Go-Lab

Global Online Science Labs for Inquiry Learning at School

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Go-Lab classroom scenarios handbook

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Executive Summary

This deliverable presents the Go-Lab scenarios handbook. This handbook offers six different scenarios that are meant to help teachers design ILSs. Each scenario represents a specific pedagogical method within the overall Go-Lab inquiry approach. The six Go-Lab inquiry scenarios are labelled as follows:

- The basic scenario
- The jigsaw approach
- Six changing hats
- Learning by critiquing
- Structured controversy
- Find the mistake

In a later stage, when a suitable modelling tool has been found or created we will add a seventh scenario, Learning by modelling

Each scenario is characterised by a dedicated set of inquiry phases with specific activities within those phase.

The current deliverable presents an extended description of all six scenarios, including considerations for design and background information. In that respect it can be seen as a "reference book". The scenarios are further offered in Graasp, the Go-Lab authoring environment (www.graasp.eu). Graasp will offer teachers the opportunity to select a specific scenario and after selecting a scenario a pre-structured ILS is offered with the correct phases and a brief description of the design of each phase in the ILS. The content of these descriptions from Graasp is also offered in this handbook (Chapter 2). Each scenario also has links to example ILSs that follow the scenario.

This scenario handbook also contains a series of "tips and tricks" (T&T) for creating ILS, These handy tips for creating ILSs are also offered on the Go-Lab support platform (http://go-lab-project.eu/tips-tricks).

The approach we have taken to create the scenarios and the T&Ts has been a combination of a top-down and bottom-up approach. Part of the work has been inspired by the literature (e.g., Weinberger et al., 2011) and part was extracted from ongoing work of creating ILSs. These have been ILSs created by the Go-Lab team (around 25 in number) and ILSs created by a large set of teachers, for example in Go-Lab Erasmus courses and the Go-Lab 2014 and 2015 summer schools in Marathon. This scenario handbook therefore reflects the current theoretical state of the art together with a grounding in actual teacher practices.

This deliverable will be followed by a "pretty print" version that can be used as a scenario handbook for Go-Lab.

Table of Contents

1 Introduction

This Go-Lab scenarios handbook is directed towards Go-Lab teachers and intends to support the design of Go-Lab Inquiry Learning Spaces (ILSs). ILSs are the Go-Lab learning environments that include an online laboratory together with instructional guidance (text, videos, and tools (apps)).

This handbook offers six different pedagogical structures or "blueprints" for ILSs; these blueprints are called *scenarios*. A scenario is defined as: "A Go-Lab scenario describes, in a *domain independent way*, all activities, materials, and interactions for teachers and learners that comprise a complete (online and offline) Go-Lab inquiry learning experience. Scenarios differ in the activities included and in the combination of a) offline and online activities b) individual or collaborative actions c) distribution of activities between teachers and system, and c) sequencing of activities".[1]

A scenario is offered in two ways:

a. A pre-structured ILS in Graasp that can be used as a starting point for ILS development. After selecting a lab at Golabz (www.golabz.eu) several scenarios are offered as starting points for creating an ILS. These "scenario ILSs" have the correct phases for the scenario and per phase brief guidelines for the design of that phase. Each scenario ILS contains links to at least one example ILS, showing the scenario in a concrete domain.

b. A printed description of these guidelines in the current scenario handbook.

The build-up of this scenario handbook is as follows. Chapter 1 describes three elements. First, the workflow of designing an ILS is outlined. Second, we present a "glossary" of terms that play a central role in Go-Lab. Third, we describe the main template that is the basis of all scenarios. Chapter 2 describes the set of six scenarios and guidelines on how to implement them in an ILS and present the links to one or more example ILSs for each scenario. Chapter 3, finally, presents a larger set of general *Tips and Tricks* (T&Ts) that help to shape ILSs. These T&Ts can also be found on the Go-Lab support site (http://go-lab-project.eu/tips-tricks).

1.1 The ILS design workflow

We assume that the starting point for choosing, adapting, or developing an ILS most often is based on the science topic that is being taught and that different steps will follow this initial choice. The presumed steps are;

1. The first decision concerns the online lab to be used. This online lab can fit a topic of which the teaching potentially can be improved by taking a more inquiry-based approach. In the following steps we assume there is a suitable online lab available in the Go-Lab repository.

