous use-levels only in specific circumstances (for example, in trying some modelling approaches or communicating ideas while planning model building).

2.1.7. Metadata

In addition to these use-levels, the conceptual modelling environment contains tools for annotating models and for describing metadata. These metadata may contain core information such as the model description and the educational goals. Also references to the motivational texts (from newspapers, magazines, technical literature) used to present the knowledge explored in the model should be included in the metadata. The model description should be made prior to starting the modelling process and should make reference to the use-level adopted. The metadata should then be updated when a new versions of a model is created or when the model is finished. Additional information about the modeller, date of model preparation and references to similar models will provide a capacity for models to be archived and reused. This will create potential for exchange of models and educational materials within a community of qualitative and conceptual modellers in education.

2.2. Virtual characters

DynaLearn will implement virtual characters into the learning environment to act as agents to engage and motivate the student during a modelling exercise. These virtual characters may take on a diversity of roles in education, including virtual teachers, advisors, learning companions and autonomous actors [2]. Empirical evidence has shown that pedagogical agents may engage learners and improve their perception of the learning task ([19]; [23]). They may reduce negative affective states of learners and promote motivation, engagement and self-confidence.

One of the challenges for DynaLearn is to design a coordinated set of agents that collaboratively provide added value to the conceptual modelling workbench as instruments for an engaging communicative interaction, using a coordination of pointing gestures and speech, and a rich repertoire of verbal and non-verbal behaviours. Particularly, different characters should be approachable for the learners to convey different kinds of 'knowledge' (e.g. general help, explaining the knowledge captured in a particular model, taking a quiz, learning companions, feedback on model errors, teachable agents, etc., as defined in the Description of Work, p. 10).

The DynaLearn project will explore multiple agents that may take on multiple roles, depending on the pedagogical objective to be achieved. The functionalities of the main characters in the DynaLearn software will provide learners with basic help and feedback. Learners may develop educational teachable agents to teach their peers. Other agents could play the role of a learning companion, a collaborator that foster learners' progress. The virtual characters will compare different models, pointing out similarities and differences, and others will provide questions for learners to answer

Communication between the virtual characters and learners will require a set of dialogues and templates for delivering educational content and for asking questions and giving answers. The agents' faces display emotions and some gestures that will complete the communication skills. The presentation of dialogue templates will use a narrative planner. Inspiration for presenting the curriculum comes from AutoTutor teaching tactics [15].

The teaching tactics used in AutoTutor start with the agent asking questions and presenting problems. These are of the *Why? How? What-if? What is the difference?* types of questions. Next, the agent evaluates meaning and correctness of learners' answers and gives feedback to the students. Some hints may be provided during the interaction, for example phrases to prompt for specific information; to give additional information that is missing; to correct bugs and misconceptions.

2.3. Semantic technology

Semantic technology will be used in the DynaLearn software to create ontologies based on the terms found in conceptual models. These ontologies may be useful to compare the model vocabulary to existing vocabulary in external resources and update them, if needed. The operation of the semantic technology requires the organisation of a concept into an existing taxonomy. This task includes term grounding (normalisation according to external resources), term integration (to check if a term exists in an ontology), to check if it is consistent with it (that is, the term relations also exist in the ontology). Finally, after expanding the ontology by including new terms / relations, the model integration occurs (grounding and integrating all the terms used in the model in the vocabulary).

3. Analisys of existing curricula on environmental science

This section presents an overview of the environmental science curricula in secondary and tertiary educational levels, in the institutions represented within the DynaLearn consortium.

3.1. EU directives for science education

Due to the strong increase of human pressures on the environment, the conservation and restoration of our natural environment and the development of sustainable strategies on both, a local and a global level, form central contemporary scientific, social and political issues. The high contemporary need for an adequate Environmental science education for a sustainable development has consequently been recognised globally (UN-Decade of Education for a Sustainable Development)[1]. On an European level the Eurydice network[2] systematically captures the organisation of education across the European member states, and also focuses on the ways Environmental science are currently taught and is identifying how to make Environmental science education more efficient and interesting [13].

Currently, environmental education in primary and secondary school systems is mainly embedded across different subject areas, in particular geography and natural sciences (notably biology) whereas in some countries an interdisciplinary thematic approach is used [35]. Unfortunately, the content and pedagogy associated with such curricula are increasingly failing to engage young people with the further study of science[3] [27]. These authors therefore recommend, based on an extensive analysis of science education in Europe, it is essential for improving student engagement to develop and to extend the ways in which science is taught. The DynaLearn project aims to contribute to that target by the production of interactive software and models on basic and contemporary Environmental science issues.

3.2. Existing curricula in environmental science at the national level

As a subject, Environmental science encompasses a wide range of scientific disciplines that should to be brought together in order to develop understanding about Earth systems and resources, and the many interactions among its physical, chemical, biological, social, economic and cultural components. As such Environmental science provides an integrated, quantitative, and interdisciplinary approach to the study of environmental systems. The DynaLearn project aims to bring new educational tools to Environmental Science education at the secondary and to higher educational levels. As part of this a new comprehensive curriculum needs to be developed to integrate all the essential topics, themes and educational goals for advancing Environmental science education. Therefore, a study of current curricula for secondary education and undergraduate university levels that address Environmental Science issues for the partner countries/institutions was undertaken to identify existing expectations and requirements for the DynaLearn curricula. This was done at both the secondary (Section 3.2.1) and university education levels (Section 3.2.2) to identify resources that may be utilised during development of topics, model and educational objectives.

[1] http://portal.unesco.org/education/en/ev.php-URL_ID=27234&URL_DO=DO_TOPIC&URL_SECTION=201.html

[2] http://eacea.ec.europa.eu/eurydice

[3] http://www.pollen-europa.net/pollen_dev/Images_Editor/Nuffield%20report.pdf

3.2.1. Environmental science at secondary educational level

Elements of Environmental science are present in all educational levels in the partner countries. In Bulgaria, for example, there are systematic lessons in primary school concerning natural resources with emphasis on biodiversity and nature conservation. The pupils learn about unity and diversity of living world (main biomes, typical ecosystems, popular/representative organisms) and main threats that man can cause to during its own and social/economic life. However, in most of the partner countries Environmental Science is taught as a component of more traditional subject titles such as the biological and physical sciences at the secondary level. Therefore, in most cases elements of Environmental science are traditionally part of the knowledge learned under the natural sciences curricula, which also include physics, chemistry and geography. In fact, notions of agriculture, mining of mineral resources, energy production by combustion of fossil fuel, oil and fuel production, some industrial processes and manufacturing of various goods, and environmental pollution effects on nature and human health are subjects in all textbooks used in secondary education level.

In Austria the main themes of the DynaLearn curriculum (such as Earth Systems and Resources, Living World, etc.) at the secondary school level are found in subjects such as Biology, Geography, Economics and Environmental Sciences. Additionally, some topics are also included in History and Social Studies, Chemistry, Household Economics and Food Supply. Human-nature and economics-nature relationships form an important content of the main school subjects. Meanwhile, in Brazil the Environmental science themes are included in the subjects of Biology and Geography. Often Environmental science issues are explored in interdisciplinary projects, a cornerstone of modern Brazilian secondary education level pedagogy. A similar situation is found in Bulgaria where all the main themes are distributed in the fundamental natural disciplines (Physics, Chemistry and Biology). In Israel, environmental issues are being addressed primarily in the Geography curriculum of the secondary education level. Two of the main concepts in the curriculum are mankind-environment issues and environmental management and conservation. The pedagogical rational is to develop and cultivate the students' higher order thinking skills while they actively construct their knowledge. Simultaneously, the curriculum also strives to develop their social and environments values (e.g. "caring, awareness and responsibility to maintain the environment while showing active involvement").

In the UK Secondary level education from 11 to 16 is covered by the different national curricula of the member countries (England, Scotland, Wales and Northern Ireland). From the age of 14 to 16 years old students are taught within the context of the General Certificate of Secondary Education (GCSEs). At this stage Environmental science themes are covered within traditional subjects such as geography and the biological and physical sciences. Education is not compulsory after the age of 16 years in the UK and all education after this is termed Tertiary Education. In most cases this is in the form of A Levels (General Certificate of Education, GCEs) potentially followed by an honours degree at a University or similar Further Education establishments. An A level qualification consists of advanced subsidiary (AS) and A2 units. The AS is a stand-alone qualification and is worth half a full A level qualification. It normally consists of two units (assessed at the standard expected for a learner half way through an A level course) that together contribute 50 per cent towards the full A level. The A2 is the second half of a full A level qualification. It normally consists of two units (assessed at the standard expected for a learner at the end of a full A level course) that together are worth 50 per cent of the full A level qualification.

At this level there is no national curricula for the courses and curricula and content are set by a number of different examination bodies that can offer accredited A level qualifications. In most cases these A levels still follow traditional topics such as geography, biology, physics, chemistry and geology. In all these subjects the curricula covers topics relevant to Environmental science, and although the actual content may differ among the different exam boards, the general themes in Environmental science remain similar. Currently only one examination group (AQA) offers a specialised course in Environmental Studies.

Within this course the two AS units are "The Living Environment" and "The Physical Environment" that cover the essential concepts relating to the biotic and physical components of the environment and their importance, and relation, to human activities and resources. In the A2 units, "Energy Resources and Environmental Pollution" and "Biological Resources and Sustainability", the future problems of and sustainability of physical and biotic resources are studied (AQA 2007).

The existing secondary and tertiary qualifications in each of the partner countries have detailed curricula documents describing contents, concepts and learning objectives important to the course. These resources will be utilised during the development of the DynaLearn curricula for Environmental Science to ensure that the content can be used to address the most appropriate learning objectives and outcomes where the models are to be delivered at a secondary education level.

3.2.2. Environmental science at the university level

With respect to the terms of undergraduate levels, FUB has a very interesting composition of the topics. The majority of the concepts came from correlated areas and courses as Biology, Agronomy, Geology, Veterinary, Geography, Politic Science and others. It was interesting to observe that the all of the main seven topics adopted in DynaLearn curricula were found in a myriad of Institutes and Departments, ranging from Ecology to Civil Engineering, for example. University of Brasilia, as other Brazilian universities, offer post-graduate courses on Environmental science, or have topics of it distributed in Biology, Geography, Chemistry, and Forestry courses.

In Austria, Environmental science education at an undergraduate university level is taught within a variety of Bachelor's programs, like Landscape Architecture and Planning, Environment and Bio resources Management and Environmental engineering, Biology and Environmental protection and Geography and Environmental System Sciences. A comprehensive overview of Bachelor's programs on Austrian Universities shows that Environmental science is an important content of the curriculum.

In Bulgaria, most of the basic DynaLearn environmental topics are represented in the current curricula of ecological and environmental education of students both in Bachelor, but especially in Masters Programs of the University of Sofia. The Bulgarian Academy of Sciences is granted to educate PhD-students only, including in Environmental science, but the curricula are specific/individual.

In higher education (at TAU), environmental issues are being addressed primarily at Porter School of Environmental Studies (PSES). PSES promotes new areas of interdisciplinary environmental research, introduces novel environmental teaching programs and places environmental issues on the academic and public agenda. In UK, a number of universities provide Environmental science contents distributed in undergraduate and graduate courses.

