# SCY Scenario handbook and pedagogical plans, final version

# DI.3

***Authors***

*Armin Weinberger (UT) , Ton de Jong (UT ), Jan Dolonen (UiO), Cecilie Hansen (UiB), Anastasios Hovardas (UCY), Margus Pedaste (UTE), Anders Kluge (UiO), Sten Ludvigsen (UiO), Muriel Ney (UJF), Zacharias Zacharia (UCY), Astrid Wichmann (UDE), Vibeke Vold (UniDigital), Barbara Wasson (UiB), Anne Lejeune (UJF), Alex Verkade (PRAK), & Yuri Matteman (PRAK),*

## Science Created by You (SCY)

(Project number IST-212814)

Date: 24-02-2011

## Dissemination level:

| | | |
|---|---|---|
| ☒ | PU | Public |
| ☐ | PP | Restricted to other programme participants (including the Commission Services) |
| ☐ | RE | Restricted to a group specified by the consortium (including the Commission Services) |
| ☐ | CO | Confidential, only for members of the consortium (including the Commission Services) |

**page intentionally left blank**

# Executive summary

This deliverable comprises of a repository of scenarios that can be (re-)used and modified by educational designers. The set of twelve scenarios presented in the current deliverable is based on the initial set as presented in SCY deliverable DI.2 and has been updated on the basis of experiences with implementing two of the scenarios in three concrete missions; these are the “design challenge” and the “inquiry learning” scenarios. For the development of a fourth, ongoing, mission the “design an experimental procedure” scenario is used; first experiences from this design process are also presented. Two new scenarios were added: “Teaching thinking” and “Junior Pro”. The final collection of pedagogical scenarios as displayed in the current deliverable, vary with respect to learning arrangement (individual, small group, class, larger online communities), location (classroom, home, field supported with mobile technology), and the roles and involvement of teachers. The scenarios specify further learning goals and intermediate products of learners.

The handbook is primarily aimed at educational designers. To reach a large degree of dissemination and to also enable teachers to contribute and expand the repository, a Wiki version of this handbook is available online at the external SCY website.

# Table of Contents

# 1 Introduction

The EU-funded project *Science Created by You* (SCY) aims to progress science education through innovative learning schemes named *scenarios* and by developing a flexible open-ended learning environment that implements these scenarios. The SCY project aims to engage and empower adolescent students within the digital learning environment − called *SCY-Lab.* In SCY-Lab students embark on authentic *SCY Missions* that can be completed through constructive and productive learning activities.

SCY takes a novel approach by making students' hands-on experiences the driving force in the learning process. Students work on a mission, a project in which they have to produce something, such as an artefact, a design, or an advice. Possible examples of missions are: "Design a house that is $CO_2$-neutral", or "Manage livestock so that it produces healthier milk". Missions are supposed to be complex, multifaceted, and should encourage creative activities. The missions pose authentic tasks that are supposed to be interesting to the learners. Missions require students to self-regulate their learning activities such as searching for information, following a line of investigation, gathering data (possibly "in the field"), discussing and collaborating with others, and more. A main principle of SCY is that through these activities learners will arrive at more or less tangible products. Learners will gradually develop something that finally will be the result of their work in a mission. The elements of this result are named Emerging Learning Objects (or ELOs) in SCY, and can range from small notes, reports of measurements, to computer models, drawings, designs, and reports. These ELOs form the basis for organizing the work, to monitor progress, and to collaborate with others. The ELOs will also be the basis of assessment by the teacher, peers, and themselves. Students will see, create, edit, share, and discuss their ELOs in SCY-Lab. By integrating ELO-based assessment and moving beyond standard pen and paper testing, SCY aims to analyse and foster development of competence in accomplishing authentic missions by applying knowledge rather than testing recall of factual knowledge only. Moreover, self- and peer assessment should add to prepare students to defend their decisions and elaborate their arguments, use their learning partners as an additional learning resource, and continuously refine their understanding of multiple perspectives on how to approach a mission.

## 1.1 Goals of the SCY scenario handbook

The aim of the scenario handbook is to help educational designers to design SCY-missions within the general SCY-Lab learning environment. This handbook provides guidelines for and examples of activities and procedures for teaching and learning, as well as examples of conceptual problems that students and teachers can explore using SCY-Lab. In SCY, scenarios are built up by so called learning activity spaces (LAS; see DI.1 SCY-Lab component specification), in which learning activities, tools and scaffolds, as well as ELOs and other learning resources can be arranged.

This handbook comprises of a repository of scenarios that can be (re-)used and modified by educational designers. The scenarios support science education of learners of 12 to 18 years of age. The presented pedagogical scenarios vary with respect to learning arrangement (individual, small group, class, larger online communities), location (classroom, home, field supported with mobile technology), and the roles and involvement of teachers. The scenarios specify further learning goals and intermediate products of learners working on authentic tasks. Last but not least, scenarios comprise a range of cognitive activities of learning and tools supporting these activities. Examples will be given on how the scenarios are instantiated.

Within scenarios also pedagogical plans will function. A pedagogical plan defines how, within a scenario, scaffolds are used; in other words the pedagogical plan set values for how pedagogical agents act in SCY. As an example, we could look at the VOTAT agent that detects when a learner is not working systematically. This agent has parameters such as the time within learners are supposed to keep changing only one variable. As part of the pedagogical plan teachers can modify the global scaffolding parameter (low, medium or high) in order to tune to what they think fits their students best (see SCY deliverable DVII.2).

All twelve scenarios support acquisition of domain specific knowledge in science and are flexible in the sense that educational designers and teachers can modify the scenarios.

This handbook mainly addresses educational designers of SCY-Lab, who may have also read DI.1 SCY-Lab component specification, in which the formal language to build and describe scenarios is being introduced. To reach a large degree of dissemination among teachers and to enable teachers to contribute and expand the repository, a Wiki version of this handbook is available online at the external SCY website (http://www.scy-net.eu/Scenarios/).

In summary, this handbook describes:

- The pedagogical approach of SCY
- How students and teachers can work together on missions – within SCY-Lab and in the field
- How students can work individually and in collaboration with fellow students in the development of ELOs
- The experiences gained with implementing two of the scenarios in three missions.
- A set of different scenarios and that exemplify different ways to engage students in doing science

## 1.2 The SCY pedagogical approach

Learning by creating knowledge is one of the basic ideas behind *constructionism:* "… knowledge construction takes place when students are engaged in building objects.". The objects constructed can be computer models (Hestenes, 1987; Pata & Sarapuu, 2006) physical objects and artefacts (Crismond, 2001), drawings (Hmelo, Holton, & Kolodner, 2000), concept maps (Novak, 1990), computer programs (Mayer & Fay, 1987), podcasts

(Lee, McLoughlin, & Chan, 2008), experimental designs (Etkina et al., 2010), or even instruction (Vreman-de Olde & de Jong, 2006).

SCY's emerging learning objects (ELOs) include (System Dynamics) models, concept maps, artefacts, data sets, hypotheses, tables, summaries, reports, plans and lists of learning goals. All of these ELOs result from learning activities. Partly based on work by Anderson and Kraftwohl (2001) and Mayer (2002), we have identified in SCY 53 different *learning activities* with associated ELOs. For example, one learning activity is "classification of examples", for which the associated ELO is a "table with categories and examples". So that students can perform activities and thus create ELOs, SCY-Lab (the SCY learning environment) provides them with dedicated *tools* for tasks such as modelling, concept mapping, writing reports, gathering data from simulations, and analysing data tables. Tools can be adapted to the student or the context by supplying *scaffolds*, adaptations to the tools that inform or support students. One such scaffold is provision of a partly worked-out system dynamics model, instead of letting students create a complete model from scratch. Tools are supplemented with *services* that help students in their work but do not lead directly to the production of ELOs. An example of a service is the awareness service that gives an overview of the presence and activities of peer students. In summary, students perform learning activities with the help of (possibly scaffolded) tools that create ELOs and they use services for maintenance of the learning process.

To help students navigate through SCY-Lab, learning activities are grouped into so-called *Learning Activity Spaces* (LASs). A LAS is a combination of activities and ELOs that form a conceptual unit. Each LAS has one (or on some occasions more than one) central object(s) that is called the *anchor ELO(s)*. An example of a LAS is "Experiment". In this LAS students need to collect data with learning activities such as "run experiment" for which the resulting ELO is a "data set" (which is the anchor ELO for this LAS). LASs in their turn are combined into different *pedagogical scenarios*. Designers of a SCY mission can choose one specific scenario as the pedagogical theme for a mission; by so doing they will know the LASs involved, the learning activities that are supported, and ELOs that need to be produced.

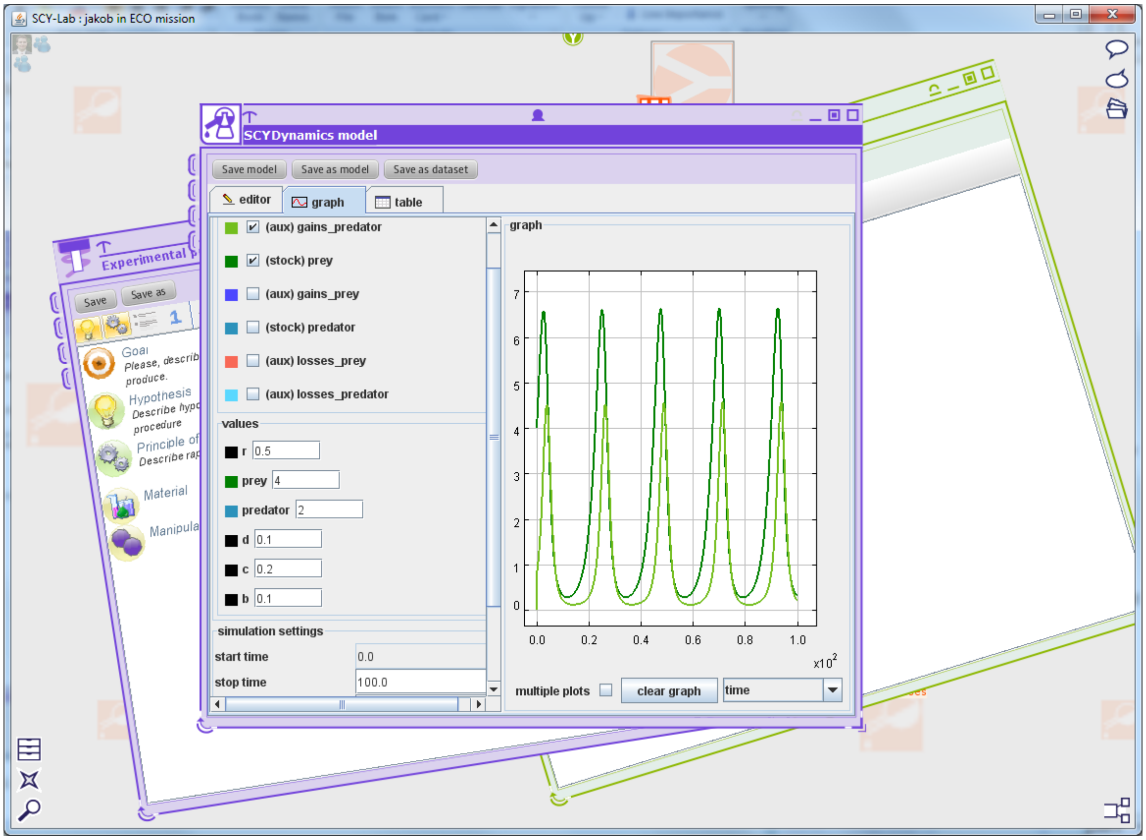


**Figure 1. Illustration of the digital learning environment SCY-Lab.**

ELOs play a pivotal role in SCY. First, they form the central pedagogical concept; the entire pedagogical approach is organized around the principle that learning is seen as producing ELOs. Second, they form the basis for collaboration among students, both implicitly by re-use of existing ELOs created by other students and explicitly as shared objects on which multiple students work at the same time. Third, ELOs are a main input for automatic analysis of student progress by pedagogical agents, leading to the shaping of the learning environment to the students' individual characteristics. Fourth, ELOs form the basis for ePortfolios and student centred assessment in SCY. A further specification of the SCY pedagogical approach and a number of related user stories can be found in de Jong et al. (2010).

## 1.3 Organization of the learning activities

In most European countries policy makers and curriculum developers recognize that in order to improve students' learning in a domain like science, learners need to be guided beyond 'fact finding' patterns and interactions. Technology-enhanced learning environments like SCY-Lab model scientific practices in science education and advance the students' capacity to reason and solve problems moving beyond fact finding. For this shift to take place two issues become crucial: First, the social organization of teachers and learners needs to be adapted in a way to favour advanced cognitive activities.

Secondly, technology should support and scaffold such cognitive activities in concert with the adapted social organisation.

In SCY-Lab the following four interwoven dimensions of communication and interactions forms the basis for learning activities;

- student-student,
- student-technology,
- teacher-student, and
- teacher-technology

To understand the activities of students and teachers in SCY we must view learning as a set of interdependent social and cognitive activities[1]. This means that when students are involved in problem solving activities the social and cognitive elements can be placed on a continuum, but need to be treated interdependently. In this handbook all the scenarios have a social or collaborative element, but they differ in how collaboration is emphasized and achieved, and further what cognitive activities are supported.

Collaborative learning means that students work together and alone depending on the task and how the task is divided over a specific time period. In the SCY scenarios the students and teachers can use SCY-Lab in different ways. For example the collaboration could be for a short period of time using a specific tool. Collaboration could also expand over an extensive period of time with the goal to build common knowledge through a joint product. Such products can have different functions, but the main point is to foster the students' abilities to question, answer, confront, elaborate, argue, and explain. Activities such as these are necessary in order to go beyond everyday conception about phenomena in science, and to develop shared conceptual understanding. However, it is very difficult for students to use and master these types of activities. That is why the different perspectives on technology-enhanced learning have developed tools and scaffolds that can enhance such processes. These tools (and their embedded scaffolds) help students with contents (e.g., simulations), with regulation of cognitive processes (planning and monitoring processes and products) and social processes (e.g., scripted tasks).

The roles of a teacher in SCY-Lab are in many ways similar to what s/he would do in a classroom, but there are also special affordances to consider. One affordance is to technically manage SCY-Lab, which is supported through a number of tools combined in a kind of cockpit view for the teacher that we labelled *SCYAuthor Runtime view*. Another affordance of SCY-Lab is to choreograph and respond to the advanced learning activities SCY-Lab aims to facilitate. For example, the teacher is supported to adapt pedagogical plans that define how scaffolds should be triggered within a scenario. Moreover, through the *SCYAuthor Runtime view* the teacher will be able to monitor the students' processes in terms of progress, collaboration and tool use and in addition the teacher will be able to

[1] By cognitive activities we mean, for instance, to recall information, categorise problems, identify relevant concepts, relate data with hypotheses, analyze a problem or phenomenon, synthesize parts into a new whole and make evaluations (see DI.1 SCY-Lab component specification).

monitor students' products. From the *SCYAuthor Runtime view* in SCY-Lab the teacher will have possibilities to intervene to resolve potential breakdowns in individual or collaborative processes.

To illustrate the basic forms of interaction and communication in SCY-Lab we will present some typical examples of how this can take place. It must be noted that these four forms of interaction are not separate but highly interwoven. For example, the interaction between students in SCY-Lab will often happen through the ELOs.

- *Student-student interaction*

Interaction and communication between learners are one of the key points advocated by the scenarios presented in this handbook. This includes how the teacher should organize the learners into groups and how to organize for communication between learners and groups of learners. However, group work is not always successful due to problems like "free passengers" or a dominant team member taking full control of the group's work. One way to overcome such problems is to create conditions for genuine interdependence between team members meaning that the learners in a group should have different sub-tasks that they need to combine in order to solve their main task. In this way all the learners need to study a part of the problem in depth and help to find a place for their particular knowledge inside the shared knowledge object that the group is producing. One way to do this is the "Jigsaw approach". For example, in a collaborative inquiry, when entering a jigsaw type of organising the learning activities the task has to be split into parts needing different types of expertise. The learners have some autonomy as they can select what type of expertise they want to engage in. However, each original group should have representatives in each of the outlined expert groups. Inside these expert groups the learners can get a micro mission where they do not create new material, but rather analyze information and existing material. Then the learners will convene back to the original groups where each of the learners now has a role of representing a particular expertise needed to accomplish the project mission.

- *Students interacting with technology*

Another key aspect in this handbook is that communication and collaboration in SCY-Lab is to a high degree done through the production of ELOs, which are artefacts that students produce during a mission. For example, learners start to work on concept map ELOs by using SCYMapper. At some point, the learners feel the need to collaborate with other students on the task that requires concept mapping. The learners see that peers are available in the chat tool and they initiate a dialogue by dragging an image of the respective other learner from the chat tool into the concept map. The other learner gets an invitation to participate in the collaboration on the concept map and accepts it, which opens a chat window. The students can add new students to collaborate with them by repeating the previous procedure. The learners working on the concept map have – depending on the tool opening it up – the possibility to edit it synchronously. For example, learners can add new concepts to the concept map at the same time without any interference. When they save this concept map as an ELO they are both considered being the authors.

SCY-Lab will in addition have pedagogical agents inside the system that deal with pattern analysis of content and learner interaction both in terms of what they produce and whether or not they collaborate. Depending on the pedagogical plan, these agents are able to scaffold learners. For example, if a learner contributes less than the others in the concept map the advisor can prompt learners to contribute and give hints to certain concepts that could be interesting to add to the concept map. The threshold to fading scaffolds out again is typically reached once the learners show the desired behaviour as it is specified in the pedagogical plan.

- *Teacher-student interaction*

In terms of teacher-student interaction, the teacher typically frames the work by introducing the project in a plenary session. An example for teacher-student interaction could be that first, the teacher explains the inquiry the learners will engage in and the structure of the work. Second, the teacher plays a short video that critically handles the issue that the learners will have to deal with in this mission. Third, the teacher organizes the learners into groups.

One method the teacher can use to organize the students is the previous mentioned jigsaw approach. In the jigsaw approach, each learner in a group assumes responsibility for a specific part of a problem. Then each member of the original group gains expert knowledge about a certain portion of the problem that the other members do not have. By hearing everybody out and sharing expert knowledge, learners are challenged to integrate different views and constructively deal with conflicts for the group to finish the task.

When doing project work there are a lot of tasks in the process that the learners consider to be easy and some that they consider difficult. In cases where the learners fast come up with solutions to a problem that look good at a glance the teacher should challenge the learners to think up alternatives. For example, if the learners are designing a $CO_2$ neutral house and they have come up with the idea to collect wind energy, the teacher can ask the following: “What if all the neighbours also have wind mills? Could that cause any potential problems?” In cases where the learners run into conceptual or procedural problems (e.g., they don’t know how to solve a problem) the teacher should contact the learners, discuss the problem, and give directions.

- *Teacher-technology interaction*

The dimension where teachers work with technology is important because the teacher will be responsible for adapting pedagogical plans that the learners will follow in SCY-Lab, monitor the learners through a teacher cockpit where the teacher also will realize (run-time) adaptations to the pedagogical plan.

The teacher has different ways for monitoring the learners. For example, the teacher can then choose to communicate with a group by right-clicking the icon representing the group or communicate with an individual learner by clicking on the image representing that person. Another example is that the teacher can right click on a group and see the periods the students have been online. When clicking on the progress bar of a group the different ELOs finished or being worked on for that group is displayed. In addition, a feature is that the teacher can be notified by a pedagogical agent about undesirable patterns, for example, one or more students not collaborating in an activity denoted as collaborative.

The teacher can intervene in two ways. First, the teacher may set parameters that influence the functioning of agents; second the teacher may intervene in the composition of the groups. As an example, of the first, a teacher may decide to present students with a simulation that has values of variables set in a stage that focuses on the problem the student is concerned with. As an example of the second, a teacher may transfer a learner from one group to another for example because the level of the new group is more apt for that student.

# 2 Adaptations of the SCY scenario handbook

In DI.2 we have presented a set of scenarios that were based on the experiences of partners in SCY and that, all together, presented an overview of a diversity of approaches that could be used within the overall SCY pedagogical philosophy (learning in real settings, learning by creating and exchanging emerging learning objects, learning in combined individual and collaborative settings, and learning by design). In this way DI.2 described ten different scenarios. After the delivery of DI.2 four developments took place that were relevant for updating the scenario handbook as reflected in the current deliverable:

- Two missions have been designed that use two of the listed scenarios. The missions “Canteen cuisine – A healthy pizza” was based on the scenario “the Design challenge”, and the mission “The SCY ECO mission” used the “Inquiry learning” scenario as a starting point. In addition, the first mission “design of a $CO_2$ friendly house” was developed concurrently with the development of the scenarios and the fourth mission DNA, which is still under development uses the “design an experimental procedure” scenario.

  This deliverable will describe the experiences gathered in these design processes and list the consequences of this for working with scenarios for design in general. An account of these experiences and the consequences for the scenario are given in Section 2.1.

- There has been extensive discussion in the project on the use of a pedagogical plan. In DI.2 the pedagogical plan was still described as a kind of specific scenario, in the current deliverable we return to its original meaning, which was setting of specific parameters within an existing scenario, in this way determining the functions of the scaffolding triggered by agents. This will be further elaborated in Section 2.2.

- Two new scenarios were developed: *Teaching thinking* and *Junior-Pro*. A short intro to these two scenarios is given in Section 2.3 and the scenarios are presented in full in the Sections 3.11 and 3.12.

- The scenario handbook has been translated into an on-line wiki that is more directed towards teachers. The set-up of this wiki is described in Section 5.

## 2.1 Experiences with the design of missions based on scenarios

### *2.1.1 The Design a $CO_2$-friendly house mission experience*

The $CO_2$-friendly house mission was the first SCY mission to be developed and it was created at the time when the scenarios were under development. In retrospect, this mission was maybe a bit too complicated to be used as a starting mission but that also gave an opportunity to learn important lessons. A number of these issues have already been presented in Deliverable DVIII.1. In this report we focus on the functioning of the scenario for the design of the mission. These experiences are divided into experiences with the LASs in the scenario, the tools in the LASs, and the division of students over LASs (group formation).

*LAS experiences*

The mission is oriented towards the design of a house and the acquisition of scientific strategies and knowledge in multiple domains. As explained in DVIII.1, this corresponds well to the scenario “Design challenge”, which has been chosen at an early stage of the mission construction. In the process, adaptations have been done on two sides: the scenario template itself (work of WP1) and its instantiation for mission 1 (work of WP8). The main reasons for these adaptations are the following: (1) Some activities are to be done in priority in a given LAS, but can be done in another LAS to avoid too much back and forth navigation between LASs, (2) the scenario is presented with a suggested navigation between LAS, and this navigation can be adapted.

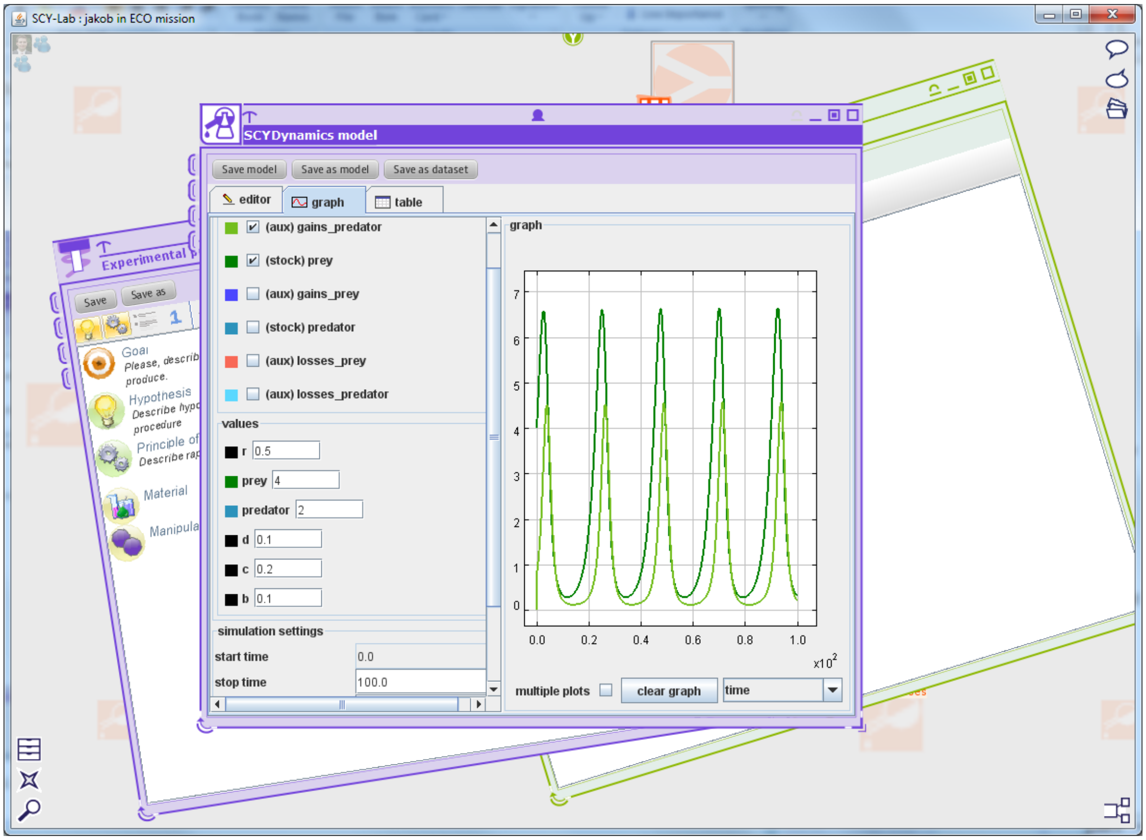


Figure **1** (extracted from DVIII.1) shows the final result of the first stage of mission 1 construction. This “big picture” is a presentation of the scenario centered on LASs. It is accompanied by a detailed description of activities and by a table describing each LAS by their ELOs (see DVIII.1).

In a second stage, mission designers felt the need to add another representation of the scenario, this time focusing on ELOs. It is the ELO map (Figure 2 in DVIII.1). Collecting a list of ELOs showed that their number was too large (more than thirty). It was thus reduced to 17 ELOs (see ELO map in DVIII.1). For instance, a search for information initially led to an ELO ‘annoted bibliography’. This is not a mandatory ELO anymore. Note that LASs are still present in the ELO map, but not in the front: the anchor ELOs are tagged and each of these ELOs is central for a particular LAS.