[1] In previous work we have used the word "lesson plan" to indicate an ILS plus off-line activities. To avoid terminological discussion we now only use the term "scenario".

2. After a suitable online lab is selected the next decision concerns the pedagogical structure to be used. For this there are several options. The first two apply when an appropriate existing ILS is already present in the Go-Lab repository:
    a. A search through the Go-Lab repository renders an ILS on a) the topic that needs to be taught and b) a pedagogical approach (scenario) that is preferred. In this case *the ILS can be directly offered* to the students.
    b. If there is an ILS available that does not fully answer the requirements but is close to these, it can still be selected and then *adapted until the ILS fulfils the needs*. This could mean, changing (adapting or replacing) the available resources, tools (apps), etc. in the ILS. The online lab most probably will stay unchanged.
3. If there is no appropriate ILS available, Go-Lab supports the creation of a suitable ILS in two consecutive steps:
    a. If there is no ILS that can be directly used or adapted, *a scenario can be selected from the available Go-Lab scenarios* that a) fits the educational objectives b) fits the students' prior knowledge and inquiry skills, and c) is organisable in the classroom.
    b. After having chosen a specific scenario *a new ILS based on this scenario can be created*. First an online lab is selected form Golabz. Then an appropriate scenario is selected. This selection gives an ILS with phases that are characteristic for the chosen scenario, with the lab in the correct phase and with brief instructions in each phase on how to shape that phase. The ILS is created from this scenario ILS by inserting instructional material (videos, texts) in each phase, and inserting and adapting the available tools (apps) for this domain.
4. Finished ILSs can be published on Golabz so that other teachers can re-use them (Step 2 above).

Figure 1 shows this work flow in a diagram.

The Go-Lab scenario handbook facilitates this process in a number of ways:

- First, it defines a set of six more general pedagogical scenarios.
- Second, for each of the six scenarios it presents a "scenario ILS" that has the structure of the scenario and a brief instruction in each phase on how to populate this phase. When an ILS is created from Golabz always the basic scenario is presented. If a more advanced scenarios is intended to be used, these can be accessed from Graasp, see Figure 2.
- Third, example ILSs for these scenarios are made available. These example ILSs are briefly described in this deliverable.

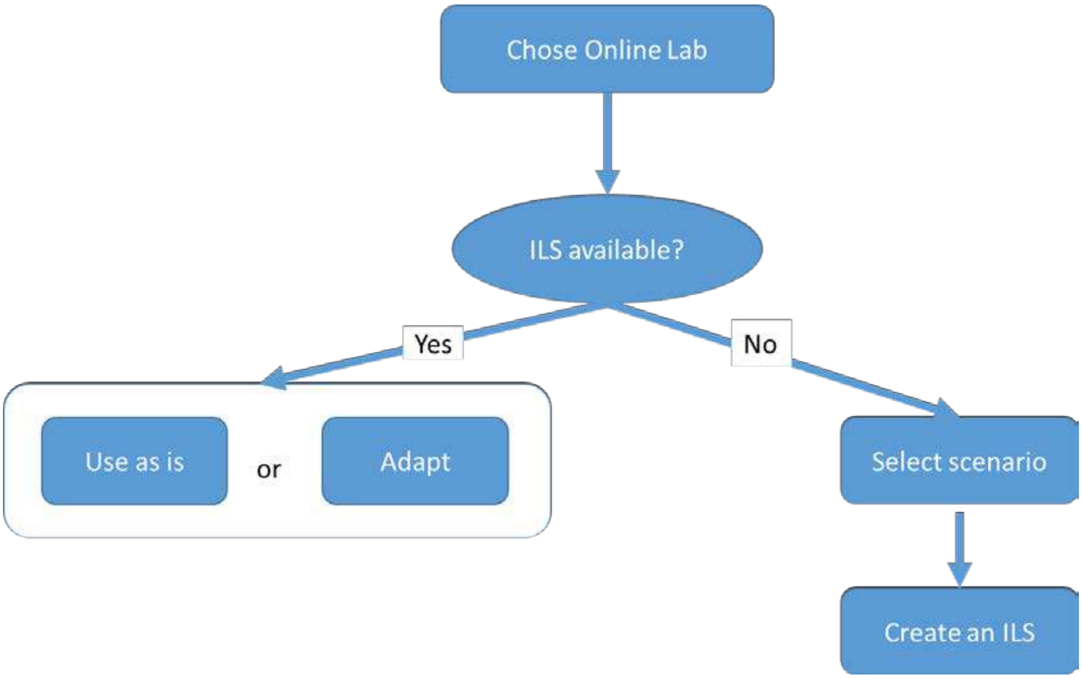


Figure 1. Workflow when authoring an ILS.