3.3. Educational goals to be achieved in environmental science

Defining appropriate educational goals and outcomes are a key step to developing useful curricula for education at both the secondary and university level. The study of existing curricula identified that these educational goals and learning outcomes are generally well defined for existing courses at both secondary and university level. These objectives and goals are often defined in terms of both specific topic goals and generic learning goals. Examples of current national curricula goals and learning outcomes are detailed below.

3.3.1. Content specific goals

In general the topics and themes delivered in programmes covering Environmental science aim at the development of an understanding of the interrelatedness of humans and their social and political systems with nature. Therefore, an understanding of natural processes and the effects of human activities on the environment form an important content. "Human-nature" and "nature-economics" relationships are of high relevance. Other important issues are energy use, tourism and agriculture and their effects on the environment, the effects of global change on living conditions and the environment and the sustainable use of limited resources. The basis for understanding the effects of human behaviour on the environment is formed by learning about natural environmental and ecological factors and processes acting on a local and global environment.

At the University undergraduate level the current curricula on Environmental science aim at the development of sectoral (domain specific) skills, and of other interdisciplinary skills, environmental skills, social and reflexive skills, economic skills, technical skills, jurisprudential skills and language skills. Of special interest for the DynaLearn project is the intended development of interdisciplinary and spatial (environmental) skills like interdisciplinary and cooperative working, identification of interconnections/cross-links, cross-linked thinking and acting, integration of different paradigms and points of view, feeling responsible for the environment, global thinking - local acting, identification of the conflicts of environment, economy and society (and science), identification of the landscape as habitat, sustainable management and sustainable use of resources and environmentally friendly economy.

3.3.2. Generic learning goals

Definition of generic learning goals and outcomes is now common practice for development of curricula. Given this the DynaLearn project will frame the topics and content developed to achieve content-specific goals within suitable generic learning goals. Examples of generic learning goals from Brazil and the UK are given below.

Although in the UK there is no national curriculum for A Level standard courses, and courses are defined by the relevant examination groups, there are national guidelines and standards for the learning goals and objectives at this level. In addition to the specific learning goals published in the curricula for specific A Level courses there are national descriptions of the generic learning objectives and standards required at the AS and A2 levels. The Qualifications and Curriculum Authority (QCA) defined the assessment objectives for A Level Biology as:

1. Knowledge and understanding of science and of how science works. Candidates should be able to:
    a. recognise, recall and show understanding of scientific knowledge;
    b. select, organise and communicate relevant information in a variety of forms.
2. Application of knowledge and understanding of science and of how science works. Candidates should be able to:
    a. analyse and evaluate scientific knowledge and processes;
    b. apply scientific knowledge and processes to unfamiliar situations including those related to issues;
    c. assess the validity, reliability and credibility of scientific information.

3. How science works. Candidates should be able to:

    a. demonstrate and describe ethical, safe and skilful practical techniques and processes, selecting appropriate qualitative and quantitative methods;

    b. make, record and communicate reliable and valid observations and measurements with appropriate precision and accuracy;

    c. analyse, interpret, explain and evaluate the methodology, results and impact of their own and others' experimental and investigative activities in a variety of ways.

In addition to these general assessment objectives the subject-specific curricula identify learning objectives and outcomes in terms of the knowledge and skills delivered at each level.

University courses and modules in the UK are also now prescribed in course prospectuses and curricula with detailed aims, programme outcomes in terms of knowledge and understanding, together with intellectual, practical and transferable skills that will be developed. At the University of Hull each course programme and specific module curricula details the particular learning and teaching methods that are applicable and the learning outcomes (knowledge and understanding, intellectual skills and transferable skills) that each will deliver.

In Brazil, nationwide educational goals to be achieved with the curricula in secondary schools are presented in the National Curriculum Parameters (PCN). Here, the goal is not only to address the knowledge presented in the disciplines, but to also use it as means to develop cognitive Competencies and Abilities. These competencies and abilities are listed below.

- Abilities:
    - Comprehend the multi signification of the language;
    - Identify central and peripheric information, presented in different languages, and its interactions;
    - Inter-relate objects of knowledge in different areas;
    - Organise strategies of action and select methods;
    - Select explicative models, formulate hypothesis and predict results;
    - Elaborate cohesive and coherent texts, with thematic progression and compatible structuring;
    - Apply adequate methods to the analysis and resolution of problems;
    - Formulate and articulate arguments appropriately;
    - Make inferences (inductive, deductive and analogical);
    - Critically analyse the solution found to a problem-situation;
    - Confront possible solutions to a problem-situation;
    - Judge the adequacy of technical, social, ethic, and politic options in the decision taking.
- Competencies:

- Dominate the Portuguese Language, basic knowledge of a foreign language (English, French or Spanish) and dominate different languages: mathematic, artistic, scientific, etc;
- Comprehension of natural phenomena, of technological and intellectual production of the cultural, artistic, politics and social manifestations, as well of the philosophic, historic, and geographic processes, identifying articulations, interests and values involved;
- Decision taking when confronting a problem-situation;
- Construction of consistent argumentation;
- Elaboration of proposals of intervention in the reality, demonstrating ethics and citizenship, considering the socio-cultural diversity as inherent to the human condition in time and space.

Both these "content-specific" and "generic-learning" types of educational and assessment goals can be used to help formulate the goals to be used at the different use-levels within the DynaLearn tools and curricula. During the development of topics and models educational goals will be defined depending on the use-levels that are most applicable to the educational context in which the DynaLearn approach will be used.

3.4. Organising the DynaLearn environmental science curriculum

Given the diverse nature of topics that are relevant to Environmental science curricula, together with the potential application of the DynaLearn for self-motivated and self-directed learning, the structure of the DynaLearn curricula can be viewed as a web of topics rather than a linear sequence of topics. Taking this "web of topics" perspective, the DynaLearn software can provide opportunities for students to explore interesting knowledge in any number of different sequences created according to the users' needs or interests. However, default routes can also be defined and will be suggested to beginners. In this case, models provided by project experts will be organised according to the following general principles: (a) from simple to complex issues; (b) from practical (observations or experiments) to theoretical aspects of the domain; (c) from fundamental to periphery themes [17].

In the DynaLearn project, these principles will be applied to assignments that explore components first, such as single model fragments, and then specific states in behaviours, in which different model fragments are combined to represent qualitatively distinct states of the system. Having studied isolated states, the users could the further explore behaviour paths in simulations, in which the sequences of states would represent typical behaviours of the system.

Within each topic or among different topics of the curriculum, contents can be organised in different ways. Following [17], DynaLearn will adopt three ways to create sequences of contents: those related to concepts, to scientific investigations, and sequences that explore how knowledge is to be used.

In sequences related to concepts, the content follows the logic of knowledge organisation. For example, topics on availability of natural resources and human population growth precede topics related to the world carrying capacity. In DynaLearn this can be done by establishing correlations between the models available in the repository, or between model fragments or specific simulations.

Sequences related to investigations are those that try to reconstruct the some idealised methodology used by scientists. For example, these sequences would explore observations, hypotheses formulation, hypotheses testing and theory formulation. This approach to curricular sequencing is of special interest for this project given that DynaLearn tools for modelling excel in supporting learners in representing alternative hypotheses about a particular issue. Also learners can compare the results obtained in different simulations to test if each hypothesis is true. Having pre-selected simulations and adequate bibliographical support, learners may combine a set of hypotheses and formulate qualitative theories about specific domains.

Finally, in sequences related to how knowledge is to be used, organisation of content depends heavily on the context. For example, in topics related to energy and global changes, learners could first explore concepts involved in the use of fossil fuels for industrial production, transportation, consumption of goods and CO_2 release to the atmosphere during all these activities. This knowledge can be further used to explain themes related to global warming and the consequences for the climate, natural ecosystems, agricultural production and human well being.

The DynaLearn curricula will identify suitable pathways and sequences for students to move between exploring different topics and themes. Pre-requisite and similar topics and themes will be identified for each model and topic developed. It is anticipated that this is an area where the semantic technology will provide avenues for students to explore similar topics and create learning sequences.

4. Criteria for selecting themes to be addressed in the curriculum

Humans live in two worlds, a natural one, constituted by plants, animals, micro organisms, soil, air, water, that precede us and of which man is part of. The other world was created by human culture, and includes institutions, religion, education, science and technology, legislation, and so on [12]. Integrating these two worlds is essential for sustainability. Understanding how the integration works is the main goal of Environmental science studies. This section presents an overview of a generic Environmental science curriculum, based on the seven main themes defined in the DoW. After thoroughly reviewing existing curricula and the context provided by each DynaLearn partner, the themes were selected in accordance to the following requirements: relevance for the Environmental science; adequacy to the local context of the partner who is going to develop model contents and educational material; and potential for motivating the use of the learning tools available in the DynaLearn software. Each of these three requirements is examined below.

4.1. Relevance for environmental science

In this section, the selected topics are presented in accordance to their relevance to Environmental science curricula, taking the general DynaLearn curriculum based on the seven themes as the basis. In section 5 these topics are associated to educational goals to be achieved with the support of the DynaLearn software (section 2). The topics selected for further development with the DynaLearn tools are underlined.

4.1.1. Earth systems and resources

In Environmental science curricula, the Earth is seen as part of the living systems and the source for many of vital resources, both for biological processes and for the economic basis of human societies. There are many opportunities for DynaLearn tools to be used in Environmental science curricula, exploring marine systems, continental systems, which include both land and freshwater systems, and their interaction with the atmosphere.

Earth systems are moulded by a number of natural driving forces. Climate factors are among the strongest ones and as such are an essential component of any Environmental science studies. Extreme natural phenomena as earthquakes, tsunamis, volcanic eruptions and floods, have caused big changes on Earth systems. In fact, the Earth is a dynamic and constantly changing system. Natural processes forming riverine landscapes and habitats constitute interesting topics for environmental curricula.

Mankind has explored the Earth's crust for more than a millennium, searching for minerals used in several man-made products, such as iron, copper, aluminium, oil, plastics, synthetic fabric and so on. Mining and drilling have been an essential human activity, though often results in social and environmental devastation.

A clear knowledge of nutrient availability and cycling, such as the Carbon, Nitrogen, Phosphorus and Sulphur biogeochemical cycles is fundamental to understanding the importance of the earth systems to the living world and to human societies [26]. Besides a general view on these cycles, the DynaLearn project will pay special attention to the water cycle, as it has important connections with all the vital processes in the biosphere, and to the economic aspects of human society. Flood events in river catchment areas deserve special attention in Environmental science curricula as they paradoxically contribute to create wealthy civilizations, such as the Egyptian society that flourished around the fertile margins of the

Nile, and to cause some of the worst natural disasters, such as the flood of Yangtze River, in China, that killed 37 million people in 1931 [12].

Understanding which processes create and maintain natural habitat dynamics forms the basis of sustainable habitat management, which has become a central issue for the preservation of many wildlife species, in order to avoid the loss of habitat or to assure its ability to regenerate. This is not a trivial task as for some species it may require understanding the thermal dynamics in freshwater bodies, and for others, their adaptation to environmental stress. This last topic provides opportunities to explore fundamental processes such as diffusion, osmosis and active transport. This topic also provides opportunities for models that explore the basic mechanism of mass transport, for example, in the passage of water through a plant, and the effects of the size of the organ or the organism, and the effect of the surface area (membranes) on gas exchange.