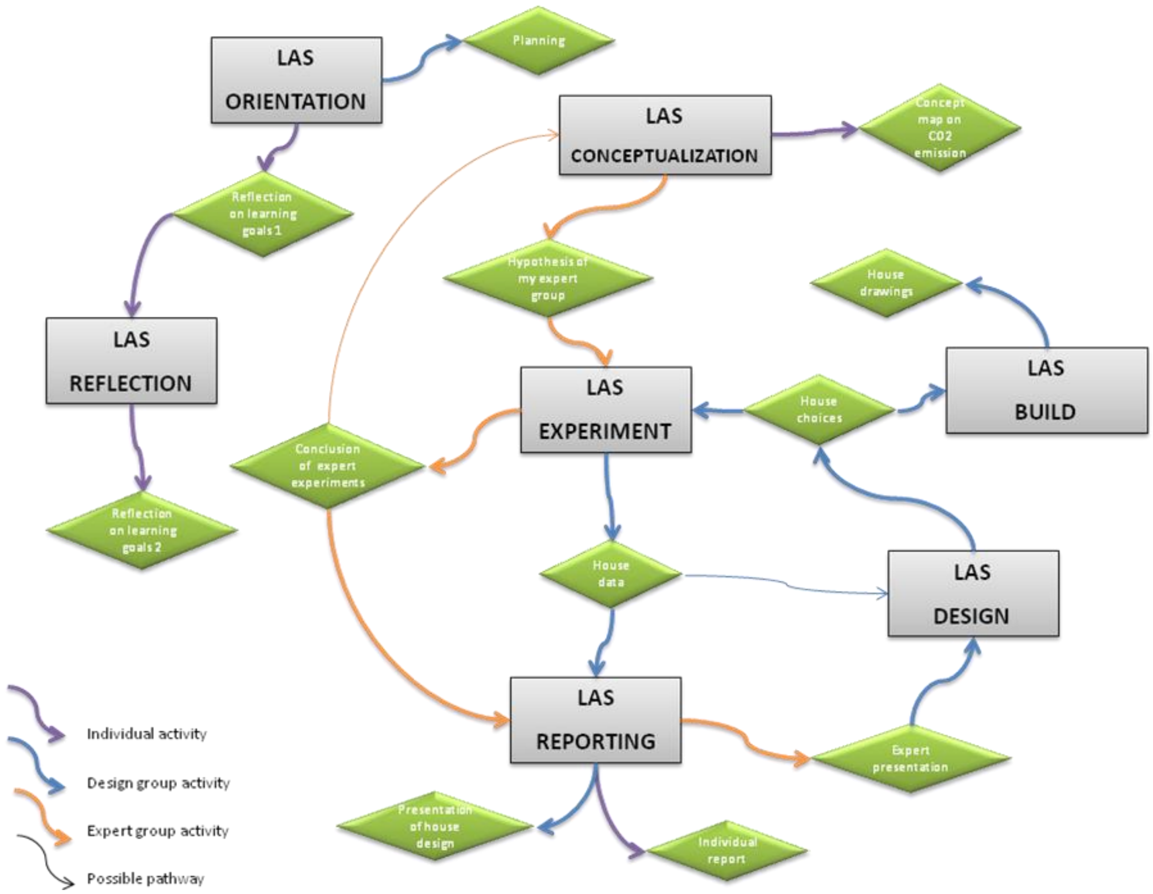


**Figure 2. Scenario 'Design challenge' adapted for mission 1: the big picture.**

Finally, a last stage in mission 1 construction concerning LAS is the mission map. It was built based on anchor ELOs and LASs (see Figure 3).

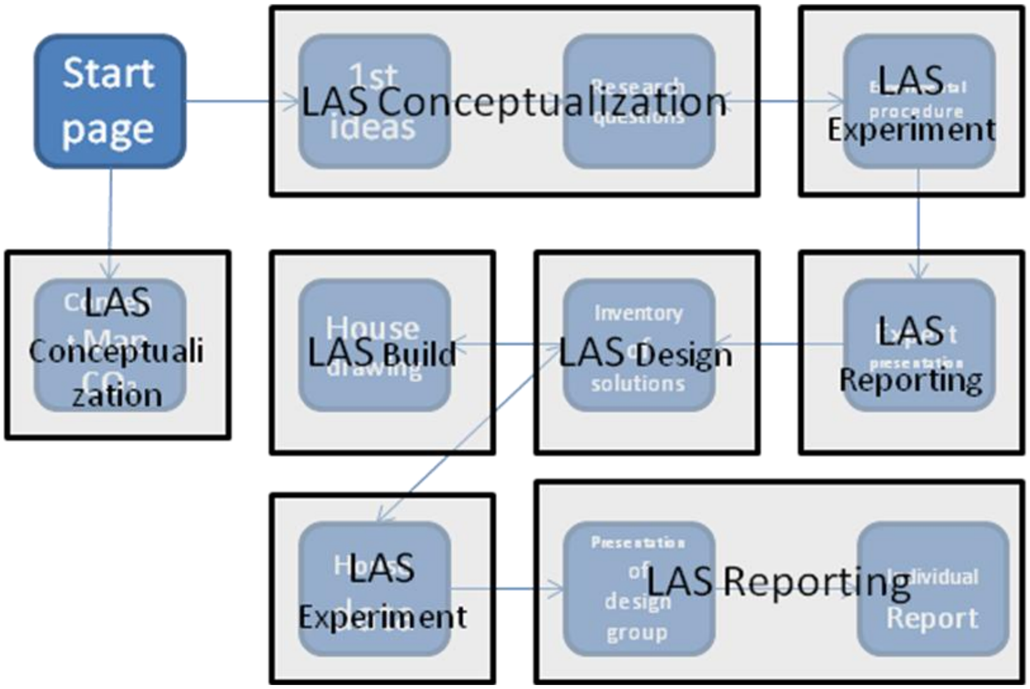


**Figure 3. The mission map with the name of LASs superimposed.**

We are now going into more details about how we adapted the scenario and why. Table 1 shows a comparison between the template scenario and the scenario actually used for mission 1.

**Table 1. Comparing lists of LASs in the template scenario and in mission 1**

| LAS from WP1 in the Design Challenge | LAS from WP8 in mission 1 | Anchor ELO |
|---|---|---|
| **Orientation** | Not for this version | (Reflection on learning goals when rubric tool will be available; Planning still under discussion) |
| **Conceptualization** | Conceptualization | 1st Ideas, Research questions |
| **Design** | Design | Inventory of solutions |
| **Build** | Build | House drawing |
| **Experiment** | Experiment | Experimental procedure<br>House data |
| **Evaluation** | | |
| **Reflection** | Not for this version | (Reflection on learning goals when rubric/portfolio tool will be available) |
| **Reporting** | Reporting | Expert presentation<br>Design presentation<br>Individual report |

The LAS Reflection is not used in mission 1, but it belongs to the scenario and is described in detail in DVIII.1. It has not been implemented in SCY-Lab for the first trial of mission 1. The goal for students is to verify that the concepts and skills that have been defined previously are mastered, using a self-assessment tool (Rubric tool). The tool and corresponding ELO could be later developed based on the work done in WP3. This work was not done at the time of the design of mission 1.

The LAS Evaluation was excluded from the scenario from the beginning, because it needed work from WP3 (playful peer assessment) that was not done at that time (currently this tool is available).

The LAS Orientation is included in the description of mission 1 (DVIII.1) as a first step in discovering the mission. It was not implemented in SCY-Lab in order to reduce the number of LAS and too much back and forth navigation between LASs.

An important aspect of the scenario is the jigsaw approach that refines this scenario. It led to further adaptations of the scenario. This will be discussed in the section 'assigning students to LASs'.

*Tools*

The ELO map shows set of ELOs to be produced by students with associated tools. Some tools have been developed or improved after completion of mission 1.

Specific tools (related to the content of mission 1): house simulation, unit converter.

Generic tools: SCYLighter, SCYMapper, SCYDataviewer, Math Tool, SCYED (Experimental Design).

Tool developed outside SCY: Google sketchUp, Text editor, Power point.

*Assigning students to LASs.*

A jigsaw grouping scenario has been included into the Design Challenge scenario. Students form groups of 4 or 5. Each group sketches a house in the end. At some point, each student chooses a domain expertise and goes and works with other experts of the same domain. They acquire expertise by doing bibliography search and experiments. Therefore, there are phases where students work with their design group and phases where they work with their expert group. There is also some individual work to be done.

Each phase has been described by its LAS. Coming to the design of the computer environment, one issue was whether the same LAS used in different phases should be one single page in SCY-Lab. To avoid confusion, it was decided that there would be two pages or two LASs. For instance, students can go to a LAS "experiment" with their design group and later to a LAS "experiment" with their expert group, but not find exactly the same resources and ELOs each time.

### *2.1.2 The SCY ECO mission experience*

The SCY ECO mission is developed for learning about topics on the cross-section of biology and ecology as they are covered in most of the curricula in Europe: i) influence of abiotic ecological factors on the size of a population, ii) influences of light on the level of photosynthesis, iii) relations between trophic levels in an ecosystem, and iv) the concept of pH and the changes of pH in water bodies. The selected topics enable students to discover real life problems that appear in different areas of Europe. By extensive use of natural resources – abiotic and biotic – human beings have changed their environment seriously. In many countries we can find lakes that are almost lifeless because the needs of natural processes like photosynthesis, respiration, trophic relations etc. have been not taken into account. It has caused problems of decreasing biodiversity and increasing pollution. This mission is for discovering natural processes and also helps to understand how every person could have a positive effect on saving our environment for future.

*LAS experiences*

The SCY ECO mission (Mission 2) has been developed with the inquiry learning scenario described in SCY deliverable DI.2 as the starting point. In the development of Mission 2 the main idea and the learning goals of this scenario have remained unchanged but we found it necessary to make some adaptations.

The LASs in the "Inquiry" scenario as they were mentioned in DI.2 are: orientation, information, analysis (hypothesis generation), design (experimental procedure), experiment, analysis (data interpretation), and design (problem solution). Firstly, it could be confusing that the same LASs (analysis and design) appear twice in the same scenario even if they are there in a different meaning (content). Secondly, we found some inconsistencies concerning the descriptions of LASs between DI.1 and DI.2. Therefore, the following changes were implemented:

a. According to DI.1 the LAS "Analysis" is on the one hand for identifying key issues, limitations and constraints, categorising problem which are activities for defining a problem, and formulating research questions and hypotheses. At the same time this LAS is in DI.1 for constructing relations and relating data with hypothesis /theory – these are activities in the final stages of inquiry on the basis of data. However, DI.1 also lists the LAS "Conceptualisation" which is applicable for defining a problem and formulating research questions and hypotheses – there are activities like "identify relevant concepts, variables, principles and criteria" and "generate hypothesis". We therefore replaced the LAS "Analysis: Hypothesis generation" with the LAS "Conceptualisation".

b. According to DI.1 planning an experimental procedure takes place in the LAS "Experiment". Therefore, we placed the LAS "Design: Experimental procedure" in the LAS "Experiment".

c. The LAS Analysis as described in DI.1 already contains activities for relating data with hypothesis and theory. We see it as the final stage of inquiry learning, while this activity is paraphrased as answering research question and making decision on the hypothesis. In mission 2 we can say that these activities are needed for writing the solution to the problem. Therefore, there is no need for additional LAS Design. The only activity in this LAS is "design an artefact". In composing DI.2 we had an idea that the students can design a solution as an artefact in this LAS but actually it is not needed according to the experiences of developing mission 2.

The revised form of the Inquiry learning scenario would contain the following LASs as described in the first version of DVIII.2:

1. *Orientation*

   First, students are reading a story about a problem situation. Students have to analyse this problem situation, identify a goal state of the problem, identify their learning goals, and means – select devices, tools, and strategies to approach this particular problem.

2. *Information*

   Next, students collect additional information. They have to browse resources for topic specific information. Therefore, there are composed unique learning objects and given a list of relevant web-based resources. Students are provided with a text tool that enables them to collect texts and images from the process of information collection.

3. *Conceptualisation*

   Based on the problem identified in LAS orientation and information collected in LAS information students have to generate research questions (generating research questions is not an activity of LAS Conceptualisation in DI.1 but it should be added) and hypotheses. Therefore, they identify relevant concepts, variables, principles and criteria for solving each particular problem. Here, a glossary of mission-specific concepts can be used.

4. *Experiment*

   Students design an experiment that is appropriate for testing hypotheses set before. Therefore, they define experiment goals and design experiment. In the case of two topics students plan and conduct a real experiment and in the case of other two topics they design an experiment that can be conducted with SCY dynamic modelling tool. Here, experimental design tool will be applied. Next, students run the experiment, import data into SCY specific data processing tool, organize it there and interpret the results.

5. *Analysis*

   The final stage of inquiry is making inferences on the basis of the data collected. In this LAS students have to relate data with hypothesis in order to answer research questions.

A final issue of applying LASs in developing mission 2 has been related to the activities defined in each LAS. It is agreed that not all activities of LAS are always needed and can be left out. However, in mission 2 we see the opposite. Some activities are carried out without these activities being mentioned in a LAS. For example, in the LAS “Orientation” students i) read a story about a problem situation, ii) analyse this problem situation, iii) identify a goal state of the problem, iv) identify their learning goals, and v) select devices, tools, and strategies to approach this particular problem. In DI.1 the first two of these are not defined and probably there is a need to add them.

*Applying the LASs in the mission*

We found that it may not be the most advantageous to show all LASs in the scenario for building the mission's "mission map" – the navigation tool for the students. Navigation from one LAS to another (it means from one page in SCY-Lab to another) can cause confusion and, therefore, it is useful to present some LASs on the same page (screen). For mission 2 we found that the LASs "Orientation", "Information", and "Conceptualisation" should be presented to the students as one coherent set of ELOs. It is the best option because students have to move from the "Orientation" LAS several times to the "Information" LAS and back. The same applies for the "Conceptualisation" LAS where students need additional information that is available through the LAS "Information". Thus, there are still theoretically three different LASs but students can see them as one set of activities and tools that can be used for developing different ELOs. As a result of this solution there is no need anymore for defining anchor ELOs for all these three LASs. The hypothesis as the anchor ELO of the third LAS Conceptualisation could be the only anchor ELO produced from these three LASs. This anchor ELO is thus represented in the mission map.

*Tools*

In the "Orientation", "Information", "Conceptualisation", and "Analysis" LAS we used a simple text tool and a tool for extracting notes from background information read from theory texts (either in SCY-Lab or web). For the moment these simple text tools suffice, but it is imaginable that more structured templates can be presented to students.

In the "Experiment" LAS we have applied a tool for designing an experimental procedure, the data processing tool and, for two out of four topics in the mission the SCYDynamics modelling tool. For the Data processing tool the possibility of importing data from external mobile data loggers was added.

In addition to the specific LASs from the "Inquiry learning" scenario we felt the need to add two more general spaces: one for making a concept map, and one for generating a video report. SCYMapper is used to produce a concept map of an ecosystem. This concept map is initially made before learning any topics of this mission and revised after completing each topic. The second space, the video report space, was meant to have students make a video report about their inquiry learning processes and to present it as an ELO to others. Since there is no video tool in SCY-Lab we asked students to compose their video with equipment and software available in their school and upload it to the YouTube. Next, they copy the link of this video and put it into YouTube Reference tool in SCY-Lab. They also give a title and description to it. After that this video can be played from SCY-Lab – this ELO has a link that opens web browser and starts playing video in YouTube.

*Assigning students to LASs.*

In mission 2 we are planning to use group formation when students are entering the LAS "Experimentation". The rules for group formation will be applied by a specific group formations agent (see WPV). This agent is able to suggest student grouping taking into account personal data (e.g., country, age, language, class) and the level of ELOs produced in the former stages of the learning process (e.g., level of problem formulation, research question, hypothesis, and initial concept map in the case of mission 2). In this context we have discussed the issue of what to do if some parameters are missing. The solution could depend on what parameters are missing. If an ELO that is needed is not completed then there should be given a warning to the student that he or she should go back and complete his/her particular ELO before it is possible to continue. If some personal parameters are missing then it is possible to ask students to revise their personal data. However, here comes a need to develop a solution for changing/adding personal data after registration.

There has been also the question of how to fix the minimum/maximum size of the groups. The best solution here could be to give such possibility to the teachers trough authoring tools.

### *2.1.3 Canteen cuisine – A healthy pizza experience*

Canteen Cuisine addresses the need of healthy meals at school canteens/cafeterias around the world. Today, children in Europe and the United States consume more food products high in sugar, salt, and fat content than thirty years ago. This led to the increase of many health problems including obesity, diabetes, high blood pressure, high cholesterol, heart related disease and other diet-related problems. Thus, the purpose of the Canteen Cuisine mission is to actively engage students in practices related to the canteen/cafeteria cuisine of their school. Specifically, students are asked to create a healthy pizza for their school canteen/cafeteria while taking into consideration the nutritional value of the ingredients, the human digestive system, diet-related health issues and daily exercise.

Pizza is one of student’s favorite meals/snacks. However, it is also one of the unhealthiest foods since it incorporates high levels of calories and fat. Unfortunately, pizza is served in many school canteens/cafeterias around the world without any restrictions or considerations about its ingredients. Pizza, however, does not have to be unhealthy. Taking into consideration the nutritional value of different toppings and ingredients, school canteens/cafeterias can provide a more healthy option with less fat and calories and more vegetables.

In this mission students follow a stepwise approach. First they learn about the nutritional value of food items in general (carbohydrates, fat, proteins, energy, vitamins, etc.), and of various pizza ingredients in particular. Then they familiarize themselves with the food pyramid and the classification of food categories (grains, fruits, vegetables, milk, meat and beans), information on energy (calories) and the human metabolism. Further, they learn how to read and interpret the nutritional value labels of products and how the digestive system works, including diet-related health problems. Finally, they use their new knowledge to create a healthy pizza to be served at their school canteen/cafeteria.

For the development of mission 3 the science curricula of the participating countries were analysed. A comprehensive, coherent set of concepts was selected, all related to the subject of ‘food and health’.

*LAS experiences*

It was decided that for this mission the ‘Design Challenge’ was the most suitable scenario, since mission 3’s objective was the creation of a healthy pizza. As a result, the mission was developed according to the scenario. The only modification we made concerned the ‘Report’ LAS. This LAS has students summarize their accomplishments in a written report and prepare a presentation to the class and their teacher. However, similar activities were incorporated in the ‘Evaluation’ LAS. Evaluation in this mission is more summative by nature in that students have to select the healthiest pizza out of the three pizzas they have designed in the mission. They then compare their best pizza to that of their classmates, write down their conclusions and present it to the whole class. Given the substantial overlap with the activities comprised in the ‘Report’ LAS, it was decided to exclude the latter.

*Applying the LASs in the mission*

The mission map of mission 3 is an accurate representation of its LAS-structure. There is a sequence of 11 LASs (a design LAS, an Experiment LAS, an Information LAS, four Conceptualization LASs, two Reflection LASs, one Evaluation LAS and one Build LAS), that appear on the mission map as toppings on a pizza. The Design LAS and the Experiment LAS are central to mission 3 and are visited several times throughout the mission.

*Tools*

A variety of general and mission-specific tools are used in mission 3. Table 2 below gives an overview of all tools and the ELOs they produce. In addition to the tools embedded into SCY-Lab, students could use mobile data collecting devices such as cell phones or palm-pilots. The latter is optional given that schools might not have the necessary equipment.

**Table 2. Tools that are used in mission 3 and the corresponding ELOs.**

| General tools | ELOs produced |
|---|---|
| Data processing tool | Food and exercise diary (calculations for) Health passport |
| Drawing tool | Health passport<br>Energy fact sheet<br>Map of the digestive system |
| Text editor | Notes on unhealthy diet<br>Answers to questions about pizza benefits<br>Nutrition table<br>Questions about the food pyramid<br>Fact sheet of one organ of the digestive system<br>Personal comments to five statements<br>Reflection on importance of criteria<br>Criteria table |

| | |
|---|---|
| | Criteria weight table<br>Criteria final table<br>Group report on healthiest pizza<br>Report on healthiest class pizza<br>Real pizza and grading rubrics (optional)<br>Letter to school canteen |
| Experimental procedure tool (COPEX) | Methodology steps and presentation |
| Calculator tool / Data viewer | Nutrient and energy calculations<br>Criteria table and ingredient scores<br>Criteria weight table |
| Internet browser | - |
| Mobile device (optional) | Pizza ingredient table (optional) |

| **Mission-specific tools** | |
|---|---|
| Pizza simulation tool | Virtual pizza |
| Food pyramid simulation tool | Construction of the new food pyramid |

*Group formation: Assigning students to LASs*

The process of group formation is not a main focus in mission 3. Most activities related to the design process (creating virtual pizza's) and experimentation (creating a health passport) are done individually. There are also LASs in which students need to work in groups (e.g., discussing the criteria for the optimization strategy) or with the whole class (e.g., performing a hands-on simulation of the digestive system), but there is no specific reason to match groups according to pre-set criteria. The teacher is responsible for making the groups.

### *2.1.4 Designing with scenarios – general conclusions*

After having described the three experiences with scenarios for the design of SCY missions we can come to some general conclusions.

Scenarios and their included LASs have indeed been the genuine basis for designing SCY missions. In the design process the designers have worked in a more or less flexible way with scenarios:

- The design process is one of taking a scenario and leaving out LASs that do not apply, and within LASs learning activities/ELOs that do not apply. In this way the scenario functions as an overall framework form which elements can be left out still preserving the overall character and structure of the scenario.

- Within a scenario learners may have to return to a LAS two or even more times, mainly with the objective to adapt or update an ELO. In that case sometimes the choice was made to have two (or more) different “pages” in the SCY mission so that students could identify in which “phase” they were working.
- In the other direction, student navigation was sometimes supported by including several LASs (and anchor ELOs) at one mission page.
- There was also a need to divide larger mission (ECO and Pizza) into a number of content related parts. When this was done then in each of the parts the scenario was still followed.

Finally, as it was inevitable with a number of classifications as used in our work also some inconsistencies were discovered. experiences While working with the scenario handbook we discovered a few inconsistencies. For example, the LAS “Construction” from D1.1 was named build in scenarios in D1.2. We have now used the term “build” consistently. Smaller inconsistencies over DI.1 and DI.2 also have been corrected.

Finally, on the basis of the ongoing work in the fourth mission (DNA) the design an experimental procedure scenario was extended with a conceptualization LAS.

## 2.2 The role of the SCY pedagogical plan

In DI.2 the term pedagogical plan was used to indicate a further specification of the scenario or an indication on how groups were formed. For example, in the design challenge scenario the jig-saw approach (describing a certain role play of students and group formation on this basis) was presented as a pedagogical plan. The original idea of a pedagogical plan in SCY was, however, different. In an internal glossary, pedagogical plan has been defined as:

> “This level [pedagogical plan] is about fine tuning the mission. Actors are teachers who set the parameters in the mission that was specified above. For instance, given that there is a simulation, they can set the initial state of the simulation to reflect a local situation. Or suppose that a VOTAT agent is part of the mission. This agent has parameters such as the time within learners are supposed to keep changing only one variable. Teachers can modify such parameters in order to tune to what they think fits their students best.”

In the current deliverable we have returned to the original definition.

## 2.3 New SCY scenarios

In this deliverable we also introduce two new scenarios that complement the earlier scenarios.

*Junior-Pro* is based on the principles of competence-based learning. Students always operate as junior professionals and the scenario always starts with a realistic task or assignment based on the daily work of a professional. Learners have to design a virtual or physical artefact. Taking on the design challenge, the learners iteratively design artefacts and theoretical models, test, reflect upon and present the artefacts and the refined theoretical models with the goals to acquire technical knowledge and skills. Some activities are group activities, some are individual activities. An extensive description of this scenario can be found in Section 3.12.

In the *Teaching Thinking* scenario the focus is on creative problem-solving. The scenario aims at developing students critical thinking skills. Science problems are approached from different and complementary angles with "brain-storm" alike techniques. *Teaching Thinking* makes students aware of their thinking techniques learning process. This scenario is presented in Section 3.11.

# 3 The Scenario Repository

Preparing a new lesson is a labour intensive task that probably has been done before. Some of this work has been made available online, which enables a large number of teachers to build on existing pedagogical scenarios and plans for use in the classroom[2]. In the following, a number of theoretically grounded pedagogical scenarios can be found ready to be used with students in technology enhanced learning environments. Different from other teacher resource sites, the presented scenarios are described in a uniform format to be used with different tasks and contents. This uniform format has the following components: main idea, learning goals, requirements and target groups, learning tasks, assessment of learners' products, learning activities and tools, teacher roles and responsibilities, scenario examples, and further reading. A further outline of what these format categories contain is described in the following section.

### Main idea

Here, a short description of the scenario is given explaining the main focus and functions of the scenario. The main idea of the scenario should be kept in mind when modifying details of the scenario.

### Learning goals

The knowledge and skills learners should acquire in a specific scenario can be found here. Many of the advanced pedagogical scenarios emphasize how the respective learning goals surpass inert knowledge towards applicable knowledge and skills.

---

[2] See, for instance, http://kie.berkeley.edu/KIE/curriculum/curriculumlibrary.html and http://lamscommunity.org/lamscentral

**Requirements and target groups**

Some scenarios have prior requirements to be considered: What age group is a specific scenario aimed at? What level of prior knowledge is expected? What other resources and learning material is required? How long will it take for learners to complete the scenario? How does technology support the scenario and what tools are required?

**Learning task**

Here, the following task aspects are being elaborated: typical starting points of scenarios, goal states of scenarios, and products expected from the learners in the course of the scenario and at the end of the scenario.

**Assessment of learners' products**

Here, some advice is offered on what can be assessed and how this can be done within the specific scenario.

**Learning activities and tools**

This element presents a detailed description of the learning activities foreseen within the specific scenarios. Moreover, tools will be specified that support the activities within technology-enhanced environments. A schematic graphic will visualize how the activities can be organized within a scenario showing the main activities and learner products.

**Teacher roles and responsibilities**

Most advanced pedagogical scenarios retain a number of teacher roles other than presenter, e.g., facilitator, moderator, observer, critic, modeller etc. Here these roles and responsibilities are specified for each scenario.