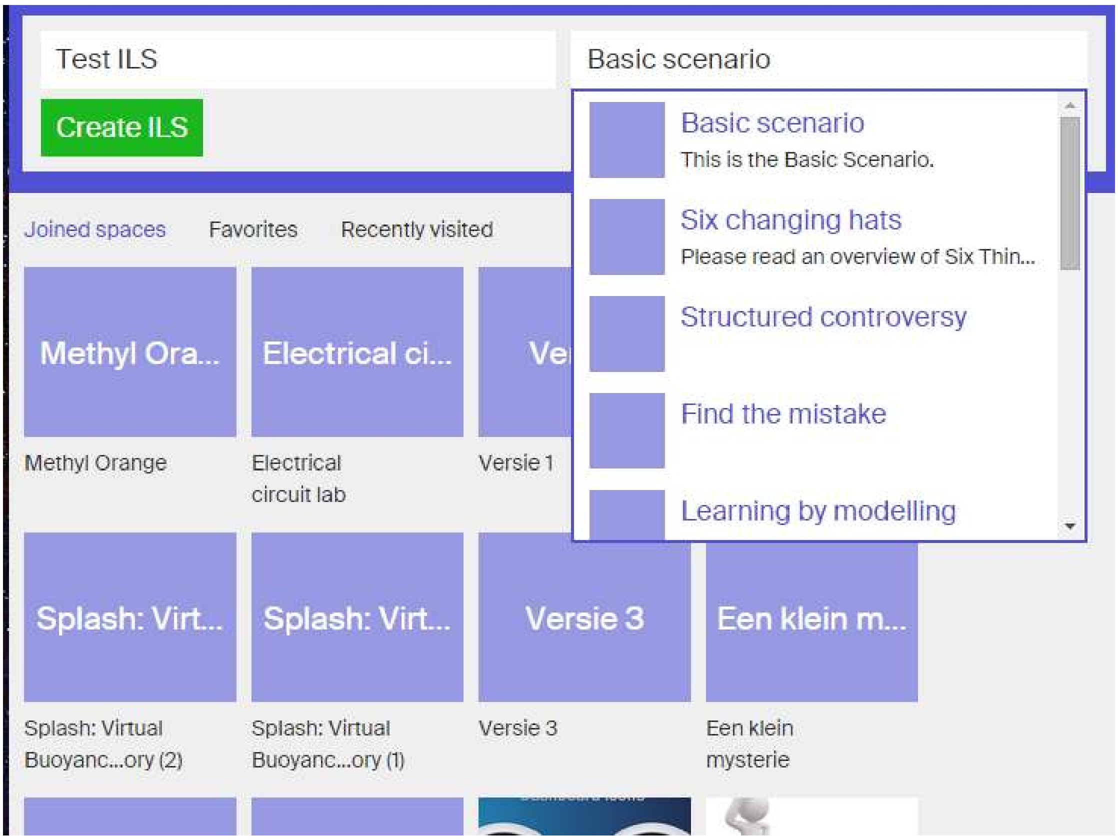


Figure 2. How to choose for a specific scenario from Graasp.

1.2 Terminology

This section defines the terminology as it is agreed upon in the Go-Lab project.

Online labs

Online labs are science labs offered through computer technology. The core activity in an online lab is an investigation (experimentation or exploration) with (physical or virtual) equipment or the possibility to work directly with the results of such an investigation (in the form of data sets). In an investigation values of variables, physical or virtual, are manipulated in order to provide insight into the relationship between variables.

We distinguish three types of online labs:

- Remote laboratories. In a remote laboratory the investigation is performed with physical equipment that is operated on a distance
- Virtual laboratories. In a virtual laboratory the investigation is performed with simulated (virtual) equipment
- Datasets/analysis tools. Datasets are outcomes of investigations with physical or virtual equipment. Datasets often come with dedicated analysis and visualisation tools that help to organize and interpret the dataset.