To maintain, or to enhance, habitat it is necessary to control of succession, cull or remove undesirable species, provide suitable conditions and create of biological corridors to link habitats [30]. Finally, management of habitat may be related to the continuity of human activities. The concept of ecological services may well illustrate these ideas – biotic and abiotic natural processes, such as nutrient cycle and pollination, are essential both for specific economic systems and the whole life to keep going [22].

4.1.2. The living world

Life has been evolving for some 4 billion years, and a number of evolutionary mechanisms contribute to living organisms being adapted to Earth systems that are also dynamic. Knowledge on the theory of evolution is required to explain how these organisms became adapted to the huge diversity of habitats provided by the Earth systems [3]. Besides understanding evolutionary processes such as selection, adaptation and speciation, knowledge on fundamental genetics and reproductive strategies is required to understand how biodiversity is created and maintained [36].

Populations constitute the basic organisational level for environmental studies. Understanding organisms' vital processes (natality and mortality), their movements (immigration and emigration), environmental factors that regulate their growth processes, their reproductive strategies (r and K) and density dependency are important aspects to be explored by in a curriculum for Environmental science.

The study of communities, the biotic component of an ecosystem, also offers interesting opportunities for DynaLearn tools to make a difference in science education. Species interactions, such as competition or positive and negative symbiosis involving two or more populations, are important processes that shape community structure. Marine ecosystems, by means of their importance for the future of the global living systems, and by current concern for their protection, will be used as a specific context for some of the DynaLearn curriculum and conceptual modelling content on species interactions.

Community-specific features, such as species diversity, disturbance, resilience, complexity and succession ([3]; [36]), also provide important issues for an Environmental science curriculum. Two examples will be developed in the DynaLearn project. Decomposition provides a good opportunity for exploring the interdependence of living things. The study of the roles and interaction of decomposers and detritivores in decomposition and recycling nutrients shows that species interdependence often requires conservation of communities of species rather than individual species.

The second example refers to a well-established concept in ecological theory. The river continuum concept explores combinations of abiotic and biotic factors that create different conditions in the upper part of the river, then the middle part and finally at the end, the mouth of the river, that are occupied by different communities, each adapted by the local conditions.

Human induced transformations to Earth systems have brought many of them to very close of the collapse. As an answer to this situation, conservation biology has been developed and included some relevant concepts, such as modern theories of island biogeography, the genetics and the survival of endangered species, metapopulations and habitat fragmentation ([29]; [20]).

4.1.3. Human population

Finding adequate habitat and resources in the Earth Systems and learning how to explore the Living World to obtain food, medicines and raw materials, the human species could grow. Despite Malthusian predictions about the limits for growth, the human population increased to 1 billion in the beginning of the 19th century, reached 3 billion in the middle of the 20th century and now it is greater than 6 billion people. Today, on average, every second 4-5 children are born and 2 other people die somewhere on the Earth.

Of course, this large population is consuming increasing amounts of resources, and producing increasing amounts of waste. The Earth's capacity to feed humans and to metabolise their residues is now actually being challenged. Studies about the dynamics of human populations are included in every curriculum of Environmental science. Humans have to learn how to combine natural factors and their needs and expectations for the future.

Human population growth is of special interest for Environmental science studies. It is the major driving force behind anthropogenic changes in Earth systems. Decisions on how many children to have are influenced by many factors, such as food security, housing, culture, religion, social services and so on [22]. Understanding the social aspects of human population growth is an essential requirement for the DynaLearn project. The Curriculum and contents developed within DynaLearn will explore these as important factors that may contribute to sustainability.

Accordingly, education is viewed as the main force that may shape the future, and as such puts influence on all the rest of human features. Relationships between health and the environment are of great interest, as they bring about a number of modern issues, such as the definition of priorities for public polices, the identification of new diseases, and the use of scientific knowledge and innovation capacity to explore Earth systems and resources, for example, biotechnological exploitation of marine organisms to create new products and processes to be used in medicine and agriculture.

After thousands of years during which human populations were mostly rural, in recent years urbanisation became a main issue, to the point at which modern man is essentially an urbanite. According to the UN Population Fund (UNFPA), since 2008 the world has reached an invisible but momentous milestone: for the first time in history, more than half its human population, 3.3 billion people, is living in urban areas[4]. Tentative of changing the modern man dwelling with the principles of the green architecture, meaning sustainable housing, in the sense that energy and resources expenditure are reduced and optimised.

While resources are becoming scarce and the Earth's carrying capacity approaches, there is a tendency to develop and to apply environmental oriented legislation in order to discipline organisation and functioning of companies, institutions and the government and to protect the environment and the future generations. Environmental education is also part of this effort, and the 3R's principle (reduce, reuse, recycle) illustrates how human behaviour has to change for a sustainable world [11].

Looking for sustainability in the economy, tourism and recreation are among the most prized alternatives for economic development. In fact, natural river landscapes are highly valued with regard to tourism and

[4] http://web.unfpa.org/swp/2007/english/introduction.html

recreation. These aspects of riverine landscapes will also be considered as a component of a sustainable development of river catchments, and furthermore will provide insight into the human perception of riverine landscapes.

Recognising the importance of education, health and economy, the UN developed the Human Development Index[5] (HDI), as an indicator of human development. HDI combines normalised measures of life expectancy, literacy, educational attainment, and GDP per capita for countries worldwide. It is claimed as a standard means of measuring human development—a concept that, according to the United Nations Development Program (UNDP), refers to the process of widening the options of persons, giving them greater opportunities for education, health care, income, employment, etc. The basic use of HDI is to measure a country's (or a regions' or the cities') development[6].

4.1.4. Land and water use

In the context of growing human population and exploitation of Earth systems and resources, it is more than expected that conflicting interests would clash when the land is to be used. The curricula and content developed in DynaLearn will also explore the causes of land-use conflicts. In fact, conflicts involving competing, adjacent or multiple land uses are often held responsible for environmental and social damages. For example, the expansion of urban areas requires transport development, such as new/enlarged roads, ports and airports. Often these examples of land occupation correspond to natural or rural areas reduction, and sometimes with population displacement. Methods of resolving land-use conflicts include legislative methods, the use of Environmental Impact Assessment (EIA) techniques to ensure that environmental impacts are considered in the planning process. Economic methods based on pricing mechanisms and cost benefit analysis are also commonly used. Land-use zoning, that includes space zoning and time zoning provide specific measures and techniques for conflict resolution.

Besides that, increasing human population requires the development of agricultural techniques that may increase food production. Problems arise when food production is obtained at the cost of reducing land covered by natural vegetation, which protects biodiversity and provides ecological services, or by using toxic substances that may pollute soil and water resources [36]. Intensive agriculture refers to the use of techniques heavily based on technological products and non-intensive labour. This approach is rooted in the 1950's so called Green Revolution, which is based on the use of machinery, chemical fertilisers, pesticides, intensive irrigation and, more recently, of genetically modified organisms ([8]; [16]).

Although the Green Revolution and intensive agriculture significantly increased productivity, paradoxically famine and malnourishment still affect millions of people in the poorest countries. In fact, two aspects may contribute to explain the bad results. Actually, low productivity is not the main cause of famine and malnourishment, but problems in the food distribution – while obesity and diseases related to the excess of certain types of food are affecting increasing numbers of people in developed countries, African populations are starving [34]. Also, techniques used in intensive agriculture had proven to cause environmental damages that may create unsustainable situations [37].

Recently there is a growing interest in agro-ecological systems, a generic approach that is strongly related to organic farming, biological pest control, sustainable management of soil and water uses, and the application of indigenous knowledge as possible alternatives that assures food security and high productivity in biodiversity friendly agriculture[7]. Complementary to these points is the use of biological

[5] http://hdr.undp.org/en/humandev/hdi/

[6] http://en.wikipedia.org/wiki/Human_Development_Index

[7] http://www.cnr.berkeley.edu/~agroeco3/principles_and_strategies.html

pest control, as an alternative to chemical pesticides, as these synthetic products affect a number of non-target species, contribute to the development of pests' resistance and may affect human health [28].

Alternative agricultural approaches may also contribute to reduce two of the main environmental problems in many countries, deforestation and erosion. Deforestation contributes to climate changes, results in biodiversity loss, may cause serious damage to ecological services and contributes to erosion, soil loss and transport of sediments to water bodies [38]. Stimulated by a growing culture of corporate greed and consumerism, and supported by spurious interests of local governments, the last areas covered by rainforests are being replaced by pasture, livestock and soya beans plantations [18].

Erosion is an important natural process that is part of both soil formation and soil loss [22]. Erosion processes are related to the deposit rich alluvial silt in river bottoms, resulting in a rich soil adequate for people to farm it. In some places, erosion occurs very rapidly, resulting in deep gullies, created where water scours away the soil and, at the extreme condition, may lead to desertification. The total annual soil loss from croplands is estimated in 25 billion metric tons. Also, it is estimated about twice that much soil is lost from rangelands, forests and urban construction sites [12].

Water use is heavily affected by land use changes and constitutes another problem with potentially difficult solutions. Flood protection measures may cause alteration of the river morphology and loss of natural floodplains, which in turn may produce effects on water and nutrient retention, both important ecological services of natural floodplains. Water issues should be generally tackled by considering the catchment area as the most important territorial unit. Key issues for understanding the meaning of integrated plans for management of catchment areas are, besides an understanding of the natural processes being active within a specific catchment, the needs and interests of local human populations and stakeholders. To achieve an integrated management, a strong integration of different scientific disciplines and a structured way of integrating the local population and different stakeholder groups are needed.

Irrigation is the only solution for food and raw materials production in arid zones of the world. However, this technique may cause the salination of the soil, hampering further use of the land for agricultural purposes. Drinking water supply is also a great concern in many arid areas, and a number of techniques have been developed for this goal. Other uses of water resources include transportation, dilution of effluents, energy production and fisheries are among the most important uses of the water, but changes in land use may provoke negative effects and hamper its use [12].

4.1.5. Energy resources and consumption

From the perspective of the energy required by the Living world, green plants play a central role: they get energy directly from the Sun, by means of the photosynthesis. This is a process that converts light, a form of diffuse energy, into high-quality chemical energy, which can be stored into sugar molecules (biomass) for posterior use. In addition, photosynthesis removes CO_2 from the atmosphere and, after a series of chemical reactions that also involves water in the interior of the chloroplast, releases O_2 back to the air. The energy converted into biomass via photosynthesis corresponds to 1-2% of the sunlight falling on plants, and this is what represents the base for almost all the biological energy[8] used by the Living world [12].

The process of releasing the energy stored in biomass by living organisms is known as cellular respiration. Aerobic respiration is a process very much similar to photosynthesis, but operating in opposite direction. A series of chemical reactions in the interior of mitochondria releases the energy stored in chemical bonds of

[8] Exceptions are the chemosynthetic organisms, in which specific reactions involving hydrogen sulphide (H_2S) or hydrogen gas (H_2) provide energy for the synthesis of organic compounds [12].

sugar molecules is released and captured in chemical bonds of other types of molecules, which in turn can be stored again for immediate use in cell metabolism. During the process, aerobic respiration degrades the sugar molecule up to the same initial molecules, while consumes O_2 and releases CO_2 into the atmosphere. A slightly different type of respiration (anaerobic respiration) does not use O_2 and stops before all the available energy in molecule of sugar is released. Anaerobic respiration may produce alcohol or other intermediate compound, which can be further used as a source of energy (see below). This way a nice balance between photosynthesis and respiration is established: the two sets of reactions absorb and release O_2 and CO_2 while energy is stored temporarily in chemical bonds.