**Scenario examples**

For some of the scenarios presented we have developed specific ideas or variations on how to further mould the scenario or how to group students when acting in the scenario. These two aspects are presented under "examples".

**Further reading**

Here some further resources for information on examples and the theoretical background of the respective pedagogical scenario will be given.

Next, the following scenarios are presented:

- The Design Challenge
- Inquiry Learning
- Problem Resolution
- Close a Case
- Decision Console
- Grasp a Model

- Designing an Experimental Procedure
- The Big Project
- Collaborative Controversies
- Co-Learn
- Teaching thinking
- Junior-Pro

## 3.1 The Design Challenge

### Main idea

Students are to design an artefact, which represents a solution to a complex societal problem related to the students' own reality, e.g., building a low-energy computer to reduce energy consumption of computers and servers. This mission contextualizes all curricular activities and the science content to be learned. Starting from a complex problem, students are guided to identify multiple aspects of the issue and approach the problem through design. Taking on the design challenge, students iteratively design artefacts (or working models) and theoretical models, test, reflect upon and present the artefacts and the refined theoretical models with the goals to acquire science knowledge and skills. Some activities are classroom-wide, some are small group activities. The learners take on different aspects of the design task, e.g., through testing different variables, and present their findings in classroom-wide activities.

### Learning goals

Applicable knowledge of multiple domains that are relevant for taking up the design challenge; deep understanding of multiple perspectives on complex systems and their overall functions, incl. functions and interactions of the system components; internalization of scientific strategies (identifying questions, constructing and systematically testing hypotheses, seeking out better (conceptual) models to explain phenomena and to solve a problem.

### Requirements and target groups

The design challenge will take about 20 hours and at least 2-3 weeks of classroom time.

The design challenge is best suited for small groups of learners to pay tribute to multiple domain resources required for designing the artefact and to keep the number of designs manageable and comparable. The design challenge typically stretches across different learning arrangements and includes individual as well as classroom activities. The artefacts could also be published and made available to larger (online) communities.

Learners should be first made familiar with the basic tools needed to design the specific artefacts. Regarding domain-knowledge, the scenario is suited for all levels of K12 students with the necessary adjustments of task difficulty being made.

Students have to be provided with several tools in this scenario to represent knowledge within the small groups, the classroom and beyond this as well as for individual reflection, e.g., SCYMapper, Modelling tool, and Note taking tool. Furthermore, tools to design and simulate the artefacts need to be provided for, e.g., SCYSIM, as well as tools to evaluate the artefacts, e.g., Data processing and visualization tool.

**Learning task**

Learners face a complex challenge and should arrive at, present and review a (working) model or prototype meeting the challenge. The learners produce design plans, intermediate and final artefacts and theoretical models as well presentations of these artefacts and models, results of experiments and scientific conclusions for complex problems.

**Assessment of learners' products**

The (intermediate) designs and experiments can be evaluated with respect to their functionality and adequacy compared with an expert model, both with respect to the single components as well as the overall structure of the model. In addition, adherence to scientific procedures is being evaluated, especially if no expert model can be specified beforehand.

Furthermore social assessments can be made based on more or less simple indicators (size, time spent, peer assessments).

**Learning activities and tools**

| | |
|---|---|
| *Orientation* | The project begins as a plenary session. First the teacher frames the whole project by explaining the mission the students will engage in. If the mission is, for instance, to build a $CO_2$-friendly house, a short video can be showing a young couple about to build a house that are having concerns about environment-related issues, i.e., global warming and $CO_2$ emissions. The video will inform about the different choices they have to make (selecting windows, building material, energy choices, approval including emission class and more). Students can ask questions and discuss content, but also explore how to structure the work. The students collect what they already know about the topic, identify learning goals, and plan the learning process using the planning tool. |
| *Conceptualization* | Here the students will try to identify the different concepts involved in the mission. For instance, what is $CO_2$, how is it produced, what types of activities in the house can produce it? What is energy, and what is the relation between energy and $CO_2$? The students will use SCYMapper to try to link the different elements and concepts together and construct hypotheses that they could investigate. Students will come back to refine their conceptual models in the course of the scenario. |
| *Design* | Students will design an artefact, e.g., a house, based on the conceptual model, e.g., the model of influences of house design on $CO_2$ emissions. |

| | |
|---|---|
| *Build* | Students actually build a real or a simulated artefact, e.g., a house using an available simulation tool. (in DI.1. this LAS was called “construction”). |
| *Experiment* | Typically with some support on how to plan and conduct valid experiments, learners design and conduct experiments with the respective artefacts they have designed. |
| *Evaluation* | Learners evaluate the data collected –by comparing results with the preset criteria and norms, e.g., regarding the amount of $CO_2$ production, and the results their peers have produced – and refine their conceptual models. For instance, students may not be satisfied with the emissions and the energy use of their house. They may reflect on and re-design their house. |
| *Reflection* | The students in the group evaluate whether they reached the mission goals and learning goals, and explain reasons for possible deviations. They will discuss how (or whether) the gradual increase in understanding led them to do modifications in the goals of the project or if other factors such as time assigned, tools limitations and lack of good information led them to reconsider their ambitions.<br><br>Learners also reflect on the processes within their group and will discuss what they would have done differently with regards to group processes, the actual content produced, and learning processes. |
| *Reporting* | The students will work to get an overview of their accomplishments and prepare a presentation to the class and the teacher. |

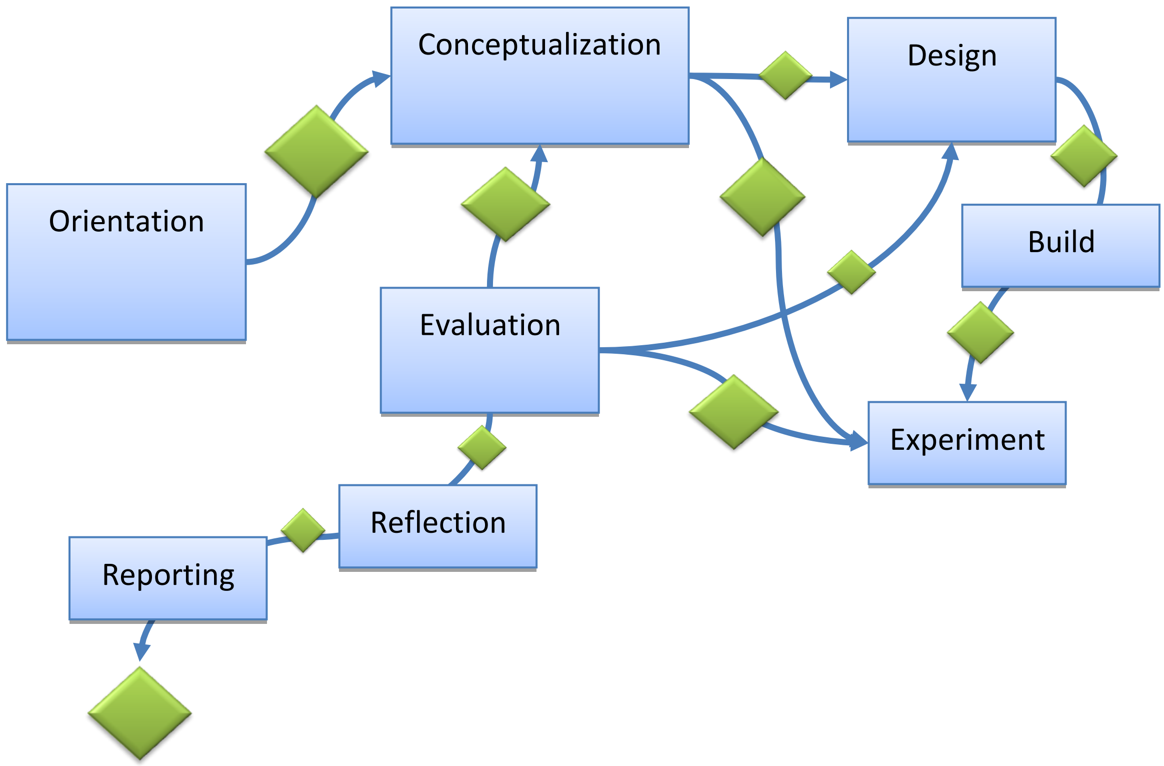


**Figure 4. Sequence of learning activity spaces of the Design Challenge.**

### Teacher roles and responsibilities

The teacher introduces scientific vocabulary and strategies, e.g., rules of how to understand / deal with diverging opinions and how to conduct fair tests; test results of several small groups conducting different sets of experiments as well as learning material conveying different perspectives upon a matter.

### Scenario examples

The examples for the design-based scenario provide details on how the task and sub-tasks can be distributed over small groups of learners, how these groups can be formed, and how roles and activities should be realized by learners in given sequences.

*Jigsaw*. The main idea of the *Jigsaw* approach is to arrange for peer tutoring within the pedagogical scenario. This is done by following a specific sequence of group formations and task divisions:

1. Building basic groups that are assigned to the overall mission. These groups can be formed randomly or informed by agents, e.g., to form homogeneous or heterogeneous groups. Random or specific group formation can be realized by the SCY collaboration tools.

2. Dividing the task into sub-tasks or domains. In case of the $CO_2$-friendly house, the four groups can be Insulation, Energy, Construction (including design) and appliances. The insulation group would rank different materials with regard to µ-

coefficient and the energy group will look into how different forms of energy creates emissions while produced and while used, and look at this in relation to power produced/used. The areas of expertise are being defined before-hand.

3. Splitting up the basic groups and assign one learner from each basic group to an expert group on the domain-specific sub-task. Learners can assign themselves to the various expert groups according to interest. Learners who cannot reach agreement instantly will be assigned randomly.

4. Equipping the expert groups with domain-specific learning material for learners to become quasi-experts in the specified field. For instance, the expert group on energy consumption would be provided with learning material on energy consumption of house appliances and different sources of energy. Learners have a specific amount of type to distribute the specified learning material within an expert group (10 minutes), individually prepare the learning material (one hour of homework), and explain and discuss the learning material within the expert groups (one hour).

5. Asking learners to share and combine their expert knowledge to solve the overall mission, which is facilitated through group rewards based on individual scores, i.e., learners conceptual models will be evaluated with respect to how well each single expert aspect is being covered. The group will be rewarded based on the average amount of credits for the expert aspects. If learners have difficulties to share their expertise, a set of given questions will scaffold elicitation of the expert knowledge.

*Teams-Games-Tournament (TGT).* The main idea of TGT is to have learners to compete with peers of a comparable performance level and working on the same learning task.

1. Learning material is being presented to learners.

2. Learners work in groups on the mission with one central upcoming task (ELO) to be worked on individually, e.g., a final presentation on building a $CO_2$-neutral house.

3. Learners of different (competing) groups of comparable levels compete with each other to acquire credits for their own group. Since the design challenge is about creating artefacts, e.g., the best house model, the artefacts can be used for the tournament.

*Solution Synthesis.* The main idea of Solution Synthesis is to acquire multiple perspectives by comparing and complementing solutions to learning tasks by combining own with peer solutions. The activities include comparison of learners' products with respect to concepts considered, problem aspects addressed, and features built in.

1. Learners provide an individual solution to a task. For instance, learners build a conceptual model on $CO_2$ emissions.

2. Learners list the aspects of their own solution and the aspect of the solution of a peer whose solution should be as divergent as possible. For instance, the variables

learners have considered will be matched with a peer list of variables. The average deviation of all comparisons will be calculated by SCY and groups formed based on this deviation.

3. Learners compare and complement the lists of variables. If learners identify points on which they do not agree, they will be scaffolded to explicate their arguments.
4. Learners need to converge towards one joint solution before being allowed to continue, i.e., all learners need to indicate that they agree with the comparison being made. If learners cannot agree after a given amount of time, one of the existing solutions will be randomly selected. This procedure will also be applied in the following steps if necessary.
5. Learners rank the importance of the single features of the solution and add new features if possible.
6. Again learners need to agree on ranking of new features to add to the solution.
7. Learners are to combine their solutions and come up with one joint solution – no matter how divergent the initial learner solutions were.
8. The joint solution needs to be agreed on.
9. Learners are to continue their work based on the joint solution.

**Further reading**

Aronson, E., Blaney, N., Stephan, G., Silkes, J., & Snapp, M. (1978). *The jigsaw classroom*. Beverly Hills, CA: Sage.

Hmelo, C. E., Holton, D. L., & Kolodner, J. L. (2000). Designing to learn about complex systems. *Journal of the Learning Sciences, 9*, 247-298.

Kolodner, J. L., Camp, P. J., Crismond, D., Fasse, B., Gray, J., Holbrook, J., Puntambekar, S., & Ryan, N. (2003). Problem-based learning meets case-based reasoning in the middle-school science classroom: Putting Learning by Design (TM) into practice. *Journal of the Learning Sciences*, *12*, 495-547.

Slavin, R. E. (1995). *Cooperative learning: Theory, research, and practice* (2nd ed.). Englewood Cliffs, NJ: Prentice-Hall.

## 3.2 Inquiry Learning

### Main idea

Students acquire scientific inquiry skills and domain-based knowledge through discovering relations between dependent and independent variables. They start from an every-day life problem, analyze the problem situation, and define research questions and hypotheses. Hypotheses are tested through real observations, experiments, or simulations. Mobile devices like data loggers can be used for collecting data from real environment or experimental situations. The scenario can have variations depending on the stages of inquiry applied in a particular case.

**Learning goals**

This scenario is especially designed for developing students' inquiry skills and new domain-specific knowledge. However, they also acquire more general problem solving skills, analytical skills, and self-regulation skills. Depending on the particular task, students also revise existing knowledge structures about a specific phenomenon or a set of related phenomena.

**Requirements and target groups**

The inquiry learning scenario takes at least 2 to 6 lessons of learning time. Time needed depends on the experiences of the students and the stages the teacher aims to complete. In the shortest case hypothesis generation is the main aim in the first lesson and experimentation and conclusion making is the aim in the second lesson. However, a normal inquiry mission in SCY-Lab would be at least six lessons – one lesson for each learning activity space except the information space that is applied in connection with other activity spaces in different stages of inquiry. According to the teachers needs, additional lessons can be used for going deeply into particular stages.

There are no general prerequisites for applying the inquiry learning scenario. Specific needs derive from the domain-based content and the complexity on inquiry processes applied in a particular case. The teacher should analyze the content and activities before starting with students in order to avoid failure of the learning process due to lack of inquiry experiences or domain-specific pre-knowledge.

The main target group of the scenario is secondary school (age 16-19) but most of the scenario can be applied with the students in upper primary school (from age 13).

Main learning objects that have to be prepared before starting are presentations of authentic problems (narratives, videos, animations) related to the phenomenon that will be under investigation by students, and background information about the topic. In addition, materials and equipment for experimentation should be available. Other tools and materials (different rules related to inquiry stages, planning tool, web browsing facilities, note taking tool, modelling tool, experimental design tool, data analysis and processing tool) are available in the SCY-Lab.

**Learning task**

Learners have to formulate a problem, categorize it, and plan a study for investigation of relations of dependent and independent variables related to the problem. The study should be carried out and collected data would form the basis for making inferences and developing the final problem solution model. Finally, students should provide a solution for the initial problem in line with the model of the phenomenon investigated. In general, students should solve a problem and would by doing so gain a deep understanding of a particular phenomenon or a number of phenomena related to this problem.

**Assessment of learners' products**

All ELOs developed by the students in different stages of inquiry are evaluated by teachers, by peer students, or by agents in comparison with a reference ELO that is a high-quality ELO produced by experts.

The main ELOs to be evaluated are problem identification, final hypotheses, experimental plan, inferences, and final model as a problem solution. The problem statement, hypotheses, and inferences should have all relevant components derived from the actual problem statement and available data. The experimental plan should be completed before carrying out the experiment and the final model should have enough information for serving as problem solution. In each inquiry stage, the student will be provided with appropriate feedback including both score and comments. Particular details of assessment will be set in each mission depending on the problem task and tools available for solving the problem.

**Learning activities and tools**

| | |
|---|---|
| *Orientation* | Firstly, students (individuals or groups) are provided with a list of problems. The problem situations can be presented as narratives, videos, or animations. Students have to conceive a problem from that, analyze a problem situation, identify learning goals, identify prior knowledge they have related to that problem, reflect on knowledge, and identify final state of the problem. In parallel with inquiry processes – students should be encouraged to take notes of their ideas and to use the note taking tool for that. The teacher has to be aware of students' involvement in discussions. |
| *Information* | Students collect additional information to prior knowledge. They have to identify available resources, browse resources for specific information, categorize problem, and identify constraints. A Web browsing tool is available for searching for information and note taking tool for making notes of relevant information. Based on the information found, students could change their initial ELOs produced during the orientation stage. |
| *Analysis* | Previously identified problem has to be used in generating hypotheses. Hypotheses should contain measurable dependent and independent variable. Students take into account their prior knowledge and generate hypothesis using modelling tool and hypothesis generation tool. The teacher should observe that they do not forget to use notes saved with note taking tool. This stage is applicable for training students' self-regulation skills because the processes of analysis can be systematically planned, monitored, and evaluated. |
| *Design* | Students design an experiment that is appropriate for testing hypotheses set before. Therefore, they identify means in applying experimental design tool, planning tool, and modelling tool (note |

taking tool can be also used for revising notes made before). Here, the difference between the experimental plan (an ELO) and planning of making the plan (a regulative process) should be understood.

*Experiment* — Students collect data with real equipment or simulator. Data import tool can be used for importing data from external devices into an electronic database as an ELO.

*Analysis* — Collected data will be analyzed and interpreted. In addition, they relate data with a hypothesis. Data analysis and processing tool have to be used in this stage. Teachers should support the learners in the case of difficulties – sometimes they do not know where to start with searches in the data.

*Design* — Finally, students design a problem solution: relate data with hypothesis and initial problem, design a model about the phenomenon that is under investigation, evaluate the structures of the model, and find a solution to the problem on the basis of the model. The model should be evaluated using also notes made through the whole learning process.

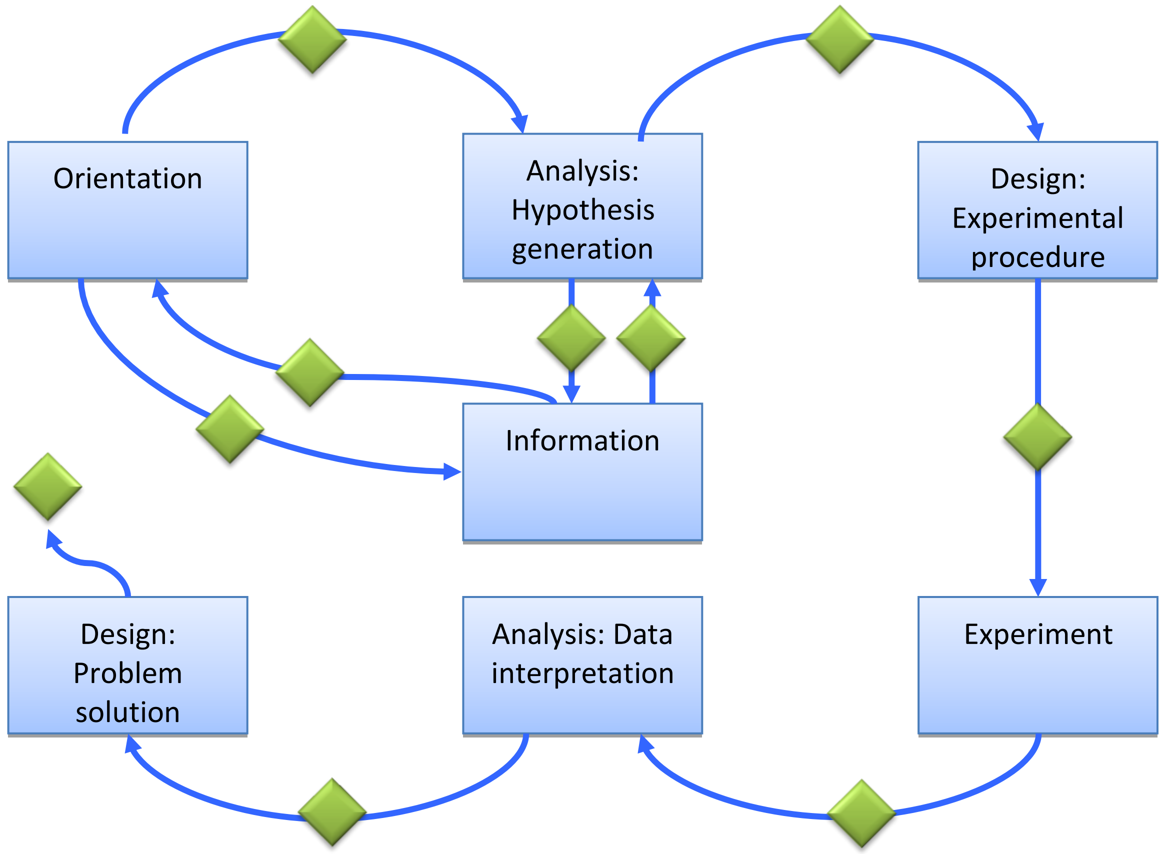


**Figure 5. Inquiry learning.**

### Teacher roles and responsibilities

The teacher prepares the problem situation to be solved in the scenario, guides students in the orientation stage, and helps to evaluate the final outcomes. The other learning activity spaces can be completed mostly without the guidance of the teacher. In some cases, the materials with appropriate background information should be prepared by the teacher. Depending on the particular problem and applied tools, support could be needed for conducting the experiments.

### Scenario examples

The examples for the inquiry learning scenario provide information on how the activities can be divided between individuals and small groups of learners. Furthermore, the plans indicate, what are suggestive sequences of these activities, and what equipment should be available for applying different plans. Work in different learning activity spaces can be seen as different lessons but according to the teachers' aims these stages can be completed in one lesson or divided into several lessons.

*Mobile learning*. This example is for fostering learning activities outside schools and for collecting real data about particular phenomena. Real data enables students to focus on deeper analysis of generalisable rules, unexpected cases, sampling issues, and validity of studies.

1. The learning process starts in a classroom. The students are instructed to form small groups. Next, the teacher provides them with a number of mobile devices that are available in school, and a list of authentic problems. The students identify the problems and discover basic functionalities of available mobile devices. Finally, groups of students formulate research questions that are related to the identified problem and that can be answered with the available mobile devices. Research questions are evaluated as SCY ELOs and feedback will be given to the groups of students. This feedback will be discussed in the groups and based on this, the final research questions will be developed.

2. The students individually follow the research questions formulated in the first stage and browse for relevant information in order to state hypotheses that will be tested with the mobile devices. Every student should propose at home at least one hypothesis per research question. At school, individual hypotheses are discussed in previously formed groups and final hypotheses are saved as ELOs in SCY. The feedback from SCY is discussed prior to the finalizing of the hypotheses. Specific SCY modelling tool and hypothesis generation tool can be applied for generating hypotheses and specific scaffolds are related to these tools.

3. Students discuss in groups a task to develop a realistic plan that can be implemented for finding answers to the research questions. The plan should be in line with the hypotheses formulated before and taking into account the tools available (mobile devices and SCY related tools). Specific experimental design tools, modelling tools and planning tools can be applied for planning and specific scaffolds are related to these tools.

4. Students in groups take their mobile devices and follow their plan in order to collect data. Collected data will be saved into a SCY accessible format using a data import tool.

5. Students individually use a computer where they analyze and interpret data and make conclusions on the basis of it. Data analysis and processing tool with specific scaffolds have to be used for that. Later, individual results and conclusions should be discussed in groups using chat-facilities. Discussion is scaffolded by SCY-Lab.

6. Presentation of the solutions of a group to other groups. General discussion.

*Simulation*. This example describes the easiest way to acquire inquiry skills in the case of strong limitations of time or equipment and materials needed for discovering particular phenomena. It enables students to understand the basic of inquiry processes.

1. Hypothesis space. Students identify individually a problem from a narrative and analyze a simulation in order to define testable variables. Based on that, they formulate research questions and hypotheses, and propose a simple plan that can be implemented in order to test hypotheses and find answers to the research

questions. SCY agents provide students with specific feedback and scaffolds depending on their ELOs saved to the system.

2. Experiment space. Students collect data and analyze it in the light of the identified problem and formulated hypotheses. They solve the problem on the basis of results of the simulation. The teacher provides appropriate guidance and feedback to the individuals. SCY agents provide students with specific feedback and scaffolds depending on their ELOs saved to the system.

**Further reading**

Crescencio, B., van Joolingen, W. R., & de Jong, T. (2006). Modeling and simulation in inquiry learning: Checking solutions and giving intelligent advice. *Simulation*, *82*, 769-784.

Harlen, W., & Jelly, S. (1997). *Developing science in the primary classroom*. Essex, UK: Addison Wesley Longman.

De Jong, T. (2006). Computer simulations – Technological advances in inquiry learning. *Science*, *312*, 532-533.

De Jong, T., & van Joolingen, W. R. (1998). Scientific discovery learning with computer simulations of conceptual domains, *Review of Educational Research*, *68*, 179-202.

Klahr, D., & Dunbar, K. (1988). Dual space search during scientific reasoning. *Cognitive Science*, *12*, 1-48.

Manlove, S., Lazonder, A. W., & de Jong, T. (2007). Software scaffolds to promote regulation during scientific inquiry learning. *Metacognition and Learning*, *2*, 141-155.

National Science Foundation. (2000) Foundations: A monograph for professionals in science, mathematics, and technology education. Inquiry: Thoughts, views, and strategies for the K-5 classroom. Retrieved from *http://www.nsf.gov/pubs/2000/nsf99148/start.htm*

Pedaste, M., & Sarapuu, T. (2009). The factors affecting multimedia-based inquiry. L.T.W. Hin & R. Subramaniam (Eds.). *Handbook of Research in New Media Literacy at K-12 Level: Issues and Challenges* (pp 270-284). Ney York: IGI.

Pedaste, M., & Sarapuu, T. (2005). *Problem solving and inquiry learning in biology. Teaching science in school, I part* (pp 84-92). Tallinn: National Examinations and Qualifications Centre.