Green plants (which for the purposes of the present work include algae and some species of bacteria) are able to perform both photosynthesis and respiration, and are called autotrophs; animals, fungi and the rest of micro organisms are only able to do respiration, and are called heterotrophs. This classification is the basis for the ecological classification of organisms respectively as producers and consumers, and explain the basic structure of food chains and food webs: producers produce biomass (and in doing so store energy and nutrients) which is used by consumers to produce their own biomass (and in doing so also store and use energy and create different combinations of nutrients) and finally a special class of consumers, the decomposers, degrade organic matter into its simplest forms and release nutrients, that become available again for the green plants. Note that the energy cannot be available again for the producers to start again the process, a restriction that is explained by the thermodynamic laws. The result is a combination of nutrient cycling and energy flow via the food web [26].

All Environmental science curricula explore the balance between photosynthesis and respiration. In fact, at the community level, the total photosynthesis and corresponding accumulation of organic material at the level of producers represents the primary production and the storage of biomass at higher trophic levels is the community's secondary production.

The DynaLearn project curricula and contents move forward exploring other sources of energy, which ultimately are often uses of solar energy by mankind. Deposits of organic material that are extracted from the ground and are capable of being burnt for fuel, chiefly oil, coal and gas, are known as fossil fuels [1]. These have been the main sources of energy since the Industrial Revolution, and because of the greenhouse emissions, society is now looking for alternative sources of energy.

Hydropower energy is widely used as source of energy; it is considered to be "clean", as the carbon released by hydropower plants is negligible. However, these plants often require large dams, created by flooding large areas of forest or rural areas. The consequences, human population displacement, habitat and biodiversity loss, and often the disappearance of sites of cultural value, are object of fierce discussions. Wind is also seen as clean energy, as it involves transformation of the wind force into mechanic energy and further into electricity. In this case, objections to wind as a source of energy are based on prices, negative effects on the fauna, noise and landscape visual pollution.

Recently the use of biomass as a sustainable source of energy is growing. This can be done in different ways. For example, using energetic forests both for restoration of degraded areas and as source of wood, vegetal coal and cellulose, and obtaining biofuels from energetic crops, such as corn and sugar cane. In this case the bio-fuel is alcohol obtained from anaerobic respiration of the sugar contained in the crops. Objections to the use of corn are based on prices and on the use of a traditional food, source of proteins, minerals and carbohydrates of high quality, for a less noble usage. The plantation approach to sugar cane production results in a number of environmental problems that include soil and water pollution by pesticides and residues of alcohol production, and by deforestation of large areas of natural forests in developing countries (Brazil being the biggest example). Other alternative sources of energy such as solar energy and hydrogen cells may also be included in the DynaLearn curricula for the sake of comparison to the above mentioned sources of energy.

4.1.6. Pollution

Pollution, as we know it, became an issue after the Industrial Revolution. Factories and the consumption of coal and other fossil fuels produced air pollution, industrial chemical discharges and untreated human waste. A remarkable catastrophic event was the great smog in London in 1952, which killed at least 8000 people. This massive event prompted some of the first major modern environmental legislation, The Clean Air Act of 1956. Since then, a number of disasters involving different types of pollution have occurred. For example, toxic waste (20000 ton of dioxin accumulated in Niagara Falls, NY, 1947-1978); oil spills (1.6 million barrels released from the Amoco Cadiz cargo, 1978) and release of radioactive material (accident in a nuclear plant in Chernobyl, 1986). The world's worst industrial disaster happened in Bhopal, 1984, when 42 tonnes of a gas used for pesticide production were released exposing more than 500000 people, killing 8000- 10000 within 72 hours, and an estimated amount of 25000 people so far[9].

However, although these events has triggered awareness in the population and a broad set of environmental legislation, everyday a huge quantity of pollutants is released in virtually all the Earth systems threatening the whole biosphere. The topics selected for the DynaLearn curricula and contents will provide an overview of the main types of pollution affecting the major types of environment. The marine environment is a highly diverse ecosystem, consisting of various sub-ecosystems, from rocky or sandy shores to deep waters, each characterised by diverse physical and chemical conditions and by typical biological communities. Studies about the chemistry and physics of marine environments may highlight some mechanisms under which these systems evolved in natural conditions, and how they are nowadays being threatened by man-made activities.

Fundamental knowledge on diffusion and osmosis[10] is required to understand how some pollutants disperse in the environment, particularly dispersal in water and air, and how they affect, considering that molecules of pollutants may have to cross the cell membrane in order to directly interfere on biological processes. Such knowledge is also required to better describe the dynamic aspects of dispersion and distribution of both conservative and non-conservative pollutants. Conservative pollutants are those that remain unchanged while passing through treatment processes, that is, their concentration do not change with time. Heavy metals, such as cadmium and lead, are conservative pollutants. This type of pollutant may be removed by the treatment processes, retained in the plant's sludge or may leave in the plant effluent. Non-conservative pollutants are biodegradable compounds, such as organic materials, and their concentration varies with time. In both cases, these two themes are interesting by their effects on the biodiversity on community structure, and on ecological services.

All the species are limited in where they can live, limited by the prevailing biotic and abiotic conditions known as their tolerance limits [12]. Limitations are due to physiological stress due to inappropriate levels of some critical environmental factor (light, moisture, temperature, specific nutrients, pH), competitor or predator species. Sometimes the requirements and tolerances of species are useful indicators of specific environmental conditions, so that the presence or absence of such species indicates something about the community or the ecosystem. Lichens are the classical example of species indicators, because they are sensitive to sulphur dioxide. If lichens disappear, it is possible to infer that sulphur dioxide is above a certain concentration [12].

DynaLearn topics include organic water pollution caused by sewage, industry and agriculture residues; air pollution caused by greenhouse gases, sulphur dioxide, nitrogen compounds, particulate material, and air toxin; and the effects of soil pollution caused by solid, toxic and hazardous waste. The curriculum and contents will include the conditions of pollutants production, their effects on the environment and on

[9] http://en.wikipedia.org/wiki/Pollution

[10] http://en.wikipedia.org/wiki/Osmosis

human health and what are the requirements for pollution mitigation. Restoration is also of great importance for Environmental science, and a case of river rehabilitation will provide the opportunity of a multiple view on the causes and consequences of pollution.

4.1.7. Global changes

As globalisation advances in creating a global society, so do human actions in creating global environmental problems. Atmospheric oxygen and ozone and the protection of the ozone layer provide a good example of how adequate legislation, international cooperation and technological advances may reduce environmental problems at a planetary scale. Atmospheric ozone is produced by the photochemical dissociation of oxygen (O_2) resulting from absorption of ultraviolet solar radiation to form atoms of oxygen (O). These atoms collide with molecular oxygen (O_2), which in turn absorbs solar radiation. This way, the ozone layer limits the amount of ultraviolet radiation reaching the ground surface [1].

It has been shown that several groups of chemical substances containing either chlorine or bromine used in industry play a role in ozone depletion. The Montreal Protocol on Substances That Deplete the Ozone Layer is an international treaty designed to protect the ozone layer by phasing out the production of a number of substances believed to be responsible for ozone depletion. It entered into force in 1989, and if the rules are successful, the ozone layer is expected to recover by 2050. Due to its widespread adoption and implementation it has been hailed as an example of exceptional international cooperation, perhaps the single most successful international agreement to date.

How do international agreements and treaties on environmental issues and cooperation for sustainability work? In a way, such agreements establish a plan to solve specific environmental problems. To be successful, they certainly establish regulations for the actions each part shall undertake in favour of common goals. The consequences of the treaties becoming into force may affect public policies and cause behaviour changes. Some of these international efforts would require more than agreements. International cooperation for sustainability is more than ever a condition to solve global problems. Qualification of human resources, technology development and transfer and projects financing are some areas that may establish the common ground for cooperation [12]. For the DynaLearn project goals, it is interesting to follow up the international agreements with a representation of possible changes in internal affairs and public policies. Natural and human factors have significant influence on climate changes effects on river catchments, especially those related to hydrology, water temperature land use and energy production. Depending on the local situation different restoration/resilience/development scenarios for riverine landscapes and aquatic ecosystem services are possible.

After the Montreal Protocol success similar treaties to control the emission of greenhouse gases are being discussed, in order to face threats from the so-called climate changes. The DynaLearn curricula and contents will explore different aspects of this global problem: global warming, drought and ocean effects. Climate change and the consequences on temperatures in marine, freshwater and land environments is certainly an elucidating topic for the consequences of global warming. Among the expected effects, increasing sea levels, changes in biological communities affecting species with more restrict tolerance limits, changes in the productivity of crop species, the expansion in the distribution area of some disease vectors. Climate change and freshwater shortage and scarcity address issues of great impact, such as human population migratory movements, loss in agriculture and livestock, decreasing economic production, increasing incidence of diseases. Biological problems related to adaptations to climate change in marine ecosystems will show interesting aspects of species interactions, habitat use and trophic structure in marine communities in response to abiotic factors.

Invasive species transported by ships all over the world became an important problem in many countries. Ballast water discharge typically contains a variety of biological materials, including plants, animals, viruses, and bacteria. These materials often include non-native, nuisance, exotic species that can cause extensive ecological and economic damage to aquatic ecosystems. DynaLearn materials will explore both the ecological and the economic aspects of invasive species.

Finally, an approach to human behaviour will focus on reducing the pressure on energy and environmental resources by changing the consumption standards, in order to achieve sustainable standards goods and services production and consumption. This theme will result in a large diversity of topics, as consumerism is associated to market forces, which do not relate to a resource saving economy. Also, in order to "decarbonise" the modern society a great deal of solutions to reduce the greenhouse gases emissions are being proposed. In fact, this topic addresses both how to remove CO_2 from the air, and how to move to a low carbon society. This last topic would require alternative sources of energy (wind, solar), stop deforestation and plant trees to recover degraded land, use bikes and public transportation, produce less waste and so on.

4.2. The local context

An overview of the reality of each partner is presented in this section. It shows how the selected topics are related to the partners' reality and expertise, and they are prepared for the next round of activities in DynaLearn, which involves the preparation of the models and lessons on the topics selected.

4.2.1. BOKU

Relevant issues for an integrative understanding of main processes of riverine landscapes form the main content of the curricula taught at the Institute of Hydrobiology and Aquatic Ecosystem Management (IHG). The institute covers an interdisciplinary team of scientists from the ranges biology, ecology, geography, history, landscape ecology and planning, and agricultural engineering. The main focus of research and education is 'Applied Running Waters Ecology' with working groups on fish ecology, riverine landscapes and benthic river ecology. These working groups encompass both aquatic and terrestrial habitats along with their biocoenoses, including anthropogenic structures and land-uses. The spectrum of activities of the IHG ranges from detailed studies of individual running water habitats or sections small-scale assessment') to the comprehensive evaluation of the functional ecological, societal and economic interrelationships in entire watersheds ('large-scale assessment'). The selection of topics and models explored by the BOKU was based on their relevance for existing upper secondary environmental science curricula in Austria and University undergraduate level curricula at the BOKU and on their potential to enhance learning and understanding of general aspects of the environment with a special focus on river catchments. Based on the expertise of the IHG the following key issues intrinsically linked to the seven main topics to be covered by the DynaLearn curriculum (Fig. 1) were identified as a framework for the definition of the specified models to be developed for the DynaLearn workbench:

- Development of different morphological river types and the effects of river regulation/land use.
- Different restoration/resilience/development scenarios for riverine landscapes.
- Aquatic ecosystem services and their affection by different human pressures.