Pedaste, M., Sarapuu, T., & Mäeots, M. (2009). Inquiry learning with ICT. In K. Pata, M. Laanpere (Eds.). TigerLearning: *Handbook for educational technology* (pp 83-99). Tallinn: Tallinn University. Retrieved from http://www.htk.tlu.ee/tiigriope/

## 3.3 Problem Resolution

### Main idea

Problem-based approaches to learning (PBL) have a long history of advocating experience-based education. Psychological research and theory suggests that by having students learn through the experience of solving problems, they can learn both content and thinking strategies. In PBL students collaboratively solve problems and reflect on their experiences. It is an inductive approach in the sense that students learn the content and concepts as they try to address a problem. The problem is central: it is ambiguous and complex in nature; it requires inquiry, information-gathering, and reflection; it has no single and simple solution; it often provokes a cognitive conflict. Above all, the problem is designed in such a way that the knowledge students should acquire is most adapted for the resolution of the problem.

### Learning goals

Learning goals include: application of problem solving in new situations, creative and critical thought, adoption of a holistic approach to problems and situations, appreciation of diverse viewpoints, successful team collaboration, and effective communication skills.

### Requirements and target groups

Groups size influence whether or not students that participate in the activities, are cohesive and interactive, show diversity in ideas and independence toward the teacher. The optimal group size suggested for many PBL is 5 to 8 students.

PBL requires time to allow students to find creative and individual solutions, and also to alternate between individual and group work. PBL thus lasts from several days to several weeks.

Originally designed for older students (mostly in medical or engineering schools), it can be used for younger students who have a basic understanding of core principles within a scientific field.

Useful tools in SCY-Lab include: idea generation tool, inquiry environment (work with data), notebook tool, decision support tool, communication tool, information gathering and annotating tool.

### Learning task

In short, students start with a given problem, make a plan for gathering information (reading, experimenting, designing, etc), pose new questions and summarise their solution and justifications of choices by presenting their conclusions.

In practice, PBL includes several steps depending on the model. Most activities are performed in group, but some should be done individually to allow for individual appropriation of knowledge.

**Assessment of learners' products and goal achievement**

Different products may be assessed: a regular journal that reports students learning and details the obstacles that have been overcome and how, a grid for critical self assessment of own knowledge, skills and attitudes, a final presentation that can be oral or written.

Assessment may be conducted alternatively by students themselves (peer assessment) or by the teacher.

What is assessed are the problem solution (creative, well justified and compared to other solutions, etc), the knowledge gained (e.g., individual knowledge test), and how well team collaboration went.

**Learning activities spaces**

*Orientation* In the orientation space, students will define learning goals and means in order to be able to look for information.

*Information* Students come to look for information, either at an early stage when they have to define their own questions or later when they started to design their own solutions and try to fill the gaps in their knowledge.

*Analysis* Students build on goals and means defined previously and information found. Indeed, they can now identify key issues and specify further the questions they want to address. They will come later, when they have data or resources and they can relate data with their hypothesis or theory. They will also come towards the end, in order to build a number of different solutions.

Since this scenario depends strongly on collaboration, which is one of the means for learning in this case, we need the debate space as well as the management space.

*Debate* Students can build a consensus on a common solution to their problem.

*Management* They plan the work process and distribute tasks among the team.

*Evaluation* Students will either evaluate others' solutions if required, or their various solutions before they can go to the debate space and select the best one.

*Reporting* This space is necessary since students have to report about their work, either in a written report or poster, or an oral presentation.

*Monitoring* This space is very important because students should not only solve problems but also learn. We want them to be able later to recognise the type of problems they can solve and know the kind of strategy they can use to solve such problems. Usually, students are provided with a method to monitor their learning (in the form or questions they should ask themselves, for example).

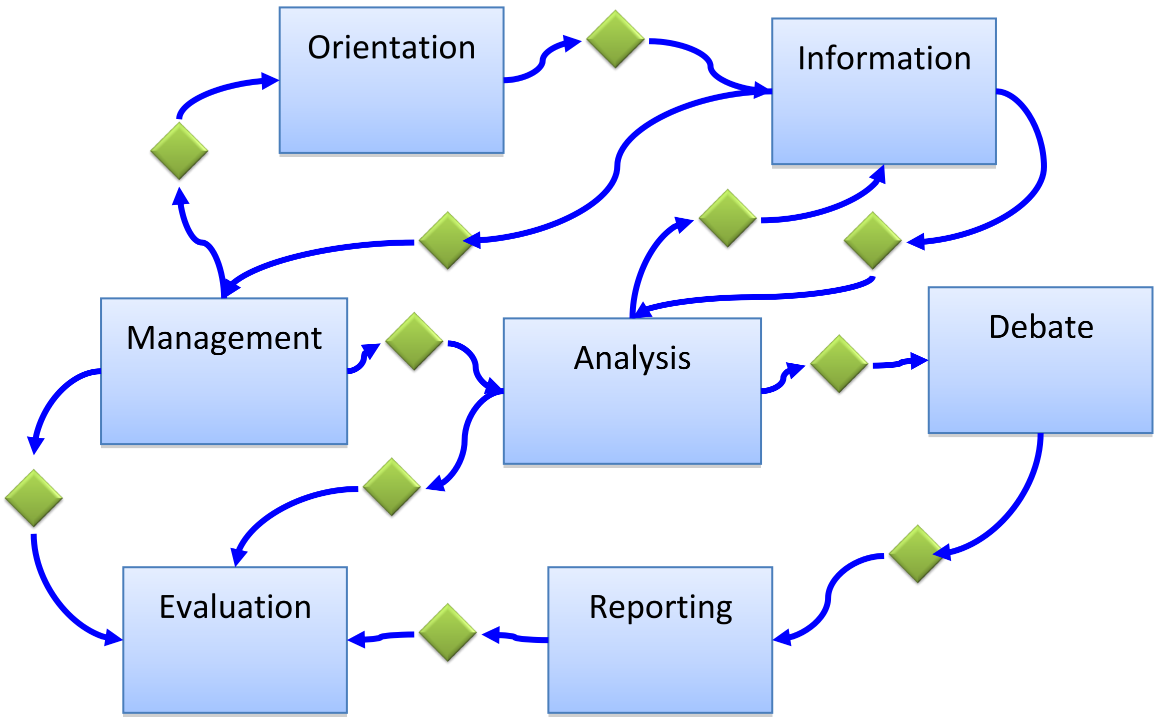


**Figure 6. Problem resolution.**

## Teacher roles and responsibilities

In a learner-centred orientation, the goals of learning in PBL are at least partly determined by the students themselves. The teacher takes over the role of a facilitator most of the time. Guidance is faded.

Roles of the teacher can be facilitated by information available in the SCYAuthor Runtime view and include:

Make sure groups stay on task, ensure that some students do not fall behind, provide answers when needed (lecture on demand, institutionalise (organise a debriefing session at the end).

## Scenario examples

PBL comprises many steps that are summarised below and grouped into three phases:

Phase 1: Problem appropriation.

The teacher has introduced an "ill-structured" problem.

Students meet without the teacher to discuss the problem statement and list its significant parts. They define what is problematic, what is interesting, and what is important to find out. They list what they already know and what needs to be found out. They list actions to be taken, and make a timeline. They may also write out the problem statement in their own words. Students summarize their ideas and make them available on the SCY-Lab. Teacher can give feedback on students' summary of the problem and planning in order to help them focus on a tractable problem.

Phase 2: Problem solving.

Students work individually and look for information to fill in missing gaps. Then they investigate possibilities and solutions. They research the knowledge and data that will support their solution (make experiments or search in database). Students meet again with a tutor to prepare a list of questions that they can ask to the teacher in a whole class session. These questions are listed in SCY-Lab. Students can also see the questions of other groups and vote for the most important questions. In a "just on time teaching" manner, the teacher will check these questions in SCY-Lab in advance and prepare a lecture that addresses the ones that received the most votes or that are important in his/her view. This lecture comes just on time when students most need it, that is, when they already have the ability to ask their own questions. Back in groups, students assess alternatives and agree on one solution.

Phase 3: Communication and debriefing.

Students prepare a report and a presentation of their findings and/or recommendations, for their classmates and teacher. This includes the problem statement, questions, data gathered, analysis of data, and support for solutions or recommendations based on the data analysis: in short, the process and the outcome. Students report not only on their problem solutions but also on their experiences, reflecting on the learning that has taken place. For that, they find questionnaires in SCY-Lab that help them reflect on their learning process and outcome. The whole class presentations are followed by a debriefing session allowing reviewing what has been learnt together with the teacher.

**Further reading**

Resources on PBL teaching and learning: http://www.queensu.ca/ctl/goodpractice/problem/resources.html

PBL in middle and high school: http://wik.ed.uiuc.edu/index.php/Problem-Based_Learning_in_Middle_and_High_School

PBL and middle school kids: http://www.higp.hawaii.edu/kaams/resource/pbl.htm#middle

Evensen, D. H. & Hmelo, C. E. (2000). *Problem-based learning: A research perspective on learning interactions*. Mahwah, NJ: Erlbaum.

Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn? *Educational Psychology Review, 16*, 235-266.

## 3.4 Close a Case

### Main idea

Formal learning environments usually involve well-structured problems, for which identification of core questions, as well as framing of the existing state and desired state can be indisputably described. In contrast, people in every-day life face ill-structured problems, which cannot be discussed on the basis of a particular, certain answer. Instead, in ill-structured problems there are disputants who disagree about appropriate solutions. Case-based learning is a pedagogical method which uses real-world case studies as starting points. A case study is composed of an engaging and controversial story, usually a dilemma. In the case of science education, the dilemma should require a basic understanding of certain scientific principles. The context of a case is intended to enable learners to put themselves in the role of being an actor in the situation. It provides rich contexts for framing issues and facilitates experience-based knowledge construction. Former research has shown that content framed in cases is more easily remembered as the cases provide mental anchors for the facts, concepts, and principles being studied. Case-based learning advances (1) beliefs students hold about the nature of knowledge and the process of knowing, which will be developed by questioning one's own beliefs and knowledge, examining taken-for-granted practices and ideas as well as incorporating multiple perspectives; (2) their ability to think about one's own thinking and self-regulation of the learning process, which will be facilitated by validating solutions; and (3) their capacity to formulate assumptions by accompanying justification, which will be supported by integrating sound theories and principles, reconciling conflicting interpretations, and formulating coherent, non-contradictory arguments.

### Learning goals

Learning goals include: (1) understanding of concepts in particular contexts (e.g., which is the best practice concerning the building of $CO_2$-friendly houses in the European context) as well as context-independent use of concepts (e.g., which building parameters are crucial across contexts); (2) critically revisiting one's own as well as taken-for-granted assumptions; and (3) developing argumentation skills, especially regarding context-specificity and the dilemma-character of ill-structured problems.

### Requirements and target groups

*Close a Case* is most suitable for collaborative learning arrangements in the school environment. Since the scenario is demanding in terms of work load, students' groups should have a size of 2 to 4 learners so that the work load does not become a counter-motive for students. Typically, time needed to go through all learning activity spaces will amount to about 20 hours.

Students will make use of tools to analyze case studies (i.e., note taking tool, table editor, SCYMapper) to conduct interviews and WebQuests (i.e., interview format tool and web-browsing tool, respectively), and plan their learning process (i.e., planning tool). Indispensable for the scenario is a collection of exemplary cases. This case library will be gradually expanded by learners themselves.

### Learning task

First learners investigate a number of case studies under a topic. After having received feedback from expert solutions (for instance, energy experts, thermal experts, and architects in the case of building $CO_2$-friendly houses), a classroom discussion will help learners identify goal state, resources, and means to refine their initial solution. They will plan the learning process to identify learning paths and prepare a timeline. Next, they will de-contextualize case studies to come to global aspects of solution generation, which will be commented by experts in interviews conducted by learners themselves. Then, students will conduct a WebQuest to identify analogous cases on the internet. The final product is a classification of new case studies found, which will update the case library of SCY-Lab.

### Assessment of learners' products and goal achievement

Since learners will engage in analyzing and reviewing analyses of case studies, assessment is suggested to be teacher oriented instead of peer oriented. Teacher assessment should focus on three learners' products: the cognitive map that will reveal differences between their solution and expert solutions as well as context-specific limitations and constraints and de-contextualized global solutions. The classroom discussion in the Orientation Space is also crucial for monitoring goal achievement (see Teacher roles and responsibilities).

### Learning Activity Spaces

| | |
|---|---|
| *Information* | Learners will first be introduced to the topic of the case analysis, which is about to follow. The topic will be presented in the form of a controversy or dilemma to be solved. Out of a case library, students will choose texts and videos describing case studies in this topic. Students take notes on what has been read and seen.<br><br>Students re-enter the Information Space after they have validated their global solutions by expert comments in the Debate Space in order to conduct a WebQuest and identify cases with analogous solutions. |
| *Analysis* | Students use the notes taken in the Information Space to identify main aspects of the issue under study and multiple perspectives in the cases they examine, including identification and evaluation of sources of information.<br><br>After the Regulation Space, students revisit the Analysis Space to identify the conditions under which problem solving needs to take place. Learners prepare a list of limitations and constraints. |
| *Debate* | Students collaborate in groups to decide on what criteria are relevant to address the issue under study and to synthesize their views in order to come to a unanimous decision. |

Students re-enter the Debate Space to conduct interviews with experts. These interviews aim at validating the de-contextualized solutions learners came up with in the Analysis Space.

| | |
|---|---|
| *Reflection* | Learners analyze how experts have arrived at solutions in the same subject area. In this regard, learners identify experts' beliefs and knowledge and they also identify differences between experts' approaches and their own approaches to the issue under study. |
| *Orientation* | In this space, students determine goals of problem solving and criteria that should be met to consider the problem solved. They also locate where relevant information can be found and select strategies to approach the issues under study. Activities in the Orientation Space are facilitated by a classroom discussion led by the teacher. |
| *Regulation* | Students plan the learning process by identifying learning paths, sequences of activities and map them to intermediate goals. |
| *Conceptualization* | This is the Learning Activity Space where the final product of the scenario will be produced. After the WebQuest in the Information Space, students classify cases with solutions analogous to their own solutions. Activities will be accompanied by a classroom discussion led by the teacher. Classified cases will then update the case library of SCY-Lab. |

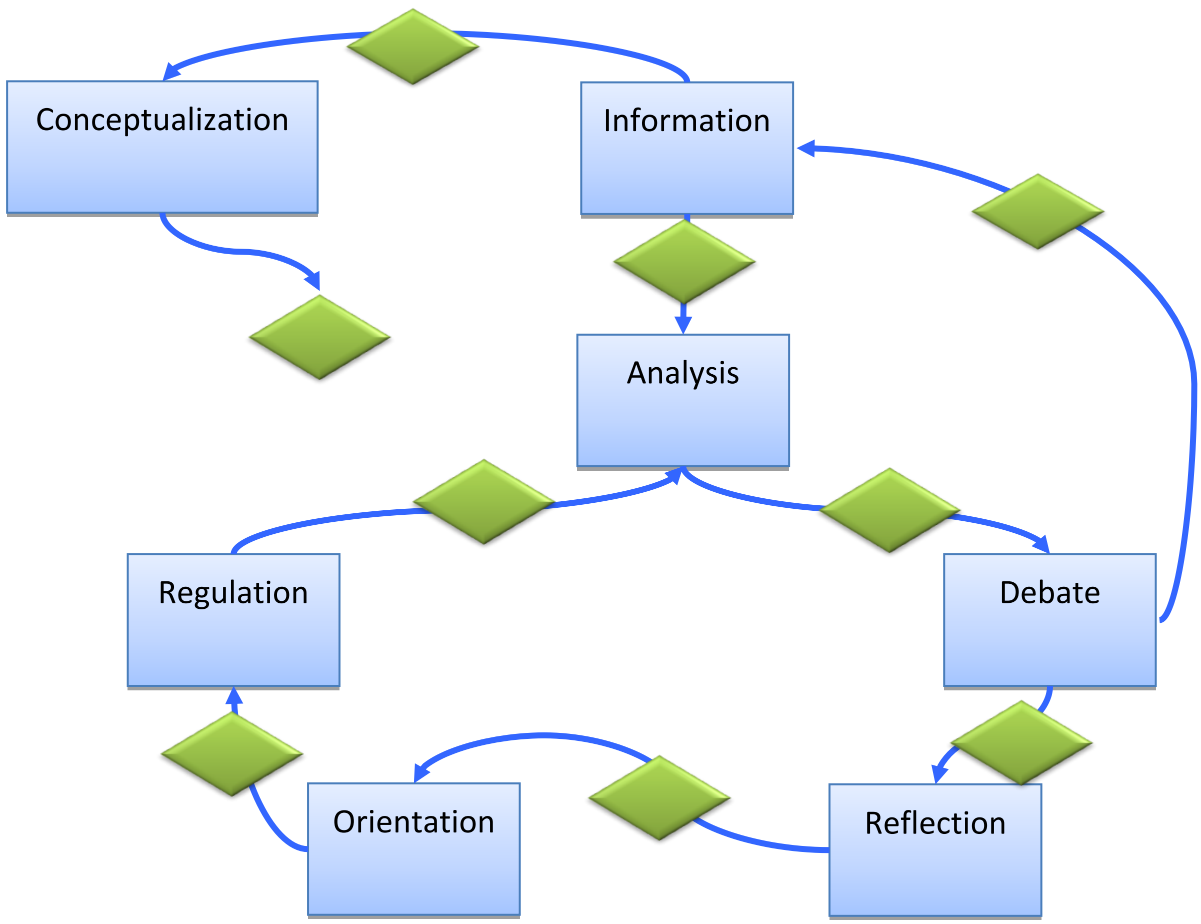


**Figure 7. Close a Case.**

### Teacher roles and responsibilities

The case library in SCY-Lab will include a number of exemplary cases, but these are not expected to cover any potential topic to be addressed under *Close a Case*. Therefore, the teacher should be responsible for screening exemplary cases as well as supplying students with additional case studies. During this stage, the teacher should locate possible learning difficulties (e.g., novel scientific concepts to be presented to students) to provide feedback and cover gaps in learners' background knowledge (e.g., explain main concepts included in case studies). Further, the teacher should orchestrate classroom discussions in the Orientation and Conceptualization Spaces.

### Scenario examples

*Peer Review Script*. To address an issue, the teacher can either choose students to scrutinize a limited number of lengthy case studies (e.g., one or two case studies in the whole classroom) or analyze an extended variety of brief cases in order to unravel the heterogeneity of views or events within them (e. g. three case studies per learner group). If the teacher makes the latter choice, a division of work load among peers is necessary for case analysis to be possible in the first place. This can be facilitated by the *Peer Review Script*, which is based on the core design principle of assigning and alternating roles that foster reciprocal activities among learners, such as questioning and tutoring. For this script, the size of learners' groups has to be confined to three students. Each learner group consisting of three students analyzes and reviews three case studies on the same topic. Each student is responsible for writing a case analysis (1) and critiquing the other two case analyses (2). After discussing critiques with peers (3), students revise their own case analysis (4). The roles of case analyst and constructive critic are supported by prompts, such as: 'These aspects are not clear to me yet'; 'We have not reached consensus concerning these aspects'; and 'My proposal for an adjustment of the analysis is …'.

*Content Analysis Script.* This script aims at assisting students in content analyzing case studies (e.g., a case study on a family that attempted to build a $CO_2$ friendly house). First, students will be prompted to select the appropriate unit of analysis, which can depend on the size of reference material that presents case studies (1). For instance, the unit of analysis can be a whole text, each text section (if available) or each paragraph (if available). Then, the coding scheme has to be defined (2), i.e., what is to be sought in the case studies (e.g., choices that should be made during the building of the house or after the house has been built). If a case study refers to a coding category, then binary data of presence/absence can be used to content analyze case studies (e.g., what choices have been made to build a $CO_2$ friendly house) (3). Alternatively, students can calculate the number of references to each coding category in line with the unit of analysis, i.e., number of references to a certain coding category in the whole text, each text section or each paragraph. The number of references usually reflects the importance given to coding categories (e.g., importance of certain choices for family members). To compare content analysis of case studies across members of the same group, an inter-rater reliability index can be computed by dividing the number of references classified by students to the same category by the total number of references. This will reveal the degree of overlap between content analysis conducted by different group members. The *Content Analysis Script* will enable students to systematically content analyze texts depicting case studies across a variety of contexts. Therefore, this script should be used when students process different cases inconsistently (e.g., use different methods to analyze the content of different cases under the same topic).

## Further reading

Choi, I., & Lee, K. (2009). Designing and implementing a case-based learning environment for enhancing ill-structured problem solving: Classroom management problems for prospective teachers. *Educational Technology Research and Development*, 57, 99–129.

Kim, H., & Hannafin, M. J. (2008). Situated case-based knowledge: An emerging framework for prospective teacher training. *Teacher and Teaching Education*, 24, 1837–1845.

McNaught, C., Lau, W. M., Lam, P., Hui, M. Y. Y., & Aau, P. C. T. (2005). The dilemma of case-based learning in science in Hong Kong: Students need it, want it, but may not value it. *International Journal of Science Education*, 27, 1017–1036.

Rybarczyk, B., Baines, A. T., McVey, M., Thompson, J. T., & Wilkins, H. (2007). A case-based learning approach increases student learning outcomes and comprehension of cellular respiration concepts. *Biochemistry and Molecular Biology Education*, 35, 181–186.

Weinberger, A., Ertl, B., Fischer, F., & Mandl, H. (2005). Epistemic and social scripts in computer-supported collaborative learning. *Instructional Science*, 33, 1–30.

## 3.5 Decision Console

### Main idea

Multiple-criteria decision-making refers to processing information in the context of situations that require weighing various criteria in order to support learners' final choice. When confronted with a multi-criteria decision-making context (e.g., which choices to make in order to reduce $CO_2$ emissions of a house without compromising occupants' comfort and without increasing the cost of building and operating the house), students attempt to reduce the complexity behind the tasks and decide without taking into account all available criteria. Learners usually base their decision on a single criterion (e.g., most important source of $CO_2$ emissions in a house) or they might base their decision on the number of the criteria (for instance, $CO_2$ emissions, occupants' comfort, cost of changes) where an option ranks first. In *Decision Console* students will base their choice on a series of criteria. Students will realize that a solution that might not have ranked first on any of the criteria might still be the most appropriate overall solution when all available information is taken into consideration.

### Learning goals

The main goal of Decision console is to facilitate development of students' reasoning skills in dealing with multi-criteria decision-making situations. A special focus of this scenario is on optimization as an appropriate reasoning strategy (i.e., taking into account all criteria to reach a decision and weighing each criterion according to its overall significance). Optimization as a compensatory strategy of multiple-criteria decision-making should be accompanied by appreciating that the most appropriate solution is determined by weighing alternatives against both their strengths and weaknesses. In the topic of $CO_2$-friendly houses, domain related learning goals for Decision console involve the relative contribution of each potential intervention during the building phase or during the operation phase in lowering the total house carbon footprint.

### Requirements and target groups

*Decision console* is best integrated in the school environment under collaborative learning arrangements. However, individual activities are suggested for the initial stage of the scenario.

With appropriate manipulation of the multiple-criteria decision-making context, the scenario is suited for both lower and upper secondary education. *Decision console* could be compatible with group sizes of 2 to 5 learners. Where larger groups are formed, longer time span should be anticipated. A typical time span for a complete cycle through the Learning Activity Spaces scheduled amounts to about 20 hours.

Concerning resources and tools, the initial task involves an introductory text or video (for example, a video on options for reducing $CO_2$ emissions from houses). Students will use note taking tools (e.g., text editor) and tools to represent selected information (e.g., schematic drawing tool, SCYMapper). Learners will also use a voting tool for a classroom vote. The planning tool will be used in the Orientation and Management Space to identify the goal state and plan the work process, respectively. After learners have reached a decision, they will present it by means of the report tool.

**Learning task**

Learners first read a text or watch a video, which introduces the multi-criteria decision-making context. Learners will have to develop their own criteria to evaluate alternative solutions (for instance, $CO_2$ emissions, occupants' comfort, cost of changes), rank alternative solutions with respect to each criterion, account for the relative importance of each criterion and assign weights (e.g., $CO_2$ emissions more important than occupants' comfort, and the former two more important than cost of changes), as well as obtain an overall evaluation for each solution by estimating the total sum of all criteria (namely, sum of multiplying rank by weight across criteria). The solution with the highest score is to be judged as the optimal one. Optionally, another cycle can start, where students will have to implement the decision-making skills they have acquired in another context.

**Assessment of learners' products and goal achievement**

Special attention will be paid to assessing three learners' products that are crucial for acquiring decision-making skills. Specifically, criteria selected by students to elaborate on rival solutions (ELO number 8) should be included in a pre-determined set of relevant criteria. Next, the non-weighted table (ELO number 9) should incorporate ranked solutions along the same measurement scale. Finally, the weighted table (ELO number 13), where students are to base the final output of the scenario, should be the result of multiplying ranked solutions with weights set across criteria according to their importance in configuring students' decision-making process.

**Learning Activity Spaces**

| | |
|---|---|
| *Information* | The first activity of the scenario takes place in the Information Space, where learners read a text or watch a video that introduces them in a complex decision-making context. |
| *Analysis* | Students identify the main aspects of the problem under reference. |
| *Debate* | After having identified key issues, learners construct arguments that refer to the decision-making context by formulating claims and providing data and any other evidence to justify their claims. In a classroom discussion led by the teacher, students attempt to negotiate and synthesize their views by building consensus on the issue. |

Students re-enter the Debate Space, where they identify the main arguments used by peers in a classroom discussion. Learners are expected to appreciate the multiplicity of views and the complexity of the decision-making context and realize that they have to resort to a compensatory decision-making strategy, namely, taking into account all relevant criteria to reach a decision.

Students enter once more the Debate Space to rank solutions and prepare the unweighted and weighted tables. The difference between unweighted and weighted tables is that the latter are weighted by coefficients allocated by students to criteria according to their importance in the final decision.

*Reporting* Students come up with a decision to address the complex context within which the problem has been articulated. It is expected that learners will try to simplify the decision-making context by adhering to a non-compensatory strategy, for instance by concentrating on a single criterion they hold as the most important. As soon as students have reported their decision, they are directed back to the Debate Space.

Learners re-enter the Reporting Space to describe the unweighted and weighted tables with solutions ranked across chosen decision-making criteria. The description of the weighted table is the final product of the scenario.