Fig. 1 shows the relationships of the identified key issues for a sustainable catchment to the main topics to be covered within the DynaLearn project.

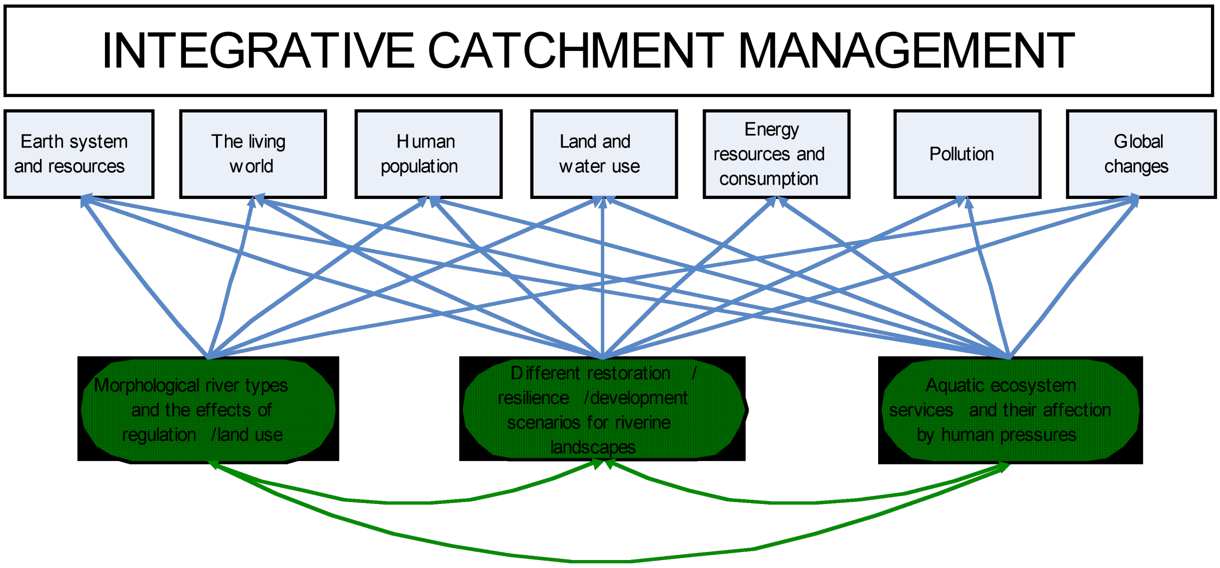

Figure 1: Key issues identified for the development of the curriculum on sustainable catchment management in relation to the main topics to be covered within the DynaLearn project.

4.2.2. CLGE

Sharing the general view that the science curricula are subject to a worrying decline and the number of students is falling (less students take science curricula and more drop out) for the last decade, under the DynaLearn project the CLGE-team is aiming to develop environmental curricula for creating capacities of learners to understand and interpret the unity and diversity of ecological/ environmental entities and processes, pressures and impacts, situations and states, and to develop their own social/civil position and (pro)active behaviour supportive to the societal, environmental and nature sustainability.

Within WP6 the activities of the CLGE-team will be developing of learning curricula for two most common categories of water bodies – rivers and lakes, which are the main source of water resources for humans (Earth Systems & Resources). Rivers and lakes are not simply volumes, which contain water, but they are an environment for tremendous biological diversity of aquatic ecosystems (Living World) in the same time, and use to provide humans with various ecosystem services. Humans and their societies (Human population) explore commonly the water as a renewable resource (Energy resources & consumption) losing side of fragility of aquatic ecosystems and threatening the capacity of water bodies to provide further these services (Land & Water Use) by polluting the waters (Pollution) and/or changing the natural water circles (Global Changes).

Based on their own expertise, the CLGE-team will develop similar curricula for two most common types of water bodies – rivers and lakes, including their riparian/fringing communities. The basin/watershed approach is accepted as basic/fundamental one. After constructing the physical and biological (leading species, communities, trophic structure, mass/energy flows, etc.) elements/entities of two categories of water bodies, similar processes will be studies in comparison with river and lake ecosystems. Developing such model curricula, the CLGE-team will teach students of unity, similarity and differences between entities and processes in rivers and lakes, of responsible environmental variables and ecological communities for their running and/or preservation, thus providing them with knowledge how to manage environmental situations/states in order to ensure sustainable development of both natural environment/resources and prosperity of human society.

4.2.3. FUB

The University of Brasilia was created in 1961, soon after the Brasilia foundation, with the mission of becoming involved with the problems of the Central Brazil. Accordingly, this region has undergone significant changes over the past 50 years. Agriculture focussed on bio-fuel, livestock production and grains to export point out for the need of sugar cane, pastures and soya. In this context it is clear the necessity of better understand the meaning of the ecological services and the principles of conservation biology. FUB is also involved with important national and international questions, including biodiversity management, water resources management, deforestation, erosion, consumerism, control of greenhouse emissions, and alternative sources of energy. Four institutions at FUB are at the front line of Environmental science: Institute of Biological Sciences, Forestry, Geography and the Centre for Sustainable Development.

FUB also holds a number of programs aiming at to strength the secondary educational level, which includes initial and continuous training secondary school teachers, curricula discussions and the development of educational projects. Finally, FUB holds expertise in qualitative reasoning models and uses in educational settings, including support for learners with special needs (deaf). FUB expectations on DynaLearn products rely on flexible software and a set of models, with different levels of complexity, and a methodology for building models. The combination of these products would facilitate the use of DynaLearn in the classroom, both in secondary and tertiary educational levels.

4.2.4. TAU

The combination of environmental research, policy analysis and cooperative endeavours makes TAU a qualified partner deeply involved in developing viable solutions to the fundamental environmental problems confronting the Mediterranean Basin[11]. Environmental issues are being addressed primarily at The Porter School of Environmental Studies (PSES). The PSES promotes new areas of interdisciplinary environmental research, introduces novel environmental teaching programs and places environmental issues on the academic and public agenda. These interdisciplinary studies include areas such as technology and climate change, global warming and renewable energy, epidemiology and sustainability.

As such, of the marine environment is of great importance for TAU, as it provides biological and physical resources for the whole country. Studies in marine biology at TAU include coral and artificial reefs' sandy and rocky shores, sea grass beds, benthos and pelagic zones. Besides that, the local context shows the strong relevance of understanding environmental problems related to climate stress, water resources shortage, green architecture, agriculture and soil exploitation, and sustainable development.

Several ecosystems that are found in Israel will be studied during the DynaLearn project. These include terrestrial: including coastal sand cliffs, sand dunes, and islands; marine: including coral and artificial reefs' sandy and rocky shores, sea grass beds, benthos and pelagic zones. Besides that several ecological processes will be studied in each ecosystem. For example, ecological succession processes, invasive species and migration, species population ecology, prey-predator interactions, food chain, and competition. Understanding the processes affecting these ecosystems will teach students of their importance and will assist students in planning conservation strategies for them.

[11] http://www.environment.tau.ac.il/Eng/

4.2.5. UH

The Hull International Fisheries Institute is a specialist research group within the Department of Biological Sciences at the University of Hull. The Institute and Department offer courses at the pre-certificate (foundation level equivalent to A level), undergraduate and post-graduate (masters) level. The Institute has vast experience in research, consultancy, education and training in the fields of fisheries science, aquatic resource planning and management and environmental assessment and management. In addition to this expertise the Department of Biology also has expertise in aquatic ecology and resource management, evolutionary biology, cellular processes and aquatic ecophysiology.

Within the University of Hull Environmental Science is covered by degree programmes in both the Biology and Geography departments. Within Biological Sciences undergraduate honours degrees are offered in the themes of Biology, Aquatic Zoology and Marine and Freshwater Biology. At post-graduate level courses are offered in a diverse range of themes covering Aquatic Conservation, Aquatic Resource Planning and Management, Biodiversity and Conservation, Aquatic Science and Management, Fisheries Science and Fisheries Policy and Planning. Within these degree programmes topics are covered in a modular basis. Within these modules students move from studying the main biological/ecological principles to building on that knowledge with the context of topics such as resource management, threats and remedies in the aquatic environment, freshwater fisheries and conservation and other modules containing environmental and applied biological/ecological themes.

Within this context UH will look to develop models and content that can be used to explore fundamental biological and ecological concepts, of use at A level, pre-certificate and early undergraduate levels, which can then be expanded to consider topics of fisheries resources and other similar advanced topics at advanced undergraduate levels.

4.3. Learning enhancement by using DynaLearn tools

In this section, opportunities for exploring environmental curricula with DynaLearn tools are discussed. Two examples are presented below, ecological services and consumerism, in order to give an idea of how the work will be developed within all the themes. The basic structure starts with the presentation of a motivational text, followed by an explanation on the importance of the topic for environment science curricula, the importance for the learners given their local context, the educational goals to be achieved and the expected use of the DynaLearn tools, namely the conceptual modelling environment, the pedagogical agents and the semantic technology.

It is important to note that any of the topics selected here could be represented in each of the six use-levels available in the conceptual modelling environment. Also, the interaction with learners will use the functionalities provided by the pedagogical agents and the semantic technology, briefly presented in section 2, and discussed in depth in the deliverable D2.1.

4.3.1. Earth systems and resources: Ecological services (FUB)

Initial explanation about the selected topic

“Mankind benefits from a multitude of resources and processes that are supplied by natural ecosystems. Collectively, these benefits are known as ecosystem services and include products like clean drinking water and processes such as the decomposition of wastes. Ecosystem services are distinct from other ecosystem products and functions because there is human demand for these natural assets. Services can be subdivided into five categories: provisioning such as the production of food and water; regulating, such as the control of climate and disease; supporting, such as nutrient cycles and crop pollination; cultural, such as spiritual and recreational benefits; and preserving, which includes guarding against uncertainty through the maintenance of diversity.”

(from wikipedia)

The topic importance for the Environmental science curriculum

Understanding the interconnection between economic systems and natural systems and processes is an important step for society to reduce deforestation, erosion, biodiversity and natural resources loss. In fact, economists used to focus only in the capital and the working force while preparing plans for economic development, and to consider environmental factors as externalities [10]. This situation has changed in the last 30 years and Environmental science courses seek to establish and make clear the relations between ecological services and the whole economy.

The topic importance for the local context

This is a sensitive topic for Brazil as the country’s economy has increased significantly in the last 70 years, at the cost of degradation of the natural capital and the sacrifice of ecological services. Deforestation, for example, while opening new areas for farming, and therefore to food and raw materials production, has contributed to increasing GHG emissions, erosion, deterioration of water resources and biodiversity loss.

Educational goals: using the topic contents to explore competences and abilities

Ecological services raise a number of problems to be solved that might contribute to the development of a number of learners' cognitive abilities. For example, given a situation related to the economic exploitation of an area covered by natural vegetation and associated educational material, the use of qualitative models may help the student to critically analyse the situation and point out positive and negative aspects of the deforestation on the basis of ecological services.