*Orientation* Learners enter the Orientation Space after they have realized in the Debate Space the need for a compensatory strategy (e.g., one that takes into account all relevant criteria). In a classroom discussion led by the teacher they identify goals of problem solving and prerequisites that should be met to apply the compensatory strategy.

*Management* Students leave the Orientation Space and enter the Management Space, where they build groups and structure the tasks ahead to implement the compensatory strategy (namely, the one that is based on the totality of relevant criteria).

*Conceptualization* In small groups, students identify which solutions are available and what criteria they will use during the decision-making process.

Students re-enter the Conceptualization Space to allocate weights to decision-making criteria.

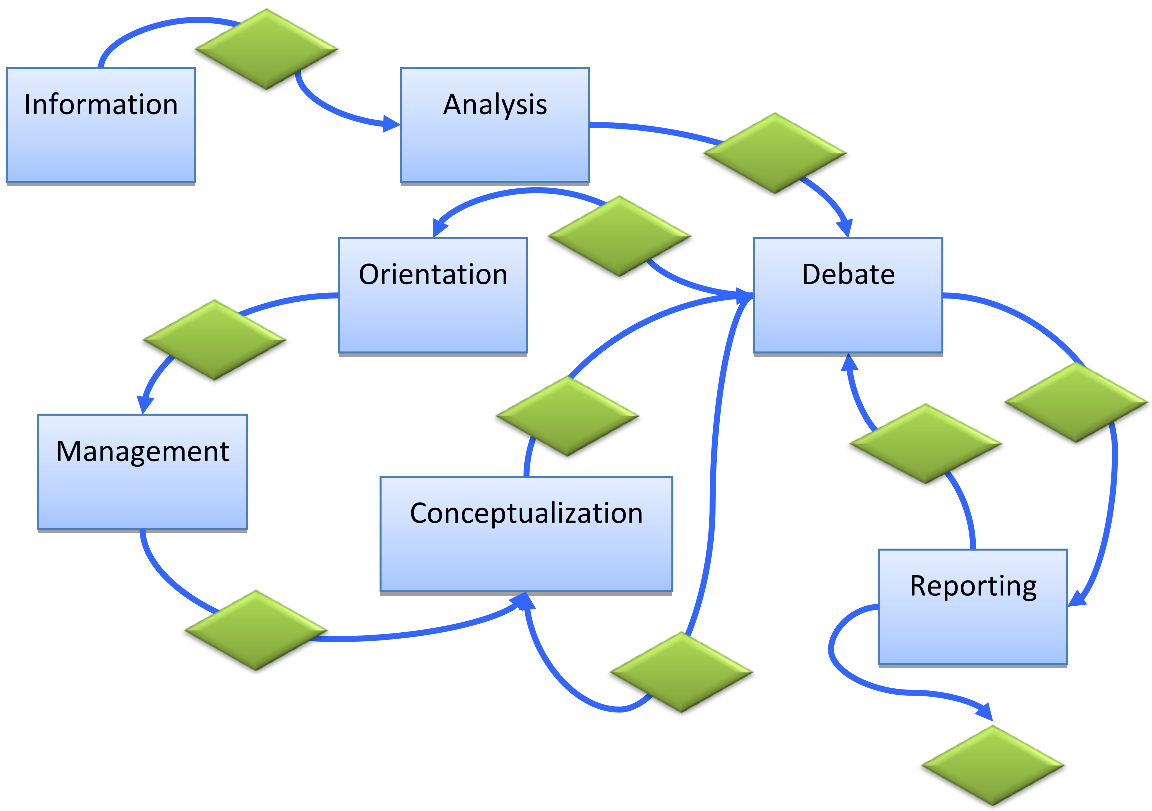


**Figure 8. Decision Console.**

### Teacher roles and responsibilities

The teacher is needed to introduce an alert in the Debate Space. After learners' first report, the teacher will redirect them back in to the Debate Space in order to elaborate on the strategy they applied to choose among rival solutions. Learners will identify alternatives, e.g., that they have to take into account all relevant criteria to reach the optimal solution. In the Orientation Space, the teacher will support learners in identifying the requirements that should be met to consider the overall task solved. Once again in the Debate Space, the teacher should check if students have weighted all criteria according to their importance.

### Scenario examples

*The ArgueGraph Script.* The ArgueGraph Script attempts to include students with highly conflicting opinions in collaborative learning groups. The script is recommended when decision making involves situations were learners encounter views which stand in contrast to their own opinions. First, students complete a questionnaire where they are requested to state their agreement with potential criteria to use in order to reach an optimal solution (1). Recordings are plotted to construct a graph, which displays each learner position along questionnaire items (2). For instance, using a 5-point Likert scale, where 1 indicates strong disagreement and 5 indicates strong agreement, there can be students with dispositions at the extremes of the scale (e.g., strong disagreement or strong agreement), as well as students with milder dispositions at the middle of the scale. The script will be activated in the Debate Space. Students with divergent attitudes will be grouped together in the Management Space (3). In the Conceptualization Space which is about to follow, students will have to reach consensus on identifying criteria as well as their relative importance in the controversy at hand (4).

*Consensus Estimation Task.* The Consensus Estimation Task should be used if peers are well- acquainted. Students are requested to state their opinion on an issue, e.g., whether they believe that the need to reduce $CO_2$ emissions proceeds over occupants' comfort (1). Then, they are requested to provide a percentage estimate of their peers who would agree with the introductory statement (e.g., that the need to reduce $CO_2$ emissions indeed precedes over occupants' comfort) (2). These two measures reflect the actual consensus (e.g., what students truly believe, namely what percentage of the class agrees that the need to reduce $CO_2$ emissions proceeds over occupants' comfort) and the estimated consensus (e.g., what students believe their peers think, namely what percentage of peers each student believes would agree with the statement) (3). Estimated consensus expressed as a percentage is expected to present a divergence from actual consensus. In the Management Space, mixed groups are to be formed (including students who agree and others who disagree with the stimulus statement) (4). Together with the final output of the scenario, students will be requested to record once again their personal stance on the stimulus statement (e.g., that the need to reduce $CO_2$ emissions proceeds over occupants' comfort) as well as to provide a new estimate for peers' views after the completion of all activities (5). The hypothesis behind using the script is that the educational intervention should result in decreasing errors in consensus estimation.

*Multi-Criteria Decision-Making Script.* The Multi-Criteria Decision-Making Script (MuCDeMa Script) is developed on the basis of students' difficulties in employing compensatory strategies in multi-criteria decision-making contexts (e.g., taking into account all relevant criteria to reach a decision). Specifically, when confronted with such contexts, students fail to appreciate the value of taking into account the entirety of available information. In this case, (e.g., if students base their decision on a single criterion or if they base their decision on the number of the criteria where an option ranks first), the MuCDeMa Script will be enacted in the Debate Space and the Conceptualization Space. Specifically, students will be prompted to construct a matrix with possible solutions (columns) (1) and criteria to judge solutions (rows) (2). Alternative solutions will be ranked along all criteria that can inform students' judgment (e.g., in terms of judging three rival solutions against the criterion of reducing $CO_2$ emissions, the best solution will take a rank of 3, the worst a rank of 1, and the intermediate one a rank of 2) (3). Then, weights will be given to criteria (e.g., reducing $CO_2$ emissions could be treated as the most important criterion and take a weight of 1.5; occupants' comfort could be treated as a criterion of intermediate importance and take a weight of 1; cost of changes could be treated as the least important criterion and take a weight of 0.5) (4) and weighted scores will be calculated for each solution (i.e., multiplication of a non-weighted table of ranked solutions across criteria with weights given to criteria to produce a weighted table; namely, a solution which has been judged best in terms of reducing $CO_2$ emissions will be granted a rank of 3 in the un-weighted table, but by multiplying the rank of 3 by the weight of 1.5 given to the criterion of reducing $CO_2$ emissions, this solution will have a score of 3 X 1.5 = 4.5 in the weighted table) (5).

**Further reading**

Dillenbourg, P., & Jermann, P. (2006). Designing integrating scripts. In F. Fischer, I. Kollar, H. Mandl, & J. Haake (Eds.), *Scripting computer-supported collaborative learning: Cognitive, computational, and educational perspectives*. New York: Springer.

Nicolaou, C. Th., Korfiatis, K., Evagorou, M., & Constantinou, C. P. (2009). Development of decision-making skills and environmental concern through computer-based, scaffolded learning activities. *Environmental Education Research*, 15, 39–54.

Papadouris, N., & Constantinou, C. P. (in press). Approaches employed by sixth-graders to compare rival solutions in socio-scientific decision-making tasks. *Learning and Instruction*.

Papadouris, N., Papademetriou, D., Kyratsi, T., & Constantinou, C. P. (2005). Developing research-based technology enhanced curriculum materials: An example in the context of decision-making skills. In Z. Zacharia, & C. P. Constaninou (Eds.), *Integrating new technologies in science and education. Proceedings of 7th International Conference on Computer-based Learning in Science '05* (pp. 342–353). Zilina, Slovakia: University of Zilina.

## 3.6 Grasp a Model

### Main idea

Modelling-based learning engages students in creating models for exploration, prediction, and knowledge construction. A model can be defined as an artefact representing a phenomenon (e.g., the carbon cycle), which includes structural components (sinks, where carbon is stored in various forms, such as the atmosphere, where carbon is stored as $CO_2$) and relations between structural compartments (e.g., processes, which transform carbon from one form into another, and let it flow from one sink into the other, for instance, photosynthesis, which transforms $CO_2$ in organic molecules). In the frame of *Grasp a Model*, learners' initial models will be compared against expert solutions and will be refined. Then, data gathered through simulation runs will be contrasted to the expected results. Differences between data and expected results are to be attributed to inconsistencies of students' initial models. The examination process of unexpected simulation results contains significant opportunities for learning, because it eventually requires an intensive reflection and adaptation of the learners' initial models. In this regard, students learn to appreciate both the strengths and the limitations of modelling. A further contribution associated with the modelling capacity pertains to the development of systems thinking, where students are given the opportunity to observe how changes in individual components of a system affect the behaviour of the remaining components and the system as a whole.

**Learning goals**

The goal of *Grasp a Model* is to improve students' modelling skills, namely: (1) formulating models; (2) extracting information from given models; (3) model revision; (4) comparative evaluation of models depicting the same phenomenon; (5) appreciating the utility of models; (6) reflecting on the process of model development and refinement. In the case of the mission to build $CO_2$-friendly houses, domain related learning goals for Grasp a model include core specifications of systems' thinking, namely, differentiating between sinks, flows, converters, and constant variables.

**Requirements and target groups**

*Grasp a Model* is ideal for collaborative learning arrangements in the school environment. Optimal group size is 2-3 learners. Classroom discussions guided by the instructor have to intervene between certain stages (see 'Teacher roles and responsibilities'). A typical time span for a complete walkthrough will amount to about 20 hours.

The basic tools are a modelling tool and a simulator. Tools to carry out an experimental procedure will also be needed (e.g., experimental design tool; data process visualization tool). Other tools to be used are the drawing tool for recording prior knowledge, a polar chart for reflecting upon one's own knowledge and skills, a planning tool to identify expected learning outcomes, a progress visualiser to evaluate students' progress through the scenario, a cognitive map tool, and a note taking tool.

**Learning task**

*Grasp a Model* consists of defining the parameters of the phenomenon under study (structural components), their interrelations (functional aspects), and reflecting on expected outcomes when simulating models. Learners' prior knowledge will be compared against expert solutions. Knowledge gaps and misconceptions will be highlighted and a refined model will be used for experimentation purposes. A series of intermediate ELOs during experimentation (e.g., experimental procedure; data) will lead to data interpretation, which will be introduced in a peer assessment phase. Evaluation reports will be used to analyze limitations and constraints among alternative models. Finally, students will reflect upon knowledge and skills acquired.

**Assessment of learners' products and goal achievement**

Local interpretations of experiment data derived by the use of learners' models to design experimental procedures will be utilized for assessment purposes. Specifically, within the frame of peer assessment and web-portfolio building, students will assess peer models and the corresponding execution of experimental designs. The reports and annotated cognitive maps, which will be produced in this manner, will be used in the Analysis Space to identify limitations and constraints of models. Students will also self-assess their goal achievement in the Reflection Space.

**Learning Activity Spaces**

| | |
|---|---|
| *Reflection* | The scenario begins with the identification of students' prior knowledge of the phenomenon that will be modelled.<br><br>Learners re-enter the Reflection Space after their initial model has been built to reflect up on expert solutions and knowledge, and they prepare a list of their own gaps and misconceptions.<br><br>Students enter once more the Reflection Space to produce the final output of the scenario, namely a critical evaluation of knowledge and skills acquired. Learners will consider what understanding has been reached and what tasks can be accomplished with it. |
| *Conceptualization* | Students identify relevant variables and build a model with sinks, flows etc.<br><br>Students re-enter the Conceptualization Space to refine their model according to goal-state identification and generate hypotheses. |
| *Orientation* | After having reflected on expert views, students come to the Orientation Space to identify the goals of model building and define which criteria should be met to consider the modelling procedure accomplished. A classroom discussion led by the teacher will facilitate students' activities in the Orientation Space. |
| *Experiment* | With hypotheses generated in the Conceptualization Space, learners design an experimental procedure, run the experiment and make a local interpretation of data. |
| *Evaluate* | The local interpretation of data is fed into the Evaluate Space, where students assess former Emerging Learning Objects, the learning process, and the refined model. |
| *Analysis* | In the Analysis Space, students identify limitations and constraints in the application of their models. |
| *Debate* | Learners enter the Debate Space with the description of limitations and constraints of their models and take part in a classroom discussion where they compare their models. |

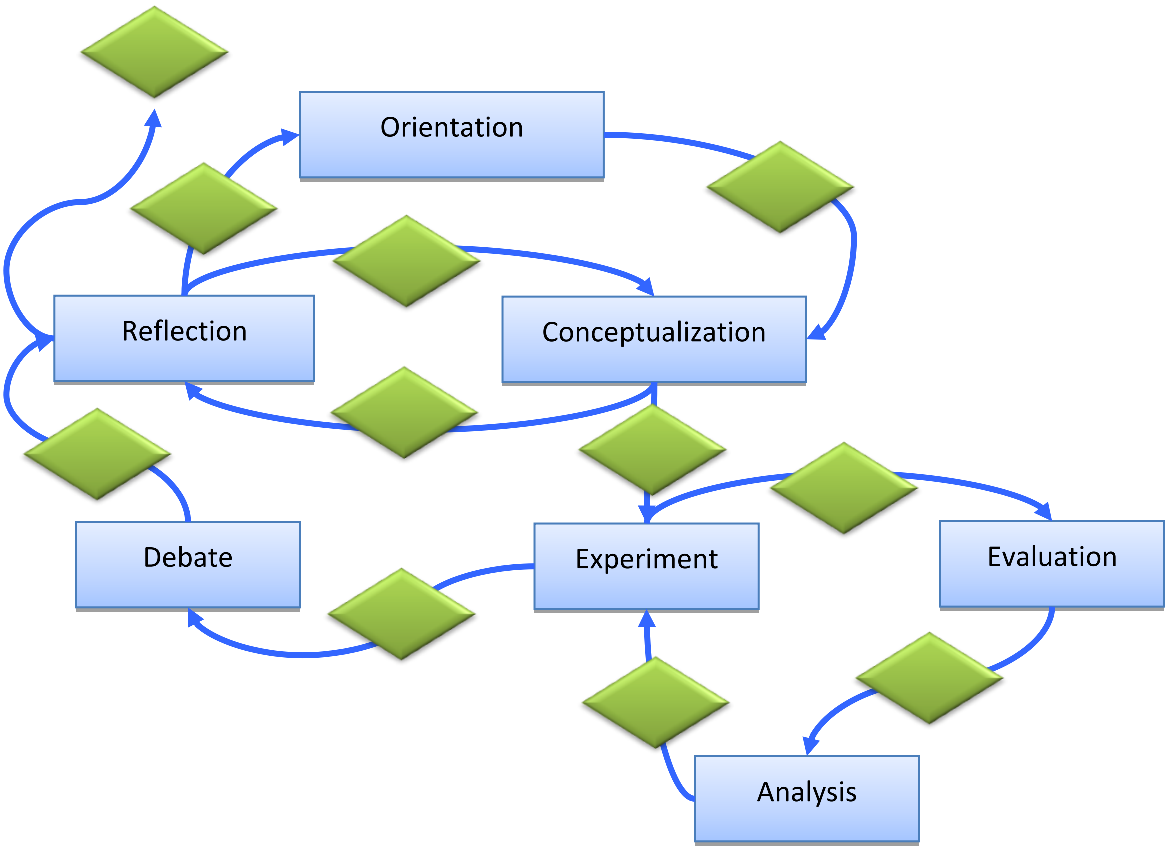


**Figure 9. Grasp a Model.**

## Teacher roles and responsibilities

Classroom discussions have to be orchestrated by the instructor to help students identify inconsistencies regarding their models (for example, not all sinks or flows integrated in the carbon cycle), and elaborate on difficulties they might have encountered. Specifically, in the Orientation Space, learners will be supported to elaborate on their knowledge gaps and misconceptions after they have compared their model with an expert solution. In the Debate Space, the instructor will provide feedback as learners compare between the structure of peer models. Further, small-group discussions initiated by the teacher will support students as they generate explanations and build on each others' ideas in the Reflection and Conceptualization Spaces.

## Scenario examples

*Modelling Script.* To scaffold the formulation of models, we can use a script which includes the following stages: (1) initially, students are requested to draw a model in order to depict a special characteristic of the phenomenon described (e.g., the carbon cycle); (2) at a second stage, students are prompted to define model compartments and relations among compartments (e.g., sinks, such as the atmosphere, the biosphere, etc.; flows, which connect sinks and transform carbon from one form into another, namely, photosynthesis); (3) the third step involves the comparison between students' model and an expert model on the basis of a rubric which refers to indispensable structural and functional parts, namely, compartments and relation among compartments, respectively; (4) students will refine their model, where they will go through at least two revisions to update their final model and justify any expert-learner model deviations in the final version (e.g., addition or deletion of model compartments; addition or deletion of interactions among model compartments); (5) at the last stage, students will reflect upon their initial drawing and will outline the differences between their first attempt and the refined model of stage 4. The Modelling Script will be enacted in the case of expressive modelling (see next section) and in the case of explorative modelling, if the model's structure or function after students' updates cannot allow learners to run their models.

*Expressive vs. Explorative Modelling.* Expressive modelling entails building a model from scratch. Instead, the explorative approach begins with a simulation-ready model and students are asked to perform exploring tasks, such as analyzing the model structure and the system behaviour to parameter variations. While expressive modelling generally is more effective in terms of learning outcomes, the explorative mode is more suitable for deepening existing knowledge. Moreover, explorative modelling takes less time and is not demanding as far as modelling skills are concerned. By combining both alternatives and switching from expressive modelling to explorative modelling and vice versa, learning environments can be adjusted to student competence and available time. Specifically, expressive modelling is recommended for competent students and when time is not a limiting factor. If the above mentioned conditions are not met, explorative modelling is the proper choice. In this case, students will be given a suboptimal model in order to discover necessities for model improvement. By exploration, students can identify what model compartments are to be refined. A mixed approach, namely, an arrangement that combines both expressive and explorative modelling, can serve assessment purposes (e.g., an explorative design used to assess modelling skills acquired through an expressive design).

**Further reading**

Arndt, H. (2006). Enhancing system thinking in education using system dynamics. *Simulation, 82*, 795–806.

Assaraf, O. B.-Z., & Orion, N. (2005). Development of system thinking skills in the context of earth system education. *Journal of Research in Science Teaching, 42*, 518–560.

Bravo, C., van Joolingen, W. R., & de Jong, T. (2009). Using Co-Lab to build system dynamics models: Students' actions and on-line tutorial advice. *Computers and Education, 53*, 243-251.

Loucas, L., & Zacharia, Z. C. (2008). The use of computer-based programming environments as computer modelling tools in early science education: The cases of textual and graphical languages. *International Journal of Science Education, 30*, 287–323.

Papadouris, N., & Constantinou, C. P. (2008). A methodology for integrating computer-based learning tools in science curricula. *Journal of Curriculum Studies*, DOI: 10.1080/00220270802123946.

Papaevripidou, M., Constantinou, C. P., & Zacharia, Z. C. (2007). Modelling complex marine ecosystems: an investigation of two teaching approaches with fifth graders. *Journal of Computer Assisted Learning, 23*, 145–157.

Saari, H., & Viiri, J. (2003). A research-based teaching sequence for teaching the concept of modelling to seventh-grade students. *International Journal of Science Education, 25*, 1333–1352.

Sins, P. H. M., Savelsbergh, E. R., & van Joolingen, W. R. (2005). The difficult process of scientific modelling: An analysis of novices' reasoning during computer-based modelling. *International Journal of Science Education, 27*, 1695-1721.

Sins, P. H. M., van Joolingen, W. R., Savelsbergh, E. R., & van Hout-Wolters, B. (2008). Motivation and performance within a collaborative computer-based modeling task: Relations between students' achievement goal orientation, self-efficacy, cognitive processing, and achievement. *Contemporary Educational Psychology, 33*, 58-77.

## 3.7 Designing an Experimental Procedure

### Main idea

The main idea is to use student-led experiment design as a means for learning science concepts and skills. Students, during practical work where they design their own experiments, are engaged in behaviours that are closer to several tasks performed by scientists: they spend more time in making sense, i.e., discussions about scientific concepts, experimental design, data analysis, decision making. They build relations between the world of facts and concrete actions and the world of models, concepts and their representations.

This necessitates a scaffolding process to establish a level of competence in the design of experiments. Students need to be helped first in structuring and later in communicating their own experimental procedure.

A typical experimental procedure comprises a list of devices, a list of operations structured in steps on how to perform the experiment and how to analyse data, and is accompanied with domain-specific drawings and data collectors.

### Learning goals

Learning goals include domain specific concepts (in physics, biology, chemistry, earth sciences), transversal skills needed in general in design tasks (analyse, represent, plan, etc), and some procedural skills (devices handling, safety issues, measurement procedures, etc). Students should acquire the ability to relate a scientific issue to a strategy including data collection, and also to relate experimental data to a conclusion. The experimental procedure is a key element in recognising these relationships.

**Requirements and target groups**

The task is complex and necessitates working in small groups (e.g., pairs). The typical time span is at least two sessions of two hours each. Preferably, there will be a sequence of sessions on different issues in order for students to become more experienced in procedure design.

The age group is 15-20 years-old so that students have some experience in laboratory work and advanced knowledge in scientific concepts (and models). For younger students, designing an experimental procedure is possible but will consist of a much simpler experiments regarding the procedures. The emphasis will be more on how to choose the right variables and vary one at a time. Here, we target an experimental procedure that is complex enough, comprise of several steps, and typically relies on a scientific model.

This scenario can take place during an exercise session class or in the laboratory (or both), depending on needs for handling experimental devices. Resources will be provided before hand. Indeed, in order to be able to produce an experimental procedure one needs to be familiar with the domain and with some experimental approaches (including methods and devices). Therefore the resources provided to students are theoretical background on the issue, technical lab sheets (methods and devices), and possibly parts of experimental procedures.

Tools in SCY-Lab are used to edit procedures, to exchange procedures, to collect data, to represent data, to process data. Additionally, a simulation of the scientific phenomena may be used in place of a laboratory experiment.

**Learning task**

The goal of the mission is primarily to solve a scientific issue (examples are: determine the nature of a liquid in a closed container based on optical index measurement, determine hominid line based on measurement of facial angle of craniums). The nature of this scientific issue can be either investigative or technological. In an investigative question, students need to state hypotheses issued from the model to determine the goal of their experiments. In the case of a design problem, which nature is more technological, the formulation of hypotheses linked to a theoretical model is not necessary. In this latter case, learners should however formulate the expected results of their experiments in order to help them design their procedure. To accomplish the mission, the following tasks are planning and testing the experimental procedure (which involves working with models, devices and methods).. The task of learners is to produce a written experimental procedure and test it (collect data and draw a conclusion). In experimental design, although some general steps can be distinguished, such as analysing and understanding the problem, operationalise variables, plan a sequence of events, and check upon validity issues, there is not a single road for finding a solution.

The main product is a written experimental procedure (main ELO). Other products are questions/hypothesis/anticipated results (texts, diagrams, drawings …), raw data, processed data, scientific results (answer to the original question), and possibly an evaluation grid (evaluation of a procedure).

**Assessment of learners' products**

Teacher could organise peer assessment of the experimental procedures. In this case, students will be provided with an evaluation grid a set of criteria that the teacher wants to emphasise, among relevance, quality of data acquisition, executability, and communicability.

Teacher assessment will focus on the final product (experimental procedure), and in particular check the adequacy between the method (experimental procedure and data collected) and the answer to the original question, as well as the justifications of the choices made.

**Learning activity spaces**

*Information* — Students will use this space either at the beginning to get a feel for the phenomena (e.g., observe video or animation) and with the theoretical background. Later they may come back to look for specific resources like technical sheets.

*Orientation* — Students identify means and define the goal of their experiment.

*Conceptualisation* — Students generate hypotheses and anticipate the observable consequences. In the case of a problem that doesn't require to state hypotheses, learners have to anticipate the expected results of their experiments.

*Design* — This is the central space for this scenario. Here students design their experimental procedure, evaluate it, build data collector (e.g., a table) that may be filled later with data.

*Experiment* — Students need to run an experiment to test their experimental procedure.

*Analysis* — Students need to analyse their data and relate their experimental results to their hypothesis and/or expected results.

*Reporting* — In a written report, students propose a final experimental procedure that may be complemented by a data analysis. They may also describe how they compare different experimental procedures or write an evaluation report.

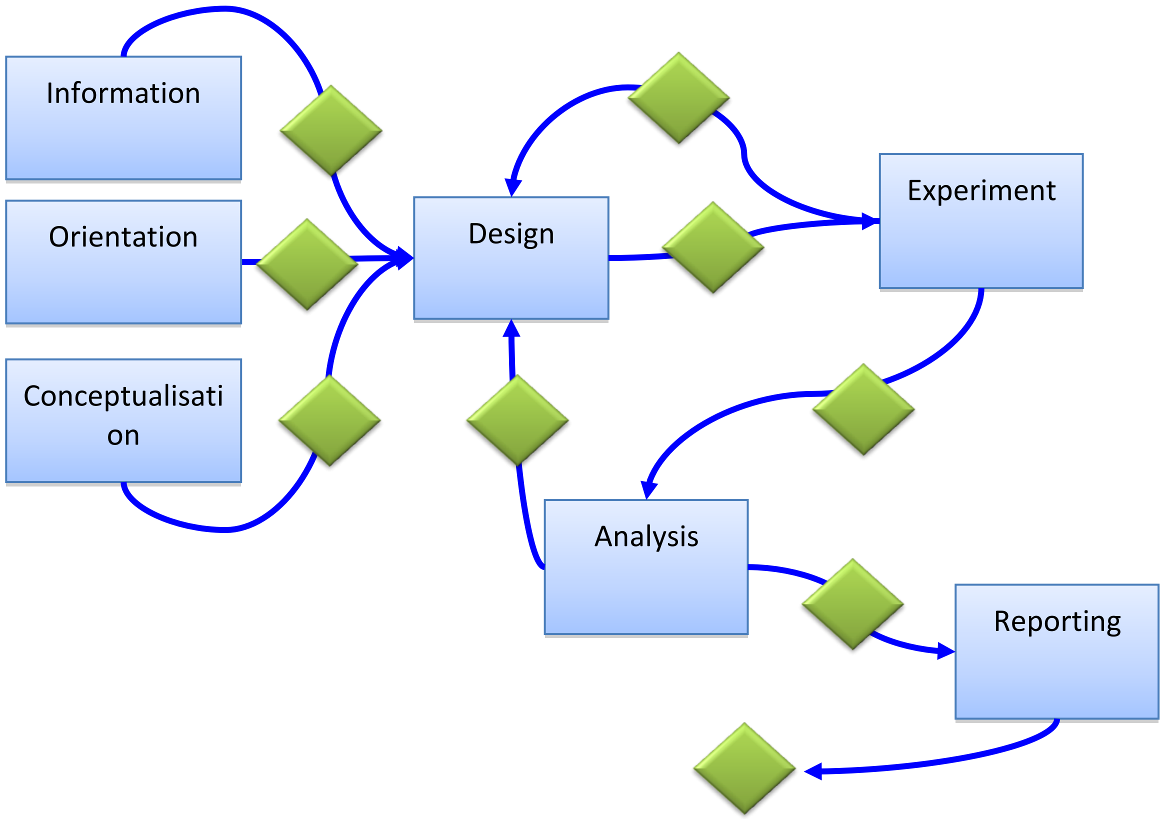


**Figure 10. Designing an Experimental Procedure.**

### Teacher roles and responsibilities

Either as scaffold embedded in the tools or as teacher interventions: help will be provided to students to structure the procedure, to evaluate it, to translate a problem into questions and later into procedure steps. The teacher will prepare the resources mentioned above in advance. During the laboratory sessions, the teacher will be there to guide students with devices handling and safety issues. Teacher's role is mainly to answer questions and provide the necessary devices if available.

### Scenario examples

*Design script.* To motivate students to write complete procedures, pairs share their procedure, i.e., the procedure is intended to be given either to peers in the same class or to students in another class of the same level or below. The receiver is supposed to later execute the given procedure. At the start, a scientific question and resources to engage in the mission are given to students. To help students appropriate the problem, the teacher may provide information on devices available (with devices and/or technical sheets), images to get a feel for the phenomenon (e.g., pictures, videos, animations, demonstrations), and useful theoretical models (in the form of exercises and/or lectures). Starting from a problem to solve or a decision to make, students have then to define experimental goals (e.g., parameters to be measured, variables to be tested, etc). They are now ready to design a procedure. The teacher may help them by giving model procedures or by pre-structuring the procedure (e.g., giving main steps). Students can run the experiment or part of it in order to test their experimental procedure, that is, they collect data and try to answer the question with experimental results. At this point, the teacher can provide feedback in different forms. This can help students refine their procedure by creating a conflict between their solution and others solutions. Possible feedback: (1) a list of experimental results obtained by other students, (2) a procedure from other students or (3) expert or reference experimental results. Finally, students have to write a procedure in the expected format and level of details that depend on who will use this procedure.

*Evaluation script.* This script aims at assisting students in evaluating an experimental procedure. First students will try to answer the question by themselves, either they design their own procedure (previous script), or they watch the teacher demonstrate an experiment and then write it down on paper, or alternatively they have a whole class discussion and collect different solutions (different experimental procedures) that could answer the question. Then students receive an experimental procedure that is said to come from other students (this procedure may in fact be constructed by teacher in order to point out specific problems). Students have to execute the procedure and then write an evaluation report based on a grid given by teacher. A procedure may be evaluated regarding relevance, quality of data acquisition, executability, communicability, each of these four themes comprising several criteria.

### Further reading

Arce, J., & Betancourt, R. (1997). Student-designed experiments in scientific lab instruction. *Journal of College Science Teaching, 27*, 114-118.

Karelina, A., & Etkina, E. (2007). Acting like a physicist: Student approach study to experimental design. *Physical Review Special Topics - Physics Education Research, 3*(2), 020106.

Girault, I., Cross, D., & d'Ham, C. (2007). Students' adaptation to a new situation: the design of an experimental procedure. Paper presented at the ESERA Conference, Malmö, Sweden.

Koretsky, M. D., Amatore, D., Barnes, C., & Kimura, S. (2008). Enhancement of student learning in experimental design using a virtual laboratory. *IEEE Transactions on Education, 51*, 76-85.

Marzin, P. & E. De Vries. (2008) How can we take into account student conceptions of the facial angle in a palaeontology laboratory work? Paper presented at the International Conference of the Learning Sciences, Utrecht, The Netherlands.

## 3.8 The Big Project

### Main idea

Project-based learning adopts a student-centred approach: a project allows students to identify and formulate their own problems. It helps in making learning relevant and useful to students by establishing connections to life outside the classroom, addressing real world concerns and developing real world skills. It begins with the idea of an end-product whose production requires specific content knowledge or skills that are central in curriculum. It raises one or more problems which engage students to work together by groups towards a common goal. The project is initialized by defining the purpose for creating the end-product and identifying their audience. Students are responsible for the project management. They finish by using their product and/or presenting it. A final step of self-assessment and reflection concludes ideally this long-term learning situation.

**Learning goals**

Domain-specific knowledge and skills; fostering motivation, engagement in learning and collaboration.

**Requirements and target groups**

The big project is a long-term learning process (it will take weeks or months) divided in several steps. Steps can alternate between classroom (e.g., for gathering information, managing time frame, modelling, etc.) and outside prospecting (e.g., experts' interviews). The big project is based on a challenging and productive question which will help students to integrate interdisciplinary knowledge in real-world issues and practices. Groups can be formed according to different strategies, one focusing on affective considerations, others on competencies/knowledge distribution.

The scenario is suited for primary school as well as for secondary school or university.

Learners are responsible for their task management, and can choose any appropriate tool for achieving the major goals of the project. Among the essential tools, we can find cognitive tools, e.g., SCYMapper, management and planning tools, e.g., diary, Note taking tools and presentation tools.

**Learning task**

The task of learners is to organize their own work in order to answer one authentic question engaging them into discovery, design, discussion, and exchange of tasks. They may produce prototypes, computer programs, physical artefacts, theatrical plays, video sequences, etc.

Learners have to ask questions, build knowledge, determine real-world solutions, test their artefacts and share their outcomes. Among their project group, learners can play special roles as usually distributed in a real-world project (*e.g., project conductor, quality manager, technical manager…).* The learning tasks evolve in cycles.

**Assessment of learners' products**

Assessment activities can be distributed into an ongoing process. The big project requires varied and frequent assessment, including teacher assessment, peer assessment, self-assessment, and reflection. Learning and assessment are not considered as separate processes.

**Learning activities and tools**

| | |
|---|---|
| *Orientation* | At the beginning the whole classroom and their teacher (note that teachers of several disciplines can work together on the project topic) discuss together on an integrating topic (e.g., usage of drugs by teenagers in France), from which various issues can be stressed (e.g., effects of drugs on social behaviour and scholar results). Students explore with their teacher which kind of end-product they could construct and identify which resources and tools they will be provided with during the whole process (the expected end-product as well as the usable resources and tools can either be chosen by students (and further validated by their teacher) or be constrained by their teacher. |
| *Management* | Groups are formed according to the chosen strategy, and eventually according to the chosen sub-topic they want to tackle. Then, each group establishes its own forecasted planning of the project process. Tasks are distributed between members depending on the role one wants to take, thus each team produces its own “Project Planning Chart”. Along the project, timelines are checked, task distribution is adjusted and roles can be exchanged within each team. |
| *Regulation*: | Teachers give some feedback on the teams’ organization and the preliminary plan is revised. Students compare the work process with the plan, re-assign roles and tasks according to necessary improvements of the project process (e.g., replacing a role due to unforeseen absence of a student). |
| *Information* | Groups collect the appropriate information they need to move toward the milestone completion. |
| *Analysis* | Here, learners can relate the gathered information with their specific needs for the current step and examine limitations and constraints under which the problem must to be solved regarding the milestone’s requirements. |
| *Conceptualization* | Here, the students will try to refine their project definition (after each milestone), generate hypothesis, or create conceptual models of a particular sub-problem. |
| *Design* | Blueprints of the whole end-product or parts of it are designed here. |
| *Construction* | Prototypes are built which are more and more refined and enriched to become at last the desired end-product each group has to produce. |

| | |
|---|---|
| *Reporting* | The current state of the project progress is periodically discussed and compiled by the group and for instance recorded in the project journal. |
| *Evaluation* | The group's artefacts and project progress are evaluated by the teacher or by peers (depending on the chosen method of assessment) along the whole learning process. |

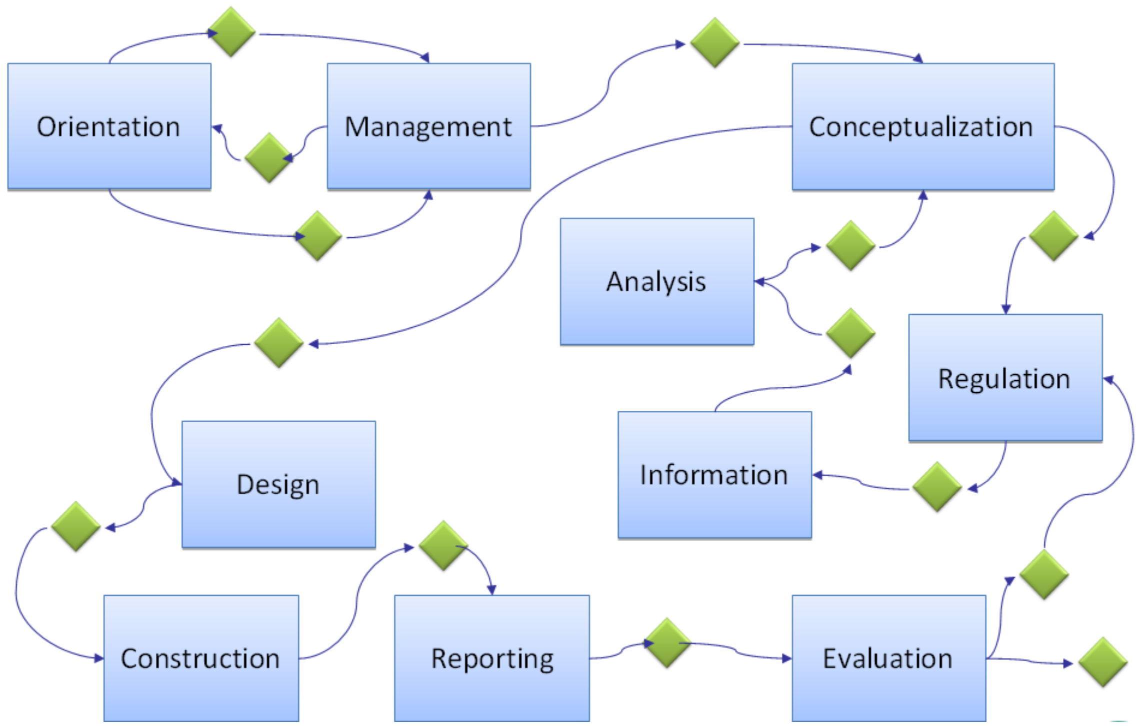


**Figure 11. The Big Project.**

## Teacher roles and responsibilities

The Big Project is leaner-centred, but teachers are to make sure that learning loops are productive and that learners engage themselves in meta-reflection, discuss and share with others.

Teachers help structuring the proposed question, gathering methods, documents or materials, regulating student work with intermittent, transitional goals. They can both work as project manager (assessing productivity and task related work, fostering engagement and collaboration), and as facilitators (advices to select resources and tools, explanations, debugging stark points…).

## Scenario example

A great deal of flexibility remains on the grouping strategy, degree of monitoring, self-project-scheduling which is on the group responsibility and assessment checkpoints. So, we present here some examples instantiated on particular topics.

*Entire semester project for 12th grade students (strong degree of self-scheduling).* The main idea is to make students explore in depth some aspects of a scientific domain they are studying (e.g., at the crossing of Physics and Chemistry with a strong link to their country policy, exploring the damages of industries' rejections on their environment).

- *Time Frame*: One day a week is spent in production teams, plus after school or weekends are freely consecrated by teams on their project advancement. The teacher decides when the project would start and when it should be finished, but he leaves the responsibility of the time frame scheduling to each particular team which is provided with for instance Project management tools.
- *Method of assessment:* Students are assigned to weekly report their results and the methodology they used into a Project Journal. The Project journal is chosen as main assessment tool of the project thus teacher can assess how well the project is planned, how well it is carried out, how well the group work together, and so on. Students are finally assessed on their whole group's progress (teacher assessment) and on their personal contribution (peer assessment inside each group).
- *Expected end-product*: Students are to produce a scientific report on the targeted topic which will be useful for their real-world neighbourhood (e.g., a Good practices' Guide that is expected to help reducing the damages of industries' rejections on their environment).
- *Groups' formation*: Different strategies can be chosen according to the effective classroom composition (heterogeneous vs. homogeneous). For instance, the *ArgueGraph Script* (see the Decision Console scenario) can be used if the kick off brainstorming on the project topic reveals highly conflicting opinions. Teams can also be formed under the students' affective considerations with the teacher's arbitration for preserving the groups' size balance. Ideally, the group size will be of three members.
- *Project implementation*: The number of loops (as defined above) is controlled in relation to the plan each team decided to follow which is recorded thanks to the Planning Management tool they are provided with.

*A shorter and more guided project (no special age is targeted).* The main idea of this approach is to make learners share information and measurements of their daily life (e.g., how much water you daily use?).

- *Time frame*: The project lasts around a month with weekly milestones before a final presentation before the whole class.
- *Launching*: The general topic is presented to learners who are assigned to collect real data from their household members and compare them with similar data from people around the world (e.g.: students' main goal could be to determine what they might do to use less water).
- *Groups' formation*: Teams are formed by the teacher(s).

- *Available resources and materials*: Students are provided with specific information and tools for how to collect, submit, and analyze the data (e.g., SCY spreadsheet editor). List of online experts they can interview and links to related topic information are made accessible for them along the whole project process. The time frame with the expected intermediate products along each milestone allows teams to self-regulate their progress and is consultable from the SCY-Lab interface.

- *First implementation step*: The first week is devoted to household data collecting. As indicated in the first milestone description, learners have to compile their data and present them according to a common format. They also have to report via a short PowerPoint presentation the methodology they used for collecting data. Each team gives her feedback on the other teams' presentations and contributes to this first step assessment. A global feedback and advices for improving their work is given by the teacher.

- *Second implementation step (two weeks)*: Each team is assigned to make predictions on the results they can collect when extending their work on their whole country. A report of these predictions is registered into their own project space. They further investigate how their hypothesis are confirmed or rejected compared to the experts' reports. The resulting comparative analysis is presented again at the end of this step. Students can process this step in their own rhythm but their teacher is supporting them for managing their collaboration.

- *Third implementation step (two weeks)*: The second step is rehearsed after a random assignment with another country (one country per team).

- *Final step and closure*: Team's reports are discussed before the whole class and students are invited to collectively summarize the results of their studies and reflect on their engagement and collaboration along the project.

**Further reading**

Barron, B. (1998). Doing with understanding: Lessons from research on problem- and project-based learning. *Journal of the Learning Sciences, 7,* 271-311.

Blumenfeld, P., Soloway, E., Marx, R., Krajcik, J., Guzdial, M., & Palincsar, A. (1991). Motivating project-based learning: Sustaining the doing, supporting the learning. *Educational Psychologist, 26,* 369-398.

Jonassen D. (1999). Designing constructivist learning environments. In C. M. Reigeluth (Ed.), *Instructional design theories and models, vol. 2: A new paradigm of instructional theory*. Hillsdale, NJ: Erlbaum.

Moursund, D. (2002). Project-based learning: Using information technology, 2nd edition.

Polman, J. L. (2000). Designing project-based science instruction: Connecting learners through guided inquiry. New York: Teachers College Press.

Schneider, D., K. & Synteta, P. (2005). Conception and implementation of rich pedagogical scenarios through collaborative portal sites. In A. Senteni & A. Taurisson (Eds.), *Innovative learning and knowledge communities* (pp. 243-268) Univ. of Mauritius.

Shapiro, B., L. (1994). What children bring to light: A constructivist perspective on children's learning in science, New York: Teachers College Press.

Thomas, J.W. (2000). A review of research on project-based learning, Retrieved June, 30, 2009 from http://www.bobpearlman.org/BestPractices/PBL_Research.pdf

## 3.9 Collaborative Controversies

### Main idea

The collaborative controversies engage students in using controversial issues as a platform for exploring scientific and ethical facets. A controversial issue can constitute a suitable context for the students to engage in critical thinking and reflection. Reasoning about questions that are controversial and involve several facets both scientific and ethical might stimulate the learners' knowledge building process. The knowledge-building process should follow the progressive inquiry learning model. The underlying idea is that if the learning process is well structured this might pose an opportunity for the students to engage in a constructive knowledge learning process.

A controversial issue is also well suited for facilitation of a collective discussion. The students can be organized in teams and discuss on individual basis or find a common point of view and stay together as a group collectively arguing their view. Teams of students can then challenge each other with controversial questions ('problems') that involve scientific and ethical reasoning. This collaboration on uncovering all aspects of a controversial issue might also help the students' knowledge building process. Hearing others point of view and getting own experience in discussing and collaborating might be beneficial with respect to abilities like critical thinking and reflection.

### Learning goals

The goal of *Collaborative controversies* is to improve students' meta-skills and domain specific knowledge. Meta-skills can be among others reasoning, project planning and collaboration. Domain specific knowledge is in natural science, social science and denominational education.

### Requirements and target groups

- Collaborative inquiry processes are essential for the *Collaborative controversies* scenario. Students will work both in groups and individually. The groups will be small with 3 to 5 in each group.
- Classes in different locations can take part and collaborate in this scenario. One team of students collaborates with another team of students at the other school forming a distributed 'combined team'.

- Project work is planned to take 2-3 weeks. An estimation of hours to use on the project work is 30.
- The controversial issue should relate to a topic that is related to the school curriculum.

**Learning task**

The learners should engage in a knowledge-learning process including all the phases in the inquiry model. That includes anything from exploration of fundamental or essential questions, investigate and gather information, create new knowledge and expertise, share and discuss discoveries and in the end to reflect and take stock.

A learning scenario using the progressive inquiry model would include the following student activities:

1. Identify initial (often) fuzzy questions.
2. Produce personal working theories (albeit incomplete or naive).
3. Collaboratively evaluate and redirect their inquiry.
4. Search for deepening knowledge by
5. Consulting more capable peers and teachers
6. Finding reference information in online resources
7. Generate subordinate and refined questions and (new problems).
8. Produce elaborated explanations and shared theories for the whole learning community.

ELOs are a list of questions, explanations and theories. They might also include figures like concept maps illustrating the relationship between questions, concepts and/or theories.

**Assessment of learners' products**

Learning results are manifested in technology as verbal expressions in the form of lists of questions and explanations. These lists constitute the ELOs that should be assessed. The learners' activities might also be assessed like their participation in the discussion, their collaboration efforts etc. Team score can also be made based on individual tests. The teacher can prepare a written test based on the material and give the team members bonus points if all members of their compromise team score over a set criterion. The overall goal is that the students should be able to reflect and contribute with arguments in a group discussion. A more specific objective is that the students should be able to see the nuances in domain based complex issues and be able to argue for or against these accordingly.

**Learning activities and tools**

| | |
|---|---|
| *Orientation* | The teacher will give an introduction to a controversial issue e.g., the big bang. The learners are presented a topic that contains both ethical and natural science issues. This build a context for the scenario in order to kick start the thinking process among the students. Examples of materials that might be used are lecture, movie, reading material etc. The idea is that some type of instruction material can be used to facilitate a thought provoking phase to frame the learning activities. |
| *Conceptualization* | This is an individual phase where all learners write down their immediate thoughts about the topic. The focus is on writing down and documenting their ideas and viewpoints. |
| *Reflection* | This is a phase of team work. Here the team share their individual thoughts/ideas inside the group. The team should write down questions for which the group can not find the answers. Finding pro and con arguments for the controversial issue is a task to be done here. Combined teams discuss and agree on three questions they will work on. |
| *Analysis* | The teams try to find answers to their questions. The teams conduct literature research and consult experts. They analyze the arguments they have gathered and check their reliability. |
| *Debate* | Class wide discussions assisted by a tutor. The teams discuss their questions and pro and con arguments are presented. The outcome of the discussion is a list of problems/questions (for the teams to choose among to work on in a later phase). |
| *Reporting* | The learners should make elaborate texts. The team will compose texts about the problem they inquired. Here the learners need to both divide the work between them and perhaps also work on their own. The finished texts will be published for both schools to read and use. |

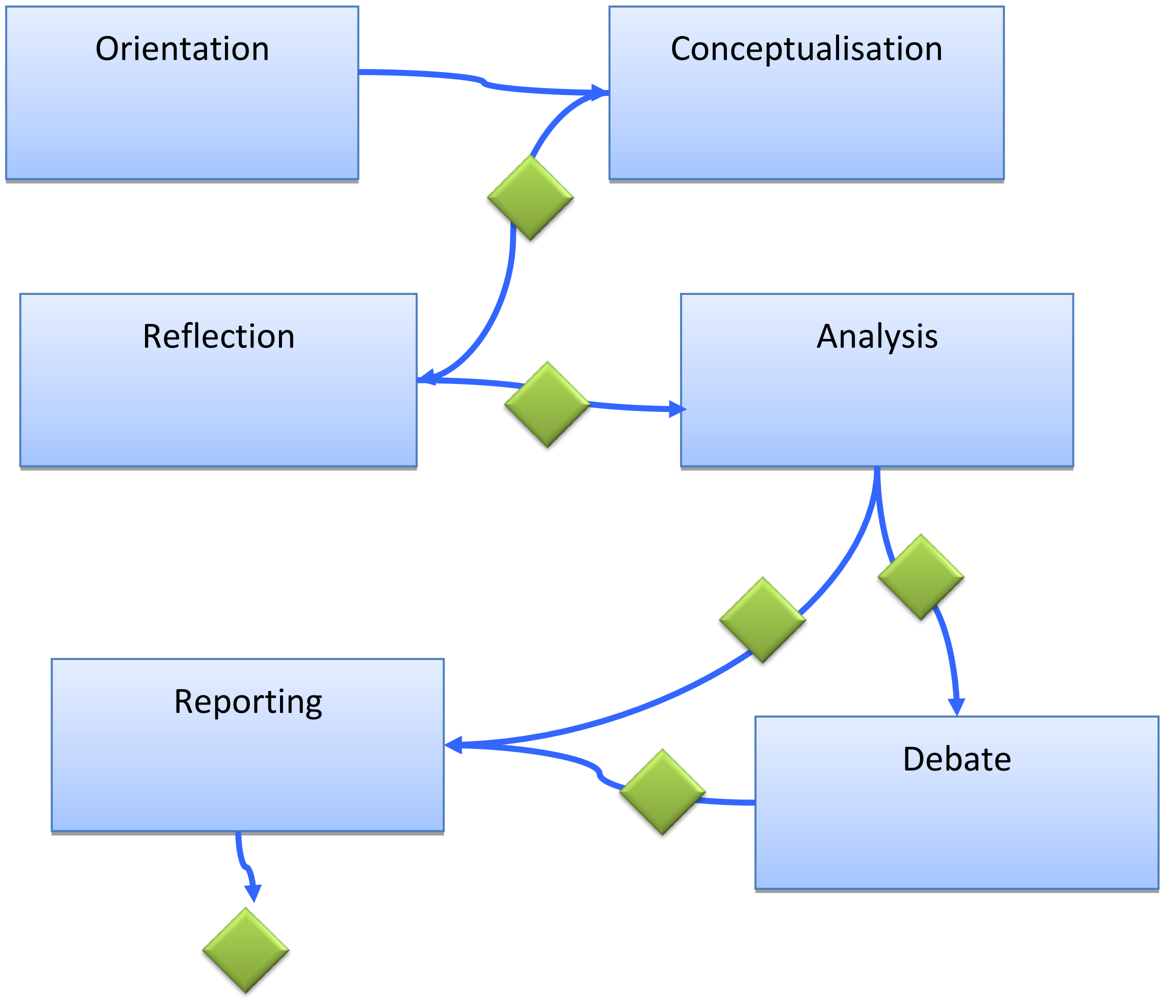


**Figure 12. Collaborative Controversies.**

Tools that the students will use in this learning scenario are text editor, chart tool, slide editor and DVD tool.

### Teacher roles and responsibilities

The teacher has the responsibility to frame the learning arrangement. This is particularly important in the start and end of the scenario. There will be plenary sessions with teachers at the start and end of each session. The teachers will also be available for questions if the pupils encounter any problems. The teacher introduces the theme to be discussed and presents the structure of the students working activities. Since the students will work in several phases individually and collaboratively the various activities needs to be structured. Thus, the students need to follow a working schedule.

### Scenario examples

The main idea of the example of *Collaborative scenarios* is to combine individual reflection with collaborative discussion sessions in order to foster students' knowledge-building process. A thought provoking session is planned in the beginning of this knowledge building process to kick start the reflection and thereafter the discussion. A specific sequence of activities has been outlined in order to lay the foundation for a successful knowledge-building process.