DynaLearn tools: using CM, VC and ST to support communication with the learner

In this context, DynaLearn tools may be useful in many ways. An example of how this topic may be developed is presented as follows. The use-level 3 (basic causal model and the state graph) in the conceptual modelling environment allows for creating simple models that establish causal relations between deforestation and other environmental factors:

deforestation → soil erosion → water resources loss;

deforestation → habitat loss → species extinction;

deforestation → fragments of vegetation → number of local populations.

Having done models about these topics, the teacher proposes an assignment in which the first causal chain is further developed in levels 4 and 5 of the CM environment, in order to create models exploring details of the relation between forest, soil and water. Using the semantic technology, DynaLearn classifies the models and establishes a relation between ontologies that include the entities forest, soil and water, and refines it doing a taxonomic reasoning and finally making the connection between the forest – soil –water system and a number of ecological services.

The pedagogical agents mediate the communication between the DynaLearn software and the learner. They play different roles, before, during and after then modelling process. One of these roles is to provide feedback to learners, with recommendations about how to improve the model in levels 4 (identifying processes) and 5 (establishing conditions for processes to start and to stop). As a sort of final homework, learners may teach an agent this knowledge about ecological services and use the agent to explain to other learners the importance of forest conservation.

4.3.2. Global Changes: Consumerism (FUB)

"Consumerism has strong links with the Western world, but is in fact an international phenomenon. Peoples purchasing goods and consuming materials in excess of their basic needs (subjective) is as old as the first civilisations (see Ancient Egypt, Babylon and Ancient Rome, for example). A great turn in consumerism arrived just before the Industrial Revolution. While before the norm had been the scarcity of resources, industrial revolutions created an unusual situation: for the first time in history products were available in outstanding quantities, at outstandingly low prices, being thus available to virtually everyone. And so began the era of mass consumption, the only era where the concept of consumerism is applicable. It's still good to keep in mind that since consumerism began, various individuals and groups have consciously sought an alternative lifestyle, such as the "simple living", "eco-conscious", and "buy local" movements."

(from wikipedia)

Consumerism is a relevant topic for the environment science curriculum, as it refers to 'bad' behaviour of the consumer, who is not aware of the problems production and consumption are causing to the environment. These are not neglectable problems, as the population is already big and is still increasing, very aggressive and seductive advertisements published in well paid media pushes the consumer to buy superfluous goods and causes the expenditure of water, energy and natural resources and the disposal of effluents and solid residues to very high levels. In fact, changing the consumer behaviour is one of the goals in any Environmental science curriculum.

Consumerism is also a relevant problem in Brazil and other developing countries, as expanding the market is a cornerstone for the economic development paradigm adopted in these countries. Against the industry goals, the media and governmental policies, environmental education seeks to reduce the consumption levels. Qualitative models and modelling have a great potential for exploring the consequences of consumerism, by presenting and comparing the current situation and possible alternatives.

Motivation for a collaborative educational project about consumerism could be done with advertisement material, newspaper and magazine texts discussing consumerism, and statistics about environmental resources used to produce some goods and services. Educational material associated to this material may include activities aiming at critically comparing possible solutions for a problem. For example, according to [12; p. 572], the impact of consumerism may be reduced by purchasing less (ask yourself whether you really need more stuff), reduce excess packaging (buy items with minimal packing and carry reusable bags when shopping), avoid disposable items (use cloth napkins, handkerchiefs and towels; avoid single-serving foods), conserve energy (walk, bicycle, use public transportation), save water (don't leave water running when washing hands, dishes and the teeth).

DynaLearn agents may help teachers to start projects, presenting the group of learners the educational material, and including in the group a companion agent also involved in the task. The group can then discuss how to start the modelling effort and decide for creating a concept map (use-level 1 in the conceptual modelling environment) around the consumerism concept. After using it to explore possible outcomes for the project, the group can start with creating basic causal models in second use-level of the CM environment. A number of possibilities can be explored, and some maybe chosen for further development. Accordingly, teachers may assign to different groups the task of expanding parts of the causal model and improving their representation in use-levels 5 and 6. In this way, the group could explore in more detail the processes associated to consumerism and not only how causality propagates in this system.

The final product of this project may be a library of model fragments assembled from input coming from all the groups in the classroom, exploring opposing consumer behaviours as follows: the impact on energy use by unconscious consumers replacing items in their house *versus* conscious consumers that use the same items for longer periods; the production of solid residues by unconscious consumers who buy items with lots of packing material and disposable packs *versus* conscious consumers that carry their own bags and avoid single-use packs; the impact on water use by unconscious consumers who don't care with long showers and open taps during toilet *versus* conscious consumers who care. Agents supported by different internal and external ontologies may run a quiz competition among the students after the end of the project.

5. Detailed description of the selected topics

In this section, the topics to be developed by the DynaLearn project are presented in more detail, focussing on a preliminary view of the educational goals to be achieved. It is important to note that at this stage of the project, only preliminary and generic goals can be established for each theme. Of course, during the modelling process specific literature, evaluation requirements and curricula links with other themes/topics will provide better conditions for refinement of the educational goals set at this stage.

5.1. Topics to be developed in WP6

In this section the topics selected for development in WP6 are presented and associated to general educational goals. Each theme is assigned to a DynaLearn partner, identified as the topic "leader". The topic leader will be responsible for the development of models and contents related to that topic, and by the integration of this topic with the other themes in the Environmental science curriculum.

5.1.1. Topics on earth system and resources

Themes	**Lead**	**Educational goals**
Climate factors	TAU	To identify the relevant climate factors for understanding the dynamics of a specific ecosystem taken as case-study; To establish causality chains that propagate changes triggered by climate factors.
Natural processes forming riverine landscapes and habitats	BOKU	To describe natural processes shaping morphological features of rivers; To compare different types of rivers and verify how the natural processes have work.
Mining	FUB	To describe how mining influences the environment, given a specific case-study; To discuss mitigation measures for the damage caused by mining, given a specific case-study,
Nutrient availability and cycling	UH	To describe the main nutrient cycles, with special attention to stocks and processes of nutrient transfer among stocks; To establish the connections between nutrient cycles and resources required by human societies.
Water cycle	CLGE	To describe the water cycle, with special attention to exploitation at vulnerable points of the cycle; To identify specific points of the water cycle in which technology and environmental education may reduce vulnerabilities.
Habitat dynamics	TAU	To identify processes relevant for the creation and maintenance of habitat features, necessary to assure the survival of a specific population

		or community; To model how natural processes influence the structure and quality of habitats required for a specific population or community as a basis to develop sustainable management strategies.
Thermal dynamics in freshwater bodies	CLGE	To describe the influence of thermal dynamics of freshwater under the thermal influences; To identify the effects of thermal stratification on species distribution and ecological processes in stagnant water bodies.
Adaptation to environmental stress	UH	To describe examples of population or community adaptation to different types of environmental stress; To compare different adaptations to similar conditions of environmental stress.
Ecological services	FUB	To describe how natural processes may affect human activities; To present the causality flow among selected factors in order to make predictions and provide explanations about a particular phenomena in a specific case study.

5.1.2. Topics on the living world

Themes	**Lead**	**Educational goals**
Evolution	UH	To present some of the basic issues required for understanding fundamental aspects of the evolutionary theory; To represent in qualitative models case studies that show how evolutionary concepts justify topics in Environmental science.
Biodiversity	CLGE	The define biodiversity in different organisational levels (populations, species, communities); To model basic principles required for representing biodiversity in the context of the impact of human actions, including conservation activities.
Reproductive strategies	CLGE	To present an overview of general aspects of sexual and asexual reproduction and how such generic models might be used to represent reproduction in specific taxonomic groups; To compare different reproductive strategies in the context of conservation activities.
Populations	BOKU	To develop general models about the vital processes (natality, mortality) and population movements (immigration, emigration) and show such generic models being used to represent the dynamics of specific taxonomic groups; To reuse population models to create representation of more complex

		interactions, such as two population models.
Species interactions	TAU	To model positive and negative interactions between different species populations; To use species interactions models to express relevant topics for understanding environmental phenomena, for example, decomposition, trophic relations, nutrient cycling and energy flow.
Community specific features	TAU	To model specific features of biological communities, as for example species diversity, disturbance and resilience, complexity and succession; To compare specific features of different biological communities.
Decomposition	UH	To describe relevant aspects of biotic and abiotic interactions involved in the decomposition process; To compare decomposition rates of different materials under different physical conditions.
The river continuum concept	BOKU	To explain how the structure of aquatic communities are influenced by the internal conditions of the water body and by its surroundings; To compare environmental conditions and communities in different parts of a river.
Conservation biology	FUB	To model basic principles of biological conservation of different ecosystems and taxonomic groups; To demonstrate applications of these basic principles in case studies specifically designed to represent relevant topics of Environmental science curricula.
Meta-populations	FUB	To represent the basic concepts related to fragmented landscape and how a set of populations interacts. To demonstrate how basic concepts related to metapopulations can be used to design conservation practices.

5.1.3. Topics on human population

Themes	**Lead**	**Educational goals**
Social aspects of human population growth	FUB	To establish the causal relations involving elements from society, culture, economy and environment related to human population growth; To demonstrate how different social aspects may influence family planning and population growth.
Education	BOKU	To establish causal relations among relevant elements from society, culture, economy and environment related to the education; To demonstrate that education may improve the conditions of a

		particular society in a given situation described in a case study.
Biotechnological exploitation of marine organisms	TAU	To establish causal relations among relevant elements from society, culture, economy and environment related to the exploitation of marine organisms in biotechnological applications; To demonstrate that biodiversity protection may improve the conditions of a particular society in a given situation described in a case study.
Health and the environment	FUB	To establish causal relations among human health aspects and environmental factors; To demonstrate situations in which changes in the environment may improve or make worse the health conditions of a specific human population.
Urbanisation	CLGE	To represent characteristic features of urban areas and show how nutrient cycles a energy flows through the cities; To model typical urban environmental problems and possible solutions for them.
Green architecture	TAU	To demonstrate relevant elements that that characterise buildings as environmental friendly; To compare buildings built according to the principles of green architecture and others built in a traditional way.
Legislation	CLGE	To represent how legislation regulates the functioning of man-made systems, by means of controlling the causality flow among specific quantities; To compare the effects on the environment of having different legislation regulating specific case studies.
Reduce, reuse, recycle	UH	To model the 3 Rs in order to put them in the context of environmental education for sustainability; To compare situations in which each of the 3 Rs may contribute to achieve more sustainable conditions.
Tourism and recreation	BOKU	To establish causal relations among relevant elements from society, culture, economy and environment related to the tourism industry; To demonstrate the viability of the tourist activity, considering given conditions in a particular case study.
Human Development Index (HDI)	UH	To model the three main elements of the HDI (economy, health and education) and how they interact to compose indicator of human development; To establish relations between environmental factors and each of the HDI components.