*Structured controversy*

1. The teacher presents a controversial topic (e.g., The teacher introduce the topic of using nuclear power plants to produce energy and shows a memorial film about the 20 year that have passed since the Chernobyl accident. This is activity estimated to take one class hour.) (Orientation).

2. The learners reflect individually about the topic of using nuclear power plants to produce energy and relevant questions to ask (e.g., what are the risks involved in using power plans to create energy? Is there any pollution from a power plant in normal operation?) This activity is estimated to take one class hour.) (Conceptualization).

3. The learners write up their thoughts and ideas about the topic (This activity is estimated to take two class hours) (Reporting).

4. The learners are coupled in pairs (teams) to share their thoughts and ideas about the topic (This activity is estimated to take two class hours) (Reflection).

5. The teams conduct literature research and prepare arguments for the pro and con side of the issue (This activity is estimated to take five class hours) (Analysis).

6. The team of learners writes a report of relevant questions and arguments for the pro and con side (This activity is estimated to take five class hours) (Reporting).

7. The teacher then calls on a class discussion to debate the three most important questions and the pro con arguments they have found. The questions and arguments are summarized and posted for all to see (This activity is estimated to take four class hours) (Debate).

8. The questions and pro and con arguments are further analyzed and literature and theories that support them are presented and discussed (This activity is estimated to take five class hours) (Analysis).

9. The learners elaborate on a text (newspaper, story) to present the relevant questions and pros and cons for this controversial issue (This activity is estimated to take five class hours) (Reporting).

This is a rather comprehensive plan for the learning activities. The learning activities are also very stringently structured with individual reflection as a first activity prior to the collaborative team and class work. The team work is also structured in a team discussion phase and a classroom discussion phase. It might be possible to simplify this approach and skip the individual orientation, reflection, and analysis activities and conduct this approach only in collaborative team mode. Another alternative is to only have one collaborative group and only have the team work and skip the collective debate, analysis and reporting activities. Or have the teams collaborate with teams from other classes instead of doing class collaboration. It is also possible to have a pedagogical scenario with role playing where each team focuses on either the pro and con side of the arguments. This is outlined in the example *Structured controversy with role playing*.

*Structured controversy with role playing*

1. The teacher presents a controversial topic (e.g., The teacher introduce the topic of using nuclear power plants to produce energy and shows a memorial film about the 20 year that have passed since the Chernobyl accident. This is activity estimated to take one class hour.) (Orientation).
2. The learners work individually with the topic and search in the literature and newspapers for more information about using nuclear power plants to produce energy. This activity is estimated to take four class hours (Conceptualization).
3. The learners write two position papers, one for the pro and another for the con side of the controversy: This activity is estimated to take four class hours. (Reporting).
4. Students form teams with 3-4 students in each. Half of the groups are asked to role-play the pro side and half are asked to role-play the con side. Each team chooses its three best arguments: This activity is estimated to take four class hours (Reflection).
5. The instructor then calls on a pro side group to present its top argument, identifying its assertion and evidence to support it. Con-group members are asked to comment on the pro argument. Rebuttal is permitted. Then, a con-group presents its best argument. Pro commentary follows with debate. This process is repeated with pro and con teams alternating their arguments This activity is estimated to take six class hours (Debate).
6. The instructor asks the groups to abandon their advocacy roles and to try to come up with a compromise statement that might be found reasonably acceptable by the opposing groups. These solutions are listed on the board with commentary by each group: This activity is estimated to take four class hours (Report).
7. The instructor or a student closes with a summary analysis: This activity is estimated to take one class hour (Analysis).

The structured controversy method is excellent for dealing with cases that are highly charged and should be added to the list of techniques for teaching case studies (Herreid 1994). It forces all parties to analyze the best evidence on both sides of the question and then to search actively for a compromise solution. When using this technique, the instructor must be sure to give clear instructions in order to get good written and oral responses. Students must understand how to write individual position papers on the pro and con sides of arguments and the proper rules of debate conduct.

### Further reading

Herreid, C. F. (1994). Case studies in science - A novel method of science education. *Journal of College Science Teaching, 23*, 221-229.

Johnson, D. W. & Johnson, R. T. (1988). Critical thinking through controversy. *Educational Leadership,* 58-64.

Johnson, D. W. & R. T. Johnson. (1992). *Creative controversy: Intellectual challenge in the classroom*. Edina, MN: Interaction Book Co.

Johnson, D., Johnson, R., & Smith, K. (1996). Academic controversy: Enriching college instruction through intellectual conflict. *ASHE-ERIC Higher Education Reports, 25*, 1-123.

Khourey-Bowers, C. (2006). Structured academic controversy: A peaceful approach to controversial issues. *The American Biology Teacher, 68*. Retrieved July 30, 2009 from http://www.nabt.org/websites/institution/File/pdfs/publications/abt/archived-table/2006/068-05-0008.pdf

Mork, M. S., Jorde, D. (2003). *Using information technology and controversy to promote argumentation in science lessons*. Paper for ESERA Conference. Retrieved July 30, 2009 from http://folk.uio.no/sonjam/publications/Mork&JordeESERA.pdf

Watters, B. (1996). Teaching peace through structured controversy. *Journal on Excellence in College Teaching*, *7*, 107-125.

Zeidler, D. I., Lederman, N. G., & Taylor, S. C. (1992). Fallacies and student discourse: Conceptualizing the role of critical thinking in science education. *Science Education*, *76*, 437-450.

## 3.10 Co-Learn

### Main idea

Learning is social, collaborative, relational and cognitive, and takes place in a historical and cultural context. Three types of interactions and communication form the basis for learning activities with such a perspective; students working with technology, student-to-student communication, and teacher-student communication. The student will be exposed to a number of different perspectives through a multitude of sources for information, experimental use of technology and the movement from abstract thinking to concrete action. The activities are explorative with relation to technology as well as characterized by exploratory conversations with peers. Teachers will frame the activities and guide the students through the process.

**Learning goals**

The learning goals are related to higher order skills such as project planning, understanding of issues in project work, how to collaborate and how to do an inquiry processes. More specifically we want the students to integrate coherent learning material as a part of a set of ELOs. Work together and negotiate with peers in an effort to reach an agreement. Observe what the others consider important. Collect information, and identify and categorize knowledge. Identify and explain concepts or variables and state their interrelations. Formulate a process devised for making an experiment that includes a goal for the experiment and an experimental procedure. Determine criteria for comparison and differentiate between datasets based on these criteria. Compare and judge versions based on earlier versions and criteria. Make the transition from one form of representation into another. Apply their new understanding in front of peers to contrast and critique each other.

**Requirements and target groups**

Intended for learners at the age from 14 to 18 where they do project work of 8 to 20 school hours. They need standard PCs to run the SCY-Lab learning environment that supports group work. The learners can also sit in groups in classrooms or group rooms while using SCY-Lab. The students will use chat, synchronized tools, and scripts (that distribute roles and activities) to collaborate. To plan the project they will use the planning tool and to present their work they need a text editor and a presentation tool like PowerPoint. They will need drawing tools, modelling tools and simulation tools to do their experiments. If the learners are not acquainted with SCY-Lab they should get an hour to get familiar with the system. The teacher should provide a kick-start video or an image that illustrates a complex issue before the students starts on their mission in SCY-Lab. Further, a set of documents should be handed out or a search engine where the students can find more information should be available.

**Learning task**

The learners are confronted with complex issue through a kick-start video or an image and through collaboration and applying an inquiry method they produce different types of objects. They will typically create working notes during their project work, but the most important tasks are the creation of a project plan with distribution of roles, and further the production of models, simulations, concepts that they explain and relate to each other, and finally a concluding report.

**Assessment of learners' products**

The teacher can through ordinary interventions assess the intermediate products and the way the students' inquire. To help the teacher in knowing when to intervene monitoring mechanisms like time spent on a task could be used. The anchor ELOs will be added to a portfolio where the teacher can evaluate them. Anchor ELOs such as final models, simulations and reports can be subjected to peer assessment by questions and commenting.

**Learning activities and tools**

*Information*

This scenario starts out with the teacher introducing a complex issue for the whole class followed by a video, an image or a document that trigger the inquiry. From this introduction the students enter into groups and each group first has to identify what they think are the key issues. Then they search either a predefined set of databases or use an internet search engine to find more information about the key issues.

*Reflection*

From the new information each group of students need time to identify and reflect on key concepts, which they should add to a concept list with explanations and examples that is shared by all groups.

*Experimentation*

In the experimentation phase each group first has to plan the work process by defining a goal for the issue they want to investigate and create an experimental procedure. In this phase it is important that the teacher pays attention because it is difficult to create plans in general. Using a modelling or simulation tool each group explores the issue. When the result from the exploration is ready each group needs time to reflect and compare results with other groups. Each group then defines a hypothesis and the teacher must pay particular attention because it is difficult to create a precise hypothesis. Each group then goes on to design a version of the issue in question using a modelling tool and/or a simulation tool. They run the models and/or simulations until the teacher or they themselves think they have enough iterations and data to validate their hypothesis and say something about their research goals.

*Report*

The data is then interpreted and evaluated, and then related to their hypothesis and research goal. Each group then needs some time to summarize and work further on the key issues that they discovered during the introduction phase, but also add new concepts that they have discovered during the experiment. The summary with important concepts, simulations and models are then compiled into a report that is represented in front of the other groups. The other groups are asked to take notes and make comments during the presentation.

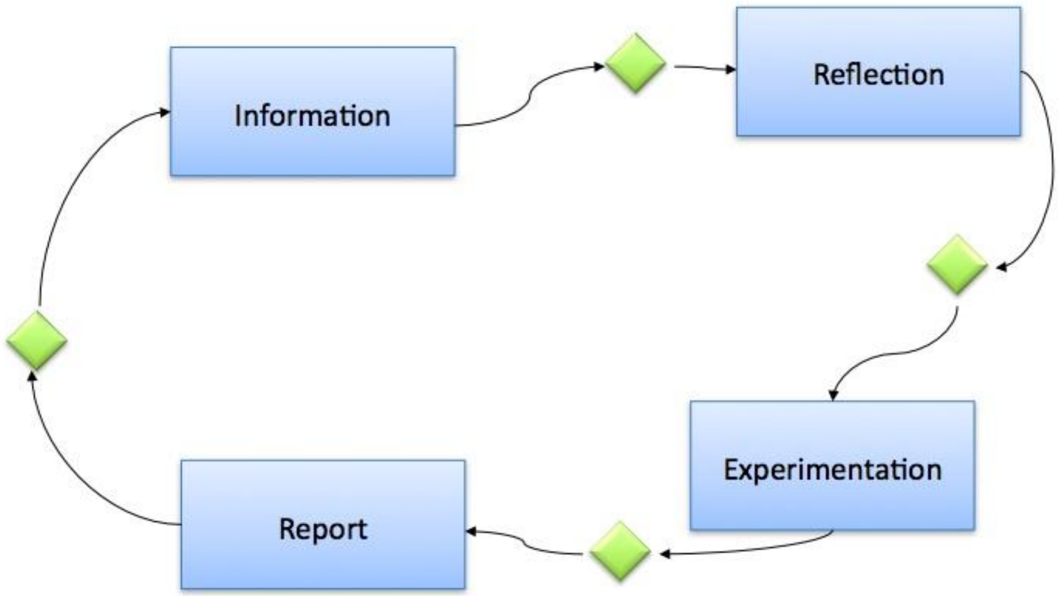


**Figure 13. Co-learn.**

### Teacher roles and responsibilities

Several teacher roles take place. The teacher has to frame the processes (introduction, create groups and summing up), and facilitate and give directions especially when it comes to planning and generating research goals and hypothesis. The pupils will use each other for exploratory conversations and the teacher must pay attention in case of conflict resolutions.

### Scenario examples

*Project work.* This example emphasizes the three basic types of interactions and communication: students working with technology, student-to-student communication and teacher-student communication. Further the students are exposed to different perspectives on the issue at hand and have to explore these perspectives with concrete actions that produce a series of ELOs.

1. The teacher begins by introducing the problem in a certain domain for the whole class. The teacher uses a local problem as an example. Further, the students watch a video that critically handles the issue.

2. Then the teacher frames the session by informing the students that they will do a scientific inquiry about this issue, that they will do project work in groups and that each group has to present their work in front of the class. They are also informed that this project will take 8 school hours.

3. The teacher divides the class in groups with 3 students in each group. Each group receives documents that describe the issue from different perspectives. From these documents each group discusses and writes down the concepts and issues that

they find most important using the text editor. Key concepts are added to a shared concepts list in SCY-Lab using the concept-mapping tool. The students add the name of the concept, an explanation and provide an example. The shared concept list is automatically saved every time somebody produces a new concept.

4. If a group of students wants to find more information about the issue the teacher has created a repository of documents and news clips where each group can search for relevant information.

5. Then each group of students enters the experimentation phase. First each group has to plan the work process. To do this the teacher has prepared a template for them to use with SCY-Lab's planning tool that includes the following fields: project name, research goal, activities to carry out, time span for each activity and division of work for each member in the group. This is a difficult task so the teacher has to visit each group to see that they get it right. Each member of each group fills out a work plan that is automatically stored as an ELO.

6. Then each group gets a little time to do exploratory work with a simulation tool within SCY-Lab and they produce simulations that illustrate different aspects of the problem.

7. When the result from the exploration is ready each group needs time to reflect and compare results with another group. Each group themselves has in their plan already pointed out which other group they want pair up with. They freely compare and discuss for about half an hour.

8. From the exploratory work and comparisons, and based on their research goal, each group generates a hypothesis using the same document where they wrote their research goal. The teacher must pay particular attention because it is difficult to create a precise hypothesis that can be verified or falsified from the information available to the students.

9. Each group then goes on to produce simulations based on their research goals and hypothesis using the simulation tool. They run the simulations until the teacher or they themselves think they have enough iterations and data to validate their hypothesis and say something about their research goals.

10. The students interpret and evaluate their data from the simulation, and then relate the data to their hypothesis and research goal. The latter means that they will have to test whether their data supports or rejects their hypothesis, and whether they can say something about the phenomenon they have investigated.

11. Then each group go on to summarize their findings in the same document where they stated their research goal and hypothesis, and add more concepts that they discovered during the experiment to the shared concept list. The summary, in addition to the simulation ELOs that are available as images and the concept list, are compiled into a Power Point presentation that each group will hold for the rest of the class.

12. Each group listening to a presentation must at least give one comment and it is also important that the teacher tries to follow up on issues that seem unclear in a presentation.

*Collaborative knowledge building*. This example emphasizes the importance of engaging students in a social process of question- and explanation-driven inquiry by imitating practices of scientific research communities. This knowledge building process entails that new knowledge is not simply assimilated but constructed through a series of interpretations and explanations. Shared knowledge advancement requires that students engage in a systematic effort to advance shared knowledge objects such as hypotheses, theories, explanations or interpretations (Muukkonen, Hakkarainen, & Lakkala, 1999).

1. When the students enter SCY-Lab in a mission based on this plan they are automatically grouped by SCY-Lab. Each group has four students and the groups are formed based on their profile in the communication tool.

2. The teacher then opens a synchronous chat with all the groups and introduces a problematic issue in a certain domain by using a local problem as an example. Then s/he plays a video that critically handles the issue for all the groups.

3. After the video each group are asked to take some pre-conceptual notes in a text editor that is shared within each group. They are also asked to save their notes as an ELO that the teacher later can use for tracking conceptual change.

4. From their pre-conceptual notes each group then creates a general research question that will guide their investigation. The research question is posted in a thread belonging to the group in a discussion board that employs categorical sentence openers (prompts) that has to be selected for each new post. The sentence openers in this case can be ‘Research question’, ‘Working theory’, ‘Scientific explanation’, ‘Comment’ and ‘Counter-argument’. For a research question the students would naturally choose the category ‘Research question’.

5. Each group then get some time to use the internet to find relevant information related to their research question. From this information they post their first working theory to the discussion board that can explain issues related to their research question. In addition they also have to post a scientific explanation that backs up their working theory

6. When a group has created a working theory with a scientific explanation an agent within SCY-Lab pops-up and tells the students within that group to look into the research questions and working theories of the other groups. The agent also tells them to post at least one counter-argument to each of the other groups’ working theory.

7. When a group has posted at least one counter-argument to all the other groups it can go on to look at the counter-arguments that they have received. Then they get some time to find more information dealing with the issues in the counter-arguments.

8. After collecting new information the group can either comment or create a counter-argument for each counter-argument stated by the other groups. The comment or counter-argument must be followed by an additional scientific argument backing up their claim.
9. At this point the teacher can choose to either let the groups make another iteration where they post a refined working theory and repeat the steps 6, 7 and 8 or let the groups enter the final step where they compile their research into a report or as a presentation for the rest of the groups.

**Further reading**

Furberg, A. L. & Ludvigsen, S. (2008). Students' meaning making of socioscientific issues in computer mediated settings: Exploring learning through interaction trajectories. *International Journal of Science Education, 30,* 1775-1799.

Muukkonen, H., Hakkarainen, K., & Lakkala, M. (1999). Collaborative technology for facilitating progressive inquiry: The future learning environment tools. In C. Hoadley & J. Roschelle (Eds.), The proceedings of the CSCL '99 conference, December 12-15, 1999, Palo Alto, pp. 406-415. Mahwah, NJ: Erlbaum.

## 3.11 Teaching thinking

**Main idea**

Students participate in creative problem-solving that challenges them to think, reflect, reason, communicate and give feedback while learning science and developing their critical thinking skills. Science problems are approached from different and complementary angles through a series of teaching thinking powerful pedagogical strategies (PPS) (Leat, 1998). In this scenario three PSS: Collective Memory, Mysteries and Odd-One-Out are combined.

*Teaching Thinking* forces the student to think and communicate on *how* one learns *something*, as well as making one aware of using knowledge to solve different mini-missions, and reflect on peer solutions. The teacher's role is to encourage these thinking and learning skills by asking the students to formulate in their own words what they have learned by doing the task, how they came up with their solutions, in what way they cooperated with the other students and the teacher, and the role of their co-learners for own learning process.

**Learning goals**

Teaching Thinking fosters the following thinking and learning skills (Duncan, McNiven and Savory, 2004):

- *Information-processing skills* - communicate and "say out loud" their knowledge, locate and collect, sort, classify, sequence, compare contrast and analyse relevant information.

- *Reasoning skills* - give reasons for opinions and actions, draw inferences, make deductions, use precise language, explain what they think, make judgements and decisions informed by reasons or evidence.
- *Enquiry skills* - ask relevant questions, pose and define problems, plan what and how to research, predict outcomes, anticipate consequences, test conclusions and improve ideas.
- *Creative thinking skills* - generate and extend ideas, suggest hypotheses, apply imagination, and look for alternative outcomes.
- *Evaluation skills* - evaluate information, judge the value of information, hear and do, develop criteria for judging the value of their own and others' work, and build confidence in own judgements.
- *Evaluation skills* - judge value of and evaluate information (what they read, hear and do). Develop criteria for own and others work and ideas, and gain confidence in doing so.

**Requirements and target groups**

The Teaching Thinking scenario (combining 3 powerful pedagogical strategies) takes 9 to 12 lessons of learning time. One iteration (i.e., activities within a strategy) can take 3 or 4 lessons depending on how the teacher uses his or her lesson time (e.g., a plenary debate session might be carried out as its own lesson). Depending on the teacher's judgement, additional lessons can be used for going deeply into particular stages.

There are no general prerequisites for applying the Teaching Thinking scenario. The teacher should analyze the content and activities before starting with students in order to avoid failure of the learning process due to lack of experience with the strategies or domain-specific pre-knowledge.

The scenario comprises individual and group work, and plenary sessions. It is suitable for 2 to 3 students in each group. The main target of the scenario is upper primary school (age 12-16) and secondary school (age 16-19).

Main resource learning objects that have to be prepared before starting are presentations of problems (narratives, videos, animations) related to the phenomenon that will be under investigation by students, and background information about the topic. Other materials, resource ELOs, to prepare in advance include the learning goals, collective memory drawing, the mystery cards, and odd-one-out concept lists. Relevant tools are available in the SCY-Lab, in particular, SCYBrowser, SCYMapper, SCYText, SCYFeedback, SCYePortfolio, except for Google SketchUp that can be used for drawing.

**Learning task**

The students are introduced to a problem and are given instructions about how to solve it. Students are divided into groups and use available tools to create a number of ELOs (concept maps, texts (explanation, story, feedback criteria, notes), drawings) on the way to reaching a solution. Finally, after the students receive feedback from peers and the teacher they are given the opportunity to revise previously developed ELOs. This sequence iterates three times cumulating in the development of an ePortfolio.

**Assessment of learners' products**

Formative assessment includes peer and teacher feedback given 1) along the way on various ELOs that form the group solutions, and 2) during the plenary debate. Self-reflection (at the group level) takes into account the peer and teacher feedback. The teacher carries out summative assessment of the ELOs added to each student's ePortfolio (the anchor ELOs plus any other ELOs the teacher has requested).

**Learning activities spaces:**

Three (of 19 possible) powerful pedagogical strategies, Combining Collective Memory, Mysteries, and Odd-One-Out are combined in this scenario.

***Collective Memory:*** *A collective memory strategy requires that a group of students work together to reproduce a text, image, diagram or graph.*

| | |
|---|---|
| *Orientation* | The learning goals and a description of the collective memory strategy are presented.<br><br>*E.g., To understand the structure and function about the different organs of the digestive system, and how they work.* |
| *Conceptualisation* | The students are given an information sheet to introduce them to the theme. In a classroom plenary lead by the teacher they brainstorm about the main concepts related to the theme. During the discussion the teacher creates a reference concept map that the students then recreate themselves.<br><br>*E.g., They are given an information sheet about the structure of the digestive system. The teacher leads a discussion on the functions of the digestive system.* |
| *Information* | The groups collect more information and take notes about the theme using a set of resources, either provided, following links to Internet resources, or by browsing the Internet.<br><br>*E.g., Students search for information about the digestive system on the Internet.* |
| *Conceptualisation* | The groups identify relevant concepts related to the theme and produce a group concept map.<br><br>*E.g., The groups identify relevant concepts related to the digestive system and create a concept map.* |
| *Design* | The teacher shows each student a schematic drawing of the theme for a few seconds and they must try to remember key information. The group works together to reproduce the schematic drawing. |

*E.g., The teacher shows each student a drawing of the digestive system.*

*Evaluation* The teacher leads a plenary discussion on criteria for giving feedback on the drawing. Each groups develops their own criteria for giving peer feedback. Each group shares their drawing and gives feedback on the other groups' drawings.

*E.g., One group decides to emphasise "correctness", while another decides to emphasise "aesthetics".*

*Reflection* Students reflect on the drawing feedback and based on the feedback they received they revise their concept map and drawing.

***Mysteries:*** *In a mystery strategy students work with a collection of information, presented on clue cards, to find an explanation to a central question. The information used can be text, images, objects, charts or a combination, presented one item per mystery card.*

*Orientation* The learning goals and a description of the mysteries strategy are presented.

*E.g., To understand the nutritional needs of a person (e.g., proteins, carbohydrates, calcium, minerals, vitamins, etc.)*

*Conceptualisation* The students are shown a trigger video/demo to introduce the theme. In a classroom discussion lead by the teacher they identify the main concepts related to the theme. During the discussion the teacher creates a reference concept map that the students then recreate themselves.

*E.g., The students watch a demo on their PCs and brainstorm on the relation between activity and food.*

*Orientation* The students are introduced to a mystery. Each group (same groups as before) is given several clue cards with partial information about the mystery.

*E.g., Mystery: Why did Sandra and Billy faint? Clue cards: 1. Sandra has been feeling dizzy lately. 2. Sandra loves to eat chocolates and sweets. 5. Sandra has been feeling extremely thirsty lately. 1. Billy had to go to the bathroom very often. 2. Billy is often tired. 3. Billy is having blurred vision. NB: Sandra* ***could*** *have anaemia and Billy diabetes.*

*Conceptualisation* The groups identify relevant concepts related to the theme and produce a group concept map.

*E.g., The groups identify relevant concepts related to the fainting* *and the clues.*

*Information* The groups collect more information and take notes about the mystery using a set of resources, either provided, following links to Internet resources, or by browsing the Internet. They use this information to revise their group concept map.

*E.g., Students search for information about their clues on the Internet.*

*Analysis* The groups analyse their collected findings and come up with a solution to the mystery. The groups should be able to "show and weight the evidence" and come to a conclusion.

*E.g., The groups analyse their collected findings and determine why Sandra or Billy fainted.*

*Design* The students use the clue cards and the information they have found to make a story that explains their solution to the mystery. They will have to be able to show and explain why they choose this solution.

*Evaluation* The teacher leads a plenary discussion on criteria for giving feedback on the story. Each groups develops their own criteria for giving peer feedback. Each group shares their story and gives feedback on the other groups' stories.

*E.g., One group decides to emphasise "correctness", while another decides to emphasise "aesthetics".*

*Reflection* The groups reflect on the feedback they have received and revise their story and concept map.

***Odd-One-Out:*** *In the odd-one-out strategy a list several concepts are given to student groups. Each group has to remove one of the concepts and the removal needs to be justified (there is no correct answer, i.e., the is no one concept that has to be removed).*

***Orientation*** The learning goals and a description of the odd-one-out strategy are presented.

*E.g., In the two first activities the students have learned about the digestive system and about exercising and nutrients to keep healthy. Now they will have to combine this information "To understand the combination of nutritional needs, exercising and how it effects the body and different organs of the digestive system."*

*Conceptualisation* Each group (the same group as before) is given several cards, each with four concepts.

The students discuss and debate the concepts and make a choice of which concept to remove. They make a note about the choices they have made (i.e., they list which concepts are left and which was removed from each card)

*E.g., Card 1. muscles, vitamins , physical endurance, minerals. Card 2. coke, caloric, running, diabetes. Card 3. bacon, gall bladder, joules , carbohydrates. Card 4. small intestine, nutrients, proteins, energy*

| | |
|---|---|
| *Design* | The students develop an explanation text to explain how the concepts fit together and why they choose the one to remove. The students need to show and weigh the evidence and come to a conclusion to justify their odd-one-out choices. |
| *Debate* | The teacher leads a discussion/debate where the groups argue for their explanation to the odd-one-out choices.<br><br>During the debate each student writes notes on the feedback they receive to be used for later reflection. |
| *Reflection* | The groups draw conclusions by reflecting on the debate using their debate notes and feedback given them. Each group revises their explanation for the odd-one-out choices. |
| *Report* | Each student prepares by adding ELOs Concept Map-1, Concept Map-2, Story, Drawing, Odd-one-out choices his or her ePortfolio |

Tools that the students will use in this learning scenario are SCY-Lab tools SCYBrowser, SCYMapper, SCYText, SCYFeedback, SCYPortfolio, and Google SketchUp .