5.1.4. Topics on land and water use

Themes	Lead	Educational goals
Land-use conflicts	CLGE	To establish causal relations involved in conflicts resulting from competing land uses in a specific case study; To compare different land-uses in order to develop management strategies for sustainable exploitation of a piece of land in a specific case study.
Intensive agriculture	CLGE	To characterise the main features of intensive agriculture and establish causal relations with society, culture, economy and environment; To demonstrate the importance of alternative solutions to limitations of intensive agriculture that may lead to environmental damage and/or unsustainable situations.
Agroecology systems	UH	To establish causal relations among relevant elements from society, culture, economy and environment related to the exploitation of consortia of agriculture, forest and livestock; To compare productivity and the environmental impact of agroecology and intensive agriculture systems.
Deforestation	FUB	To identify causal relations between society, culture, economy and environment aspects related to forest exploitation; To compare alternative approaches to the consequences of deforestation.
Erosion	FUB	To identify causal relations between society, culture, economy and environment aspects related to erosion and sediment transportation; To demonstrate possible actions that could prevent erosion, recover degraded soil and to implement sustainable soil management.
Flood protection	BOKU	To identify the main elements necessary to reduce the damage caused by flood in catchment areas; To compare different solutions for flood protection given different land-uses in specific case studies.
Integrated plans for management of catchment areas	BOKU	To demonstrate how the ecosystems play a role in supporting flora and fauna, providing services to human societies, and regulating the human environment by making explicit the causal relations involved; To compare different management plans of catchment areas in order to establish differences and similarities between integrated and non-integrated approaches.
Irrigation	TAU	To characterise the main features of irrigated agriculture and establish causal relations among society, culture, economy and environment factors;

		To compare different approaches to irrigation with respect to productivity and environmental impacts.
Drinking water supply	TAU	To describe relevant elements in natural ecosystems and man-made systems and establish causal relations related to with societal, cultural, economic and environmental aspects of drinkable water production and consumption. To compare alternative methods to obtain drinking water and to supply it to human populations in a sustainable manner.
Fishery	UH	To identify what would be the most relevant biotic and abiotic factors for fishery exploitation and establish causal relations involving these factors; To explore the ecological, social and economic aspects of freshwater fisheries and conservation.

5.1.5. Topics on energy resources and consumption

Themes	**Lead**	**Educational goals**
Photosynthesis	UH	To identify the most relevant factors involved in autotrophic energy metabolism and establish causal relations among photosynthesis and the nutrient cycling and energy flow; To present an integrated view on aerobic respiration from the molecular level to the biosphere.
Aerobic respiration	UH	To identify the most relevant factors involved in aerobic energy metabolism and to establish causal relations among them and the nutrient cycling and energy flow; To present an integrated view on aerobic respiration from the molecular level to the biosphere.
Anaerobic respiration	TAU	To identify the most relevant factors involved in anaerobic energy metabolism and to establish causal relations among them and the nutrient cycling and energy flow; To demonstrate biological and industrial applications of anaerobic respiration.
Primary production	TAU	To identify the most relevant factors involved in the production of biomass by the photosynthetic process and establish causal relations involving environmental factors with primary productivity; To represent how human actions and natural events may hamper or improve primary production and what are the consequences for natural systems and for social, cultural and economic aspects of human systems.
Secondary production	CLGE	To identify the most relevant factors involved in storage of biomass at

		higher levels of the trophic structure and establish causal relations involving environmental factors with secondary productivity; To represent how human actions and natural events may hamper or improve secondary productivities and what are the consequences for natural systems and for social, cultural and economic aspects of human systems.
Food webs and energy flow	BOKU	To define trophic relations among producers, consumers and decomposers and to describe causal relations coming from society, culture, economy and the environment that may influence nutrient cycles and energy flow through food webs; To compare different food webs in order to point out relevant factors that may hamper or improve efficiency of energy transfer and accumulation in specific case studies.
Fossil fuels	CLGE	To identify the most relevant factors involved in the use of fossil fuels, and to establish causal relations among them and society, culture, economy and environment; To compare fossil fuels to non-conventional sustainable sources of energy with respect to socioeconomic output and environmental impacts.
Hydropower generation	BOKU	To identify the most relevant factors involved in hydropower generation, and to establish causal relations among them and the requirements for a sustainable action; To compare fossil fuels to non-conventional sustainable sources of energy with respect to socioeconomic output and environmental impacts.
Sustainable sources and use of energy (wind)	FUB	To identify the most relevant factors involved in the use of wind as an energy source, and to establish causal relations among them and society, culture, economy and environment; To compare fossil fuels to non-conventional sustainable sources of energy to non-conventional sustainable sources of energy with respect to socioeconomic output and environmental impacts.
Sustainable sources and use of energy (biomass)	FUB	To identify the most relevant factors involved in the use of biomass as an energy source, and to establish causal relations among them and society, culture, economy and environment; To compare sustainable sources of energy to non-conventional sustainable sources of energy with respect to socioeconomic output and environmental impacts.

5.1.6. Topics on pollution

Themes	Lead	Educational goals
The chemistry and physics of marine environments	TAU	To identify relevant chemical and physical aspects of marine environment and establish causal relations that may explain changes in structure and behaviour of these systems due to pollution. To compare possible solutions to the effects of pollution events on the basis of social, cultural, economic and environmental aspects in specific case studies.
Diffusion and osmosis	UH	To establish causal relations among the forces that drive the movement of molecules either or not through membranes; To model and compare different situations in which the movement of molecules plays significant role and may explain the behaviour of specific systems.
Dynamic aspects of dispersion and distribution of conservative pollutants	CLGE	To identify environmental conditions that may speed up changes in the concentration of conservative pollutants and establish causal relations that may apply in water resources management; To demonstrate in specific case studies how to cope with conservative pollutants contamination in aquatic environment in order to reduce pollutant concentration to safe levels.
Dynamic aspects of dispersion and distribution of non-conservative pollutants	CLGE	To identify environmental conditions that may speed up the decay process and consequent changes in the concentration of non-conservative pollutants and establish causal relations that may apply in water resources management; To demonstrate in specific case studies how to cope with non-conservative pollutants contamination in aquatic environment in order to reduce pollutant concentration to safe levels.
Indicator species	BOKU	To identify adaptive features in some organisms that make them able to survival in stressful conditions and to establish causal relations that may be used in management actions. To present case studies in which species indicators are used to characterise pollution events in specific case studies.
Organic water pollution	BOKU	To identify elements associated production and decay of organic pollution and establish causal relations that may be used for management actions. To compare different actions for organic pollution mitigation with respect to social, cultural, economic and environmental aspects in order to point out sustainable solutions in specific case studies.
Air pollution	TAU	To identify relevant aspects of the atmosphere and establish causal relations with ecosystems that may explain changes in structure and behaviour of these systems due to pollution.

		To compare possible solutions to the effects of air pollution events on the basis of social, cultural, economic and environmental aspects in specific case studies.
Soil pollution	FUB	To identify relevant aspects of the soil and establish causal relations with society, culture, economy and environment that may explain the consequences of soil pollution. To compare possible solutions to soil pollution in order to define sustainable solutions in specific case studies.
Pollution mitigation	FUB	To identify measures that may prevent or reduce the damage caused by pollution and establish causal relations that may be used to management actions; To compare different actions for pollution mitigation with respect to social, cultural, economic and environmental aspects in order to point out sustainable solutions in specific case studies.
River rehabilitation	UH	To identify relevant aspects that characterise the rehabilitation process and establish causal relations between the river and factors that may degrade the river; To compare alternative solutions for river rehabilitation seeking sustainability and taking into consideration society, culture, economy and environment factors.

5.1.7. Topics on global changes

Themes	**Lead**	**Educational goals**
Atmospheric oxygen and ozone	CLGE	To establish relevant factors that influence the dynamics of production and consumption of oxygen and ozone in the atmosphere and establish causal relations involving human actions; To represent hypotheses about how human actions may improve or make worse the production and consumption of oxygen and ozone in the atmosphere in specific case studies.
Climate change effects on river catchments	BOKU	To demonstrate the effects of global change on water cycle, organisms, land use and energy production at the catchment level; To explore alternative scenarios for restoration/ resilience/ development of riverine landscapes and aquatic ecosystem services according to the local effects of climate change.
International agreements and treaties on environmental issues and cooperation for sustainability	BOKU	To establish relevant factors that describe the conditions for and results of legislation and international agreements and cooperation on environmental issues among institutions and/ or governments for sustainable development; To represent hypotheses about how agreements and treaties, cooperation and human actions may result in sustainable decision-

		making and management of environmental issues in specific case studies.
Greenhouse gases	UH	To identify the main green house gases and to establish the causal relations among societal, cultural, economic and environmental factors that result in these gases; To compare alternative practices and structures in order to explain choices and measures that may result in reduced levels of green house gases emission.
Climate change and the consequences of changing temperatures	UH	To represent causal relations among human-made systems, climate factors, atmospheric temperature and the consequences of temperature variation for environmental issues; To represent hypotheses about human actions may mitigate the effects of temperature variation on natural and man-made systems.
Climate change and freshwater shortage and scarcity	CLGE	To represent causal relations between human-made systems and climate factors that may result in freshwater shortage and scarcity; To demonstrate the consequences of freshwater shortage and scarcity for human-made systems and natural ecosystems and discuss how to mitigate negative aspects of these environmental problems.
Adaptations to climate change in marine ecosystems	TAU	To identify how climate factors influence the structure and behaviour of populations, communities and the whole marine ecosystem and establish a web of causal relations that result in adaptive traits; To represent hypotheses about how human actions may improve or make worse the climate conditions that affect marine ecosystems in specific case studies.
Ballast water discharge	TAU	To describe the mechanisms of ballast water invasions and establish causal relations involving threats to local species and ecosystems put by alien species; To represent hypotheses about how to contain the spread of exotic species and reduce the damage caused by these species in specific case studies.
Consumerism	FUB	To identify the most relevant factors and establish causal relations involved in the production of goods and services, advertisement and consumerism; To compare greedy and uncontrolled consumerism to a sustainable approach to consumption with respect to society, culture, economy and environment.
Low carbon society	FUB	To determine biological, social and physical aspects of human society that result in carbon emissions and to establish causal relations that may be involved in controlling the level of emissions. To compare biological or human-made systems with respect to their structure and behaviour and demonstrate how sustainable levels of carbon emissions may be achieved in specific case studies.

6. Discussion and final remarks

This Deliverable presents 70 topics associated to seven main themes defined to become the DynaLearn project curriculum. The topics were selected to fulfil the following requirements: relevance for Environmental science curricula; adequacy to the local context where the models, educational goals, learning materials and curricula will be developed and tested; potential for learning enhancement with the tools developed in the DynaLearn software.

Preliminary educational goals were defined for each of these topics, and will be useful as guidelines in the next phase of the project. For each topic a model and lessons will be developed, after research on specific literature and refinement of the educational goals, and used in evaluation activities of the DynaLearn software.

A number of challenges are posed to the DynaLearn team. Apparently the most difficult challenge is to prepare the students for learning by modelling. In fact, for the learner to be able to create models in the software, a set of preliminary activities is required. A set of expert models is needed, to serve as starting point to students that want to build up similar ideas. From this point of view, the framework for building qualitative reasoning models [7] may be adapted to novices use, and the six use-levels available in DynaLearn conceptual modelling environment (section 2.1) will be very useful. The existence of simple models, created by experts, exploring basic knowledge will complete the initial material for the modelling activities.

The 70 topics presented in this Deliverable were identified as comprehensive enough to address basic knowledge in Environmental science. Of course, some of them may look quite complex, but the idea of creating simple models that may be combined into more complex ones, an approach known as compositional modelling [14], assures the WP6 experts will get right level for simple representations of complex ideas.