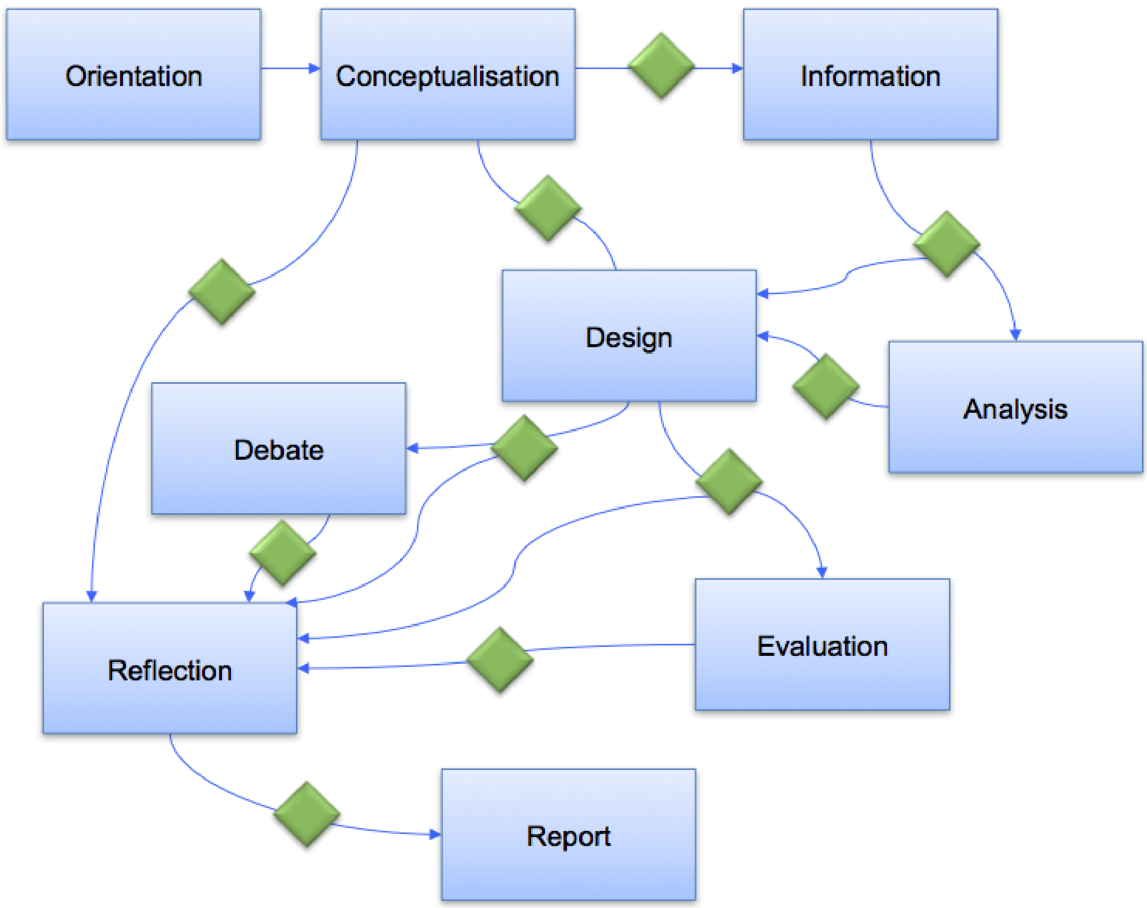


**Figure 14. Teaching thinking.**

### Teacher roles and responsibilities

This scenario requires an engaged teacher. The teacher must be positive to new ways of approaching open questions and must not give answers to the students.

The teacher is responsible for dividing the students into groups of 3-4 trying to maintain an even mix of abilities in each group. The teacher also introduces rules for engagement for group work.

The teacher discusses the learning goals with the class, describes the various strategies behind the various activities to be carried out, and informs the class that there will be peer feedback at various points and that major products will be placed in an ePortfolio that he/she will be assessed at the end.

The teacher provides formative feedback on some of the student ELOs, and in a plenary debate. During the debate plenary the teacher is a moderator, prompting when necessary, having prepared for the plenary by looking at what the students have produced (to identify knowledge gaps and disagreements/differences between the groups). Before commencing the debate, the teacher informs the students that a discussion of all explanations/arguments lead to a better understanding—where explanations/arguments are involved there is no right or wrong, and the use of evidence to support or refute an explanation/argument is important. Furthermore, the teacher informs that all must have their say. Example questions could be: *Subject questions:* *Why did you remove the concept bacon from the odd-one-out card? What are the functions of carbohydrates, fat and proteins for our body? Metacognitive questions: What was the most important information? Did you plan a strategy to try to solve the mystery?*

The teacher gives summative evaluation on the ELOs that have been added to the ePortfolio.

**Scenario examples**

The different strategies follow the same structure:

Phase 1: Introduction (set the stage)

a. Share lesson objective and expectations
b. Give explicit instructions for task and organisation
c. Include a brief, optional starter activity

The teacher should clearly explain the contexts of the lesson, rules for engagement and why they are learning. Indicate the necessity of feedback to the groups and the role of peer assessment.

Phase 2: Main part of lesson (group work)

d. Group work
e. Complete task as a group
f. Class scan by teacher to note outcomes and arguments.

The teacher should listen, observe and encourage the students to understand the necessity of a group answer since learning is part of this process of argumentation and discussion - though without teacher input. The teacher should note outcomes and arguments for plenary and for assessment.

Phase 3: Plenary (debriefing)

g. Teacher stage-manages discussion
h. Teacher summaries outcomes
i. Link to future work

This is the most important part of the lesson. Students should explain their thinking and construction of ideas. Use open questions/phrases so students explain their thought processes and how they reached a group conclusion. The teacher should prepare based on observations and ELOs, in such a way that all students feel that their contribution is valued. End the lesson talking about the thinking processes used as well as the science outcome.

**Further Reading**

*Teaching Thinking* (TT) represents different powerful pedagogical strategies (Leat, 1998) for creative problem solving (Leat & Higgens, 2002). It started as a project in the teacher education programme at Newcastle University, where they experimented with finding more flexible and creative strategies in teaching. TT builds on a number of learning theories such as cognitive acceleration (Adey & Shayer, 1994); instrumental enrichment (Feuerstein,1980); philosophy for children (Lipman, 1991); ‘probes’ for understanding (White & Gunstone, 1992); reciprocal teaching (Palincsar & Brown,1984); scaffolding (Wood & Wood, 1996); research on talk (Edwards & Westgate, 1987); social constructivism, self-theories (Dweck, 1999); and collaborative group work (Webb & Farrivar, 1994).

Teaching Thinking uses different powerful pedagogical strategies (PPS) (Leat 1998) enabling teachers to experiment with different learning environments. Currently there are 19 different well-used strategies, including Mysteries, Odd One Out, Classifying, Living Sources, Question Loop, Advanced Organiser, Audience and Purpose, Collective Memory, and Fortune Lines. PPSs are somewhat like a template and the main characteristics are that it is a strategy that represents a manageable unit of change, it is flexible and open-ended- solution, it encourages a variety of working methods, and it encourages reconfiguring the role of the subject knowledge so that the knowledge stimulates reasoning. Another crucial aspect is that the strategies encourage talk and include a debriefing discussion (Leat & Higgins, 2002).

Adey, P. and Shayer, M. (1994) *Really Raising Standards*. London: Routledge.

Dimmick, D. (2008). *Playfulness in Interaction*. Design.http://www.sitepen.com/blog/2008/06/11/playfulness-in-interaction-design/ (1/6/2010)

Duncan, S., McNiven, D. & Savory, C. (2004). *Thinking skills through science*. Cambridge: Chris Kington. (166 pages) ISBN:1-899857-55-9

Dweck, C. (1999) *Self Theories: Their Role in Motivation, Personality and Development*. Hove (Sussex): Psychology Press (Taylor & Francis).

Edwards, A. and Westgate, D. (1987) *Investigating Classroom Talk*. London: Falmer Press.

Eide, O.S. (2005) *Teaching Thinking Kreative og metakognitive læringsprosesser i klasserommet.* Notat Webpage: www.fag.hiof.no/~EL/TT/Eidenotat.doc

Feuerstein, R. (1980) *Instrumental Enrichment*. Baltimore, MD: University Park Press.

Leat, D. (Ed.) (1998): *Thinking Through Geography*. Cambridge: Chris Kington Publishing.

Leat D. & Nichols, A. (2003) *Mysteries make you think*. Sheffield: Geographical Association

Leat D. & Higgins, S. (2002). The role of powerful pedagogical strategies. *The Curriculum Journal*, *13*, 71–85.

Lipman, M. (1991) *Thinking in Education*. Cambridge: Cambridge University Press.

Palincsar, A. and Brown, A. (1984) ‘Reciprocal teaching of comprehension-fostering and comprehension-monitoring activities’. *Cognition and Instruction, 1*, 117–75.

Webb, N. and Farivar, S. (1994) ‘Promoting helping behaviour in co-operative small groups in middle school mathematics’. *American Educational Research Journal, 31*, 369–96.

White, R. and Gunstone, R. (1992) *Probing Understanding*. London: Falmer Press.

Wood, D. and Wood, H. (1996) ‘Vygotsky, tutoring and learning’. *Oxford Review of Education*, *22,* 5–16.

## 3.12 Junior-Pro

### Main idea

The Junior-Pro Scenario is based on the principles of competence-based learning as used within Technasium schools. In this scenario students always operate as junior professionals and the scenario always starts with a realistic task or assignment based on the daily work of a pro(fessional). Learners have to design a virtual or physical artifact. Taking on this challenge, learners iteratively design artifacts and theoretical models, test, reflect upon and present the artifacts and the refined theoretical models with the goals to acquire technical knowledge and skills. Some activities are group activities, some are individual activities.

### Learning goals

First of all, it is important to realize that the Junior-Pro Scenario is only useful when placed in the context of a total school curriculum. The Junior-Pro Scenario on Technasium is only part of the school curriculum, it covers 20 percent of the curriculum. This is the part where learners can develop their skills and Technasium competencies as junior researcher or developer. The other 80 percent goes to conceptual competencies. The Junior-Pro Scenario pursues three learning goals.

Learning goal 1: gain knowledge and skills about research and design

- Get acquainted with the working processes of researchers and designers.
- To apply specific research and design skills. In every assignment some specific skills are asked.

Learning goal 2: develop personal competencies related to science professions

- Discover personal motivation for technical sciences.
- Develop personal qualities or competencies necessary to become a good junior professional (Junior Pro).
- To be able to make a motivated decision for continuing schooling at the end of secondary school.

Learning goal 3: make use of theoretical knowledge and concepts

- To be able to adopt theoretical knowledge and to apply in an assignment.
- To be able to sort out, select, and use specific knowledge within the framework of the assignment

**Requirements and target groups**

Students operate in small groups of 3-4 persons, both in classroom and in companies/factories. The teacher operates as a ’learning coach’ for the students. They work 6-8 weeks on a mission during 6 hours a week, this is 42 hours in total.

Students works on a real task - derived from the daily work of a professional. This daily work can be illustrated by short video of professionals-at-work. Webquests could help to prevent students to spend too much time in ’googling around’.

Because of the group work, students need note/chat tools as well as planning tools. Most of the 42 hours that students spend on this project will be done at school – supervised by the teacher. In the junior-pro scenario the teacher has the role of ’coach’. He is monitoring the group as well as the individual process, but intervenes only if necessary. A professional plays an important role as ’commissioner’.

Depending on the task sometimes it is necessary to introduce a pre-learning activity in which learners would get acquainted with the (knowledge and skills of a) specific domain. External knowledge/skills will be introduced by the teacher or through e.g., webquests. Various tools, e.g., note and chat tools, reporting tools, planning tools, scripting tools are necessary.

**Learning task**

*Starting point*

The mission is given as an assignment by a professional. Students start their work as junior-pro’s. The project description is handed out.

*Main activities and products*

1. Orientate: identify prior knowledge, identify learning goals, identify gaps.
2. Get information: speak to a professional or teacher. Identify resources (general level); browse resources for specific information about the job/task.
3. Analysis: identify relevant concepts, variables, principles and criteria. Identify key issues; identify limitations an d constraints; identify means; indentify multiple perspectives; indicate alternatives; compare alternatives.
4. Design: design a model; design an artifact.
5. Experiment: run an experiment; test model or design; organize data; interpret data.
6. Building: build a physical or virtual artifact.
7. Reporting: draw a conclusion; summarize; explain.
8. Reflection: on knowledge and skills; reflection on individual process; reflection on group processes; reflection on work professional.

The activities 1, 2, 3, 7, and 8 are part of every Junior Pro mission. It depends on the mission which activities (4, 5 or 6) are emphasized.

In the way the Junior Pro Scenario is presented to the students they have to deliver partial product during the mission. These partial product are leading them in a logical way to the end result.

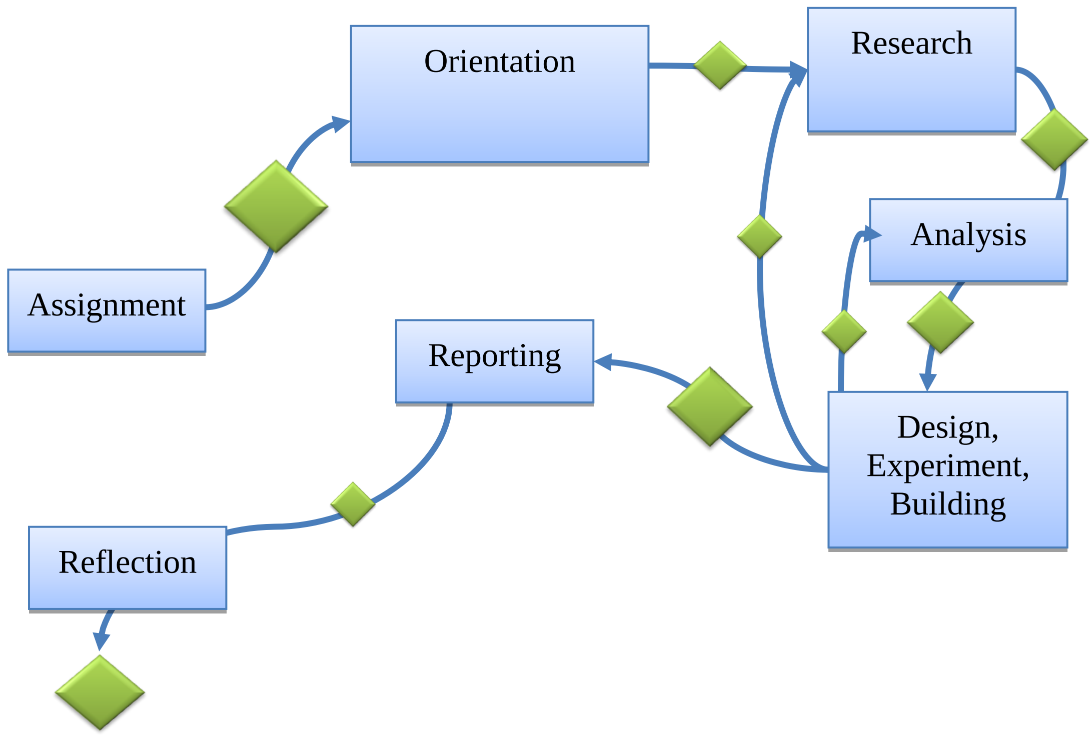


**Figure 15. Junior-pro.**

### Assessment of learners' products

Most of the ELOs can be evaluated with respect to their functionality and adequacy compared with the expert model. Furthermore social comparisons can be made based on more or less simple indicators (size, time spent, peer assessment). At the end of a Junior Pro Mission the whole project will be assessed and evaluated. It is divided into three parts, but each part interacts with the other parts.

Part 1: The assessment of the end result of the mission

The assessment of the end result will be made by the teacher and when possible together with a real professional. Teams present their results from the past weeks and explain how they managed their end result. Furthermore they explain what solution they developed in order to solve the problem of the mission. Like any other subject, it is assessed with a mark. But unlike other subjects the mark of part 1 is a group mark.

Part 2: The assessment of the contribution of each individual team member

The assessment of the contribution of a team member to the process will also be made by the teacher. In relation to this assessment task, the teacher must have a good notion of the role of every single team member. According to that the teacher needs to observe the pupils during the working process, and he has to be able to give feedback on strengths and weaknesses.

The assessment of this part is also expressed by a mark, this is a individual mark. The mark has to be given verbally in the presence of the team. The team can respond on the opinion of the teacher. The teacher has to be able to change the mark due to the arguments of the team members.

Part 3: Self evaluation and peer evaluation

All students have to evaluate themselves and their team members on the basis of the competencies (see “Main idea”). Learners also have to reflect on their own qualities in relation to the profession of that mission. Did they like it? Could they imagine themselves working is this kind of job? If yes, why? And if not – maybe even more important – why not? At the end of the evaluation they have to formulate some personal goals for the next Junior Pro Mission.

**Learning activities and tools**

The learning activities and tools belonging to the model of the Junior Pro Scenario can best described in list. They can be divided into six main categories: form a group, identify prior knowledge, listen to the professional, design a model, explain and present your model and reflect on group process.

Form a group

1. Form a group. One of the first things to do is form the groups. Sometimes the teacher will form the groups, or the students themselves will. Sometimes they will use a team role test or game that helps them to choose their group.
2. Plan the learning/work process. Depending on the project/task description the groups will try to find out what they have to do the next 6-8 weeks .
3. Distribute tasks between the group members.

Identify prior knowledge

4. Identify prior knowledge. After the professional introduces the task the teacher can ask questions helping learners to identify prior knowledge. The learners can type their prior knowledge on a e.g., note pad or a sheet.
5. Identify learning goals. Based on the project description the learners themselves identify their learning goals. These could be stored in a student and/or group profile.
6. Identify differences between prior knowledge and learning goals. Students will reflect on what they already know and what they are expected to do in this project. The ELO will be a list of gaps (’things to look up’) and a work plan.

Listen to the professional

7. Listen to professional/teacher. The professional will instruct the groups about the task to fulfil and explain how he/she would do a comparable task/job. The teacher gives additional information.
8. Identify resources (general). Student have to identify (in general) what the available resources are to fulfil the task.
9. Browse resources for specific information about job/task.
10. Identify relevant concepts, variables, principles and criteria. Students will work on central concepts and principles explaining the background of the task/problem.
11. Identify key issues. Learners will search for specific information that is needed to fulfil the task.
12. Identify limitations and constraints.
13. Identify means. The teacher may introduce one or more tools that are necessary to do the job. But also the students themselves will look for appropriate tools to use.
14. Identify multiple perspectives. The students analyze the multiple perspectives on the task/problem en indicate relationships.
15. Indicate alternatives. Students decide about alternative solutions for their design problem.
16. Compare alternatives. Students list differences between alternatives en decide which alternative wins.

Design a model

17. Design a model. Virtual or paper design of a first model.
18. Run an experiment. Students run an experiment with the model.
19. Organize data.
20. Interpret data derived from the experiment.
21. Test a model or design.
22. Draw a conclusion.
23. Design an artifact. Based on the test results with a simplified model the students design an visual or physical artifact.
24. Build a physical or virtual artifact.
25. Summarize in their small groups the students summarize the work done.

Explain and present your model

26. Explain. In their final project report and also in their presentation (ppt, poster) students explain the reasoning behind the final design and what has been learned.
27. Reflection on knowledge and skills.
28. Reflection on individual process.

Reflect on group process

29. Reflection on group processes.
30. Reflection on related work professional. Students reflect individually and in groups on knowledge, skills, their working processes in their group +individually and also they reflect on their experience as junior professional.

**Teacher roles and responsibilities**

In the Junior Pro Scenario the teacher role is mainly that to operate as coach. The teacher monitors the group and individual process, and intervenes only when necessary. A professional plays an important role as ’commissioner’. Teachers for the Junior Pro Scenario need to be competent on four areas. Each of these areas contain four types of qualities necessary for that task.

Area 1: to develop Junior Pro Missions
- To make realistic science education
- To write vocational
- To develop with outlook on curriculum
- To develop missions cyclical

Area 2: to coach learners in the working process
- To develop personal qualities and talents
- To coach teams
- To work with the Action Plan
- To plan and organize

Area 3: to assess Junior Pro Missions
- To observe development oriented
- To give feedback during the process
- To assess in a context
- To enlarge self-learning ability

Area 4: to initiate and maintain a business network
- To apprehend trade and industry
- To acquire exciting missions
- To build on win-win relations
- To bring up junior professionals

**Pedagogical plans**

Within this scenario, the Action Plan is the most important scaffold for both learners and teachers. Because the learners are their own process managers, the teacher is not able to prescribe the working process. Despite that teachers must be able to intervene in the process and has to give feedback to the team. At the same time the team has to learn to look ahead to the steps of the mission.

For this reason the Junior Pro Scenario works with an Action Plan. In the beginning an Action Plan is made by a team per week. Later the teacher can decide if the plan can be made for a longer period. In the end of the learners’ secondary school period (after 5 or 6 years) a team must be able to write a project plan independently.

**Further reading**

de Bie, D. & de Kleijn, J. (2001). *Wat gaan we doen? Het construeren en beoordelen van opdrachten.* Houten: Bohn Stafleu Van Loghum.

de Kleijn, J. & van den Brandt, C. (2010). *Zo leer je nog eens wat. De praktijk, ontwikkeling en invoering van de ICT-route.* Houten: Bohn Stafleu Van Loghum.

# 4 Advanced usage and modification of scenarios

A specific tool, the SCY Scenario Editor (SCY-SE), is available for creating and modifying pedagogical scenarios of SCY-Lab. It supports graph-based and consistent creation of LAS and pedagogical scenarios, allowing practitioners and researchers to initially design, exchange, and compare new scenarios and LAS. SCY-SE is like an advisor that supports designers, including teachers, in adding or removing LASs, learning activities, tools, or scaffolds. For example, if a teacher has an aim to leave out a specific activity that produces an ELO that is an input for another activity, then the teacher is warned about that and he or she can decide to leave out both or non of these. On top of that, the SCY-SE could indicate that one more activity or tool should be added if the teacher brings one new activity into the scenario.

SCY-SE integrates the FreeStyler environment with the SCY ontology using blackboard-based agent architecture. The blackboard serves as a repository and a shared memory and is implemented in terms of several tuple spaces on top of the “SQL Spaces/SWAT” platform. Specific agents provide consistency checks and similarity computation for LAS and scenario specifications.

# 5 General conclusions

We hope that the handbook gave a closer look at the underlying ideas of SCY. The handbook introduced the main characteristics and benefits of technology enhanced learning environments and outlined specific features of SCY-Lab. SCY-Lab is a highly innovative technology enhanced learning environment.

This handbook should encourage the use of SCY missions in regular school teaching. In this regard, we described carefully ten different learning scenarios. Each of them is based on various scientific theories that enhance their effect in learning. The literature listed in relation to all scenarios provides further background information. In conclusion, the scenarios and related learning plans described in the handbook aim to support planning and implementing many successful lessons. The easiest way to acquire knowledge and skills is possible through application of existing scenarios and missions composed by the developers of SCY-Lab. Beyond the scenarios described, the learning environment and related authoring tools provide several tools for modifying scenarios according to some specific needs. Advanced users of SCY-Lab are supported in creating new pedagogical scenarios and contribute to this growing online repository of pedagogical scenarios and plans.

# 6 References

Anderson, L. W., & Kraftwohl, D. R. (Eds.). (2001). *A taxonomy for learning, teaching, and assessing: A revision of bloom's taxonomy of educational objectives*. New York: Longman.

Crismond, D. (2001). Learning and using science ideas when doing investigate-and-redesign tasks: A study of naive, novice, and expert designers doing constrained and scaffolded design work. *Journal of Research in Science Teaching, 38*, 791-820.

de Jong, T., van Joolingen, W. R., Giemza, A., Girault, I., Hoppe, U., Kindermann, J., et al. (2010). Learning by creating and exchanging objects: The SCY experience. *British Journal of Educational Technology, 41*, 909-921. doi: 10.1111/j.1467-8535.2010.01121.x

Etkina, E., Karelina, A., Ruibal-Villasenor, M., Rosengrant, D., Jordan, R., & Hmelo-Silver, C. E. (2010). Design and reflection help students develop scientific abilities: Learning in introductory physics laboratories. *Journal of the Learning Sciences, 19*, 54-98.

Hestenes, D. (1987). Towards a modeling theory of physics instruction. *American Journal of Physics, 55*, 440-454.

Hmelo, C. E., Holton, D. L., & Kolodner, J. L. (2000). Designing to learn about complex systems. *Journal of the Learning Sciences, 9*, 247-298.

Lee, M. J. W., McLoughlin, C., & Chan, A. (2008). Talk the talk: Learner-generated podcasts as catalysts for knowledge creation. *British Journal of Educational Technology, 39*, 501-521. doi: 10.1111/j.1467-8535.2007.00746.x

Mayer, R. E. (2002). Rote versus meaningful learning. *Theory into Practice, 41*, 226-232. doi: 10.1207/s15430421tip4104_4

Mayer, R. E., & Fay, A. L. (1987). A chain of cognitive changes with learning to program in logo. *Journal of Educational Psychology, 79*, 269-279.

Novak, J. D. (1990). Concept mapping: A useful tool for science education. *Journal of Research in Science Teaching, 27*, 937-949.

Pata, K., & Sarapuu, T. (2006). A comparison of reasoning processes in a collaborative modelling environment: Learning about genetics problems using virtual chat. *International Journal of Science Education, 28*, 1341-1368.

Vreman-de Olde, C., & de Jong, T. (2006). Scaffolding the design of assignments for a computer simulation. *Journal of Computer Assisted Learning, 22*, 63-74.