The closest experience to DynaLearn was the NaturNet-Redime project (STREP project co-funded by the European Commission within the Sixth Framework Programme (2002-2006), contract no. 004074). Similarities may be found in some of the themes related to sustainability addressed by NaturNet-Redime. For example, aquatic food webs and the influence of nutrient dynamics [9], photosynthesis and respiration in aquatic environment [24], water pollution, deforestation and urbanisation [31], life cycle of fish species [25] and the role of public policies in catchment management [39]. However, in all the work done in NaturNet-Redime the goal was not learning by modelling with the support of the expert model. In this way, all the models described are far more complex than what is expected for the DynaLearn models that are being designed here.

According to the DynaLearn project approach, a curriculum can be seen as a web of topics, instead of a linear sequence of contents, and this approach opens up to new ways for knowledge organisation. This approach would cope with the diversity of students' interests and aspirations by exploring opportunities to provide interdisciplinary and contextualised contents.

Students that participate on decision-making about their curricula may become active learners, who autonomously seek for learning resources and organise their studies. They would benefit from IT tools with interesting interfaces and problems to be solved, as they do in computer games. The use of ready-to-use models, the possibility of combining parts of models in order to obtain new models, and creating new models may have a great impact on learning. Such impact can be greater if model usage and modelling activities are supported by adequate didactic material. Consequently, the DynaLearn project has the potential for benefiting teachers and students.

The initial steps described in this Deliverable indicate that knowledge consolidated in the DynaLearn Environmental science curriculum, represented in the conceptual modelling environment, delivered with the support of virtual agents and of semantic technology, has the potential for bringing scientific knowledge to learners' quotidian experience and for transforming the learning by modelling approach taken in DynaLearn into an enjoyable and productive experience.

During the next phase of the DynaLearn project, partners involved in WP6 will develop simple models and educational material about basic concepts in each of the 70 topics presented in this Deliverable. For each model, the developer will provide a model meta-description, along with supporting scientific literature about the concepts addressed in the model. Associated educational goals will be detailed, and the use-levels of the conceptual modelling environment in which the model should be explored will be explained. The model itself will be presented in details, and modelling decisions will be justified in terms of existing literature and/or learning goals. Lesson plans will be prepared in accordance to the guidelines defined in WP7, and links with other topics in the Environmental science curriculum will be established. This material will be further used for evaluation of the DynaLearn software functionalities. Evaluation will be done in two phases. After the refinement of the models and educational goals and the improvement of models and software based on the results of the first round of evaluation activities, the second round will be the final evaluation of the whole material produced in the project. Details can be found in the Description of Work (DoW), WP6 and WP7.

References

[1] Allaby, M. (ed.) (2004) *The Oxford Dictionary of Ecology*. 2nd edition. New York, The Oxford University Press.

[2] André, E. (2008). Design and evaluation of embodied conversational agents for educational and advisory software. *In* Luppicini, R. (ed.), *The Handbook of Conversation Design for Instructional Applications*, IGI Publishing Information Science Publishing, IRM Press.

[3] Begon, M.; Townsend, C.A. and Harper, J.L. (2005). *Ecology: from individuals to ecosystems*, 4th edition, Wiley Blackwell Publishing.

[4] Bredeweg, B. and Salles, P. (2009). Mediating conceptual knowledge using qualitative reasoning. *In* Jørgensen, S.E., Chon, T-S. and Recknagel, F. *Handbook of Ecological Modelling and Informatics.* Southampton, UK, WIT Press, p. 351-397.

[5] Bredeweg, B.; Bouwer, A.; Jellema, J.; Bertels, D.; Linnebank, F. and Liem, J. (2006). Garp3 - A new Workbench for Qualitative Reasoning and Modelling. *20th International Workshop on Qualitative Reasoning*. Bailey-Kellogg, C. and Kuipers, B. (eds.), p. 21-28, Hanover, New Hampshire, USA.

[6] Bredeweg, B.; Salles, P.; Bertels, J.; Rafalowicz, D.; Bouwer, A.; Liem, J.; Feltrini, G.M.; Caldas, A.L.R.; Resende, M.M.P.; Zitek, A. and Nuttle, T. (2007). *Training report on using QR for learning about sustainable development*. Naturnet-Redime, STREP project co-funded by the European Commission within the Sixth Framework Programme (2002-2006), Project nº. 004074, Project Deliverable D7.2.

[7] Bredeweg, B.; Salles, P.; Bouwer, A.; Liem, J.; Nuttle, T.; Cioaca, E.; Nakova, E.; Noble, R.; Caldas A.L.R.; Uzunov, Y.; Varadinova, E. and Zitek, A. (2008). Towards a structured approach to building qualitative reasoning models and simulations, *Ecological Informatics*, 3(1): 1-12.

[8] Cassman, K. (1999). Ecological intensification of cereal production systems: yield potential, soil quality, and precision agriculture. *Proceedings of National Academy Science*, 96: 5952–5959.

[9] Cioaca, E.; Bredeweg, B.; Salles, P. (2007). Qualitative Reasoning Model to support Sustainable Development decision making - Danube Delta Biosphere Reserve Environmental System case study. *Scientific Annals of the Danube Delta Institute (Tulcea, Romania)*, 13: 210-212.

[10] Colby, M.E. (1991) Environmental management in development: the evolution of paradigms. *Ecological Economics*, 3: 193-213.

[11] Consumo Sustentável (2005). Consumo Sustentável: Manual de Educação. Brasilia, Brazil, Consumers International/MMA/MEC/IDEC, 160p.

[12] Cunningham, W.P. and Cunningham, M.A. (2008). *Environmental science: a global concern*. New York, NY, McGraw-Hill, Higher Education, 626 p.

[13] EURYDICE (2006). Science Teaching in Schools in Europe - Policies and Research. Eurydice, the information network on education in Europe (http://www.eurydice.org).

[14] Falkenhainer, B. and Forbus, K. (1991). Compositional Modeling: Finding the Right Model for the Job. *Artificial Intelligence*, 51(1-3): 95-143.

[14] Forbus, K. D. (1984). Qualitative process theory. *Artificial Intelligence*, 24: 85-168.

[15] Graesser, A.C.; Wiemer-Hastings, P.; Wiemer-Hastings, K.; Harter, D. and Person, N. (2000). Using latent semantic analysis to evaluate the contributions of students in AutoTutor. *Interactive Learning Environments*

[16] Green, R.; Cornell, S.; Schalermann, J. and Balmford, A. (2005). Farming and the fate of wild nature. *Science*, 307: 550-555.

[17] Krasilchick, M. (1996) *Prática de Ensino de Biologia*. São Paulo, Brazil, Harbra.

[18] Laurence, W.F. and Peres, C.A. (eds.) (2006). *Emerging threats to tropical forests*. Chicago and London, The Chigago University Press.

[19] Lester, J.C.; Converse, S.A.; Kahler, S.E.; Barlow, S.T.; Stone, B.A. and Bhogal, R.S. (1997). The persona effect: affective impact of animated pedagogical agents. *Proceedings of the SIGCHI conference on Human factors in computing systems*, New York, NY, USA, p. 359-366, ACM Press.

[20] Lovejoy, T.E. (2005). Spotlight on Brazil. Editorial in *Conservation Biology*. 19(3): 587-588.

[21] Machado, N.J. (1995). *Epistemologia e didática: as concepções de conhecimento e inteligência e a prática docente*. São Paulo, Brazil, Cortez Editora.

[22] Miller, G.T. (2007). *Environmental science: working with the Earth*. 11th edition, Brooks/Cole Publishing, Cengage Learning edition.

[23] Mulken, S.V.; André, E.; and Müller, J. (1998). The persona effect: How substantial is it? *Proceedings of HCI on People and Computers XIII*. London, Springer-Verlag, pages 53-66.

[24] Nakova, E.; Bredeweg, B.; Salles, P. and Nuttle, T. (2007). A Garp3 model of environmental sustainability in the River Mesta (Bulgaria). *In* Price, C. (ed.) *Proceedings of the 21st International Workshop on Qualitative Reasoning (QR'07)*. Aberystwyth, (Wales, U.K.), 26-28 June, 2007, pages 87-95.

[25] Noble, R.A.A.; Salles, P. and Bredeweg, B. (2007). *QR models and documentation for the implementation of UK case studies on the River Trent and Great Ouse focusing on the links between the ecological and socio-economic aspects of sustainable river rehabilitation and management.* Naturnet-Redime, STREP project co-funded by the European Commission within the Sixth Framework Programme (2002-2006), Project no. 004074, Project Deliverable D6.5.2.

[26] Odum, E.P. and Barret, G.W. (2007). *Fundamentos de Ecologia*. São Paulo, Brazil, Pioneira - Thomson Editora.

[27] Osborne, J. and Dillon, J. (2008). *Science education in Europe: critical reflexions*. A report to the Nuffield Foundation. London, Nuffield Foundation.

[28] Perfecto, I. and Vandermeer, J. (2008). Biodiversity Conservation in Tropical Agroecosystems A New Conservation Paradigm. *New York Academy of Sciences*, 1134: 173–200.

[29] Primack, R.B. and Rodrigues, E. (2001). *Biologia da Conservação.* Londrina, Brazil, Midiograf Editora, 327p.

[30] Rocha, C.F.D.; Bergallo, H.G.; Sleys, M.V. and Alves, M.A.S. (2006). *Biologia da Conservação: essências.* São Carlos, RiMA-SP, 592p.

[31] Salles, P. (2007). *QR models and documentation for learning about sustainable development, focusing on basic biological, physical, and chemical processes related to the environment in the Riacho Fundo*. Naturnet-Redime, STREP project cofunded by the European Commission within the Sixth Framework Programme (2002-2006), Project no. 004074, Project Deliverable D6.4.2.

[32] Salles, P. and Bredeweg, B. (2001). Constructing Progressive Learning Routes through Qualitative Simulation Models in Ecology. *In* Moore, J.D.; Redfield, C.L. and Johnson, W.L. (eds.) *Artificial Intelligence in Education: AI-ED in the Wired and Wireless Future*. Amsterdam, IOS Press, p. 595-597.

[33] Salles, P. and Bredeweg, B. (2003). A case study of collaborative modelling: building qualitative models in ecology. *In* Hoppe, U.; Verdejo, F. and Kay, J. (eds.) *Artificial Intelligence and Education: shaping the future of learning thrugh intelligent techologies*. Amsterdam, IOS Press / Omasha, pp. 245-252.

[34] Sanchez, P.A. and Swaminathan M.S. (2005). Cutting world hunger inhalf. *Science*, 307: 357– 359.

[35] Stokes, E.A. and West, A. (2001). *Environmental education in the educational systems of the European Union*. London, Centre for Educational Research, London School of Economics.

[36] Townsend, C.R.; Begon, M. and Harper, J.L. (2008). *Essentials of Ecology*. 3rd edition, Wiley Blackwell Publishing.

[37] Vandermeer, J. and Perfecto, I. (2005). The future of farming and conservation. *Science*, 308(308): 1257.

[38] Williams, M. (2006) *Deforesting the Earth: from prehistory to global crisis – an abridgement*. Chicago and London, The Chicago University Press.

[39] Zitek, A.; Muhar, S.; Preis, S.; Schmutz, S.; Bredeweg, B. and Salles, P. (2007). *QR models and documentation for learning about sustainable development, focusing on basic ecological and socio-*

economic features for an integrative and sustainable development of the riverine landscape of the Kamp valley. Naturnet-Redime, STREP project co-funded by the European Commission within the Sixth Framework Programme (2002-2006), Project no. 004074, Project Deliverable D6.6.2.

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