Inquiry learning

Inquiry is an approach to learning that involves a process of exploration that leads to asking questions and making discoveries in the search for new understandings (based on National Science Foundation, 2000). This means that in an inquiry learning process information is not directly offered but needs to be discovered through investigation activities by learners themselves.

Guidance

Guidance is the support that helps the learner in the process of inquiry in the online lab. Guidance exists in the form of a so-called inquiry cycle that provides the learner with a set of phases as an organization of the inquiry process. In each phase the learner can be offered the following specific forms of guidance that in Go-Lab mostly consists of tools (apps) that help students to perform specific activities (e.g., stating hypotheses).

Inquiry Learning Space

An Inquiry Learning Space (ILS) is the learning environment that offers students a set of online facilities for inquiry learning following a general inquiry cycle. It includes all or a subset of:

- A specific online Lab. One of the three, or a combination of, types of online labs with a specific domain content.
- Tools (apps). Specific tools that help students perform inquiry activities.
- General tools. E.g., a calculator or a note pad
- Resources. Background material in the form of texts, videos, or other means. Background material contains domain information that students need for a proper inquiry experience. The ILS may also contain links to resources outside the ILS itself.

- Chat or other communication facilities. Means to exchange information with other students (currently not implemented in Go-Lab).

Go-Lab Portal

The Go-Lab portal (www.golabz.eu) is the main landing place for lab-owners, teachers, and students. The Go-Lab portal consists of:

- Labs. A repository of labs
  - Remote Labs
  - Virtual Labs
  - Datasets with their analysis and visualisation tools
- ILSs. A repository of Inquiry Learning Spaces
- Authoring facilities**.** These enable teachers to create or adapt Inquiry Learning Spaces for their own needs and include:
  - Facilities to adapt and re-sequence the phases of the Go-Lab inquiry cycle
  - Facilities to add or remove tools (apps) in the inquiry cycle
  - Facilities to adapt and/or translate tools (apps)
- Additional services:
  - Booking facilities. These enable the booking of remote laboratories
  - Tutoring Platform. This platform enables the exchange of services and competencies.
- Training facilities for teachers. Help facilities for teachers on all components of the portal (searching, authoring, services, and community). This is called Go-Lab support at the portal (http://www.golabz.eu/support).

Scenario

A Go-Lab scenario describes, in a *domain independent way*, all activities, materials, and interactions for teachers and learners that comprise a complete (online and offline) Go-Lab inquiry learning experience. Scenarios differ in activities included and in the combination of a) offline and online activities b) individual or collaborative actions c) distribution of activities over teachers and system, and c) sequencing of activities (see also Weinberger, et al., 2011).

1.3 Scenario template

Each scenario contains a number of core components. These are:

- Inquiry activities and their sequence.
- An additional description of activities that are done outside the ILS (offline).
- A description of what should be done by students collaboratively (or cooperatively) and individually.

1.3.1 Inquiry activities and their sequence

The basic inquiry activities in Go-Lab are summarized in five phases that form the Go-Lab inquiry cycle. The basic Go-Lab inquiry cycle (see Figure 3) consists of five phases, *Orientation, Conceptualization, Investigation, Conclusion*, and *Discussion:*

- *Orientation* focuses on stimulating interest towards the domain and curiosity to carry out an inquiry.
- *Conceptualization* consists of two alternative sub-phases, *Question* and *Hypothesis.* Both sub-phases concern the relations between independent and dependent variables about the phenomenon under study. More specific, "hypothesizing is a formulation of a statement or a set of statements (de Jong, 2006), while questioning is a formulation of investigable questions" (Pedaste et al., 2015).
- *Investigation* has three sub-phases; *Exploration*, *Experimentation* and *Data Interpretation*. *Exploration* is a systematic way of carrying out an investigation with the intention to find indications of a relation between the variables involved. *Experimentation* concentrates on selecting variables, the values and the order of the manipulation. *Data Interpretation* focuses on making meaning out of the collected data.
- *Conclusion* is a phase of reaching basic conclusions of the experiments/ investigations.
- *Discussion* is sharing one's inquiry by *Communication* and *Reflection*. *Communication* is presenting/reporting and sharing the outcomes of your inquiry with others, while *Reflection* is the process of describing, critiquing, evaluating and discussing the whole inquiry process or a specific phase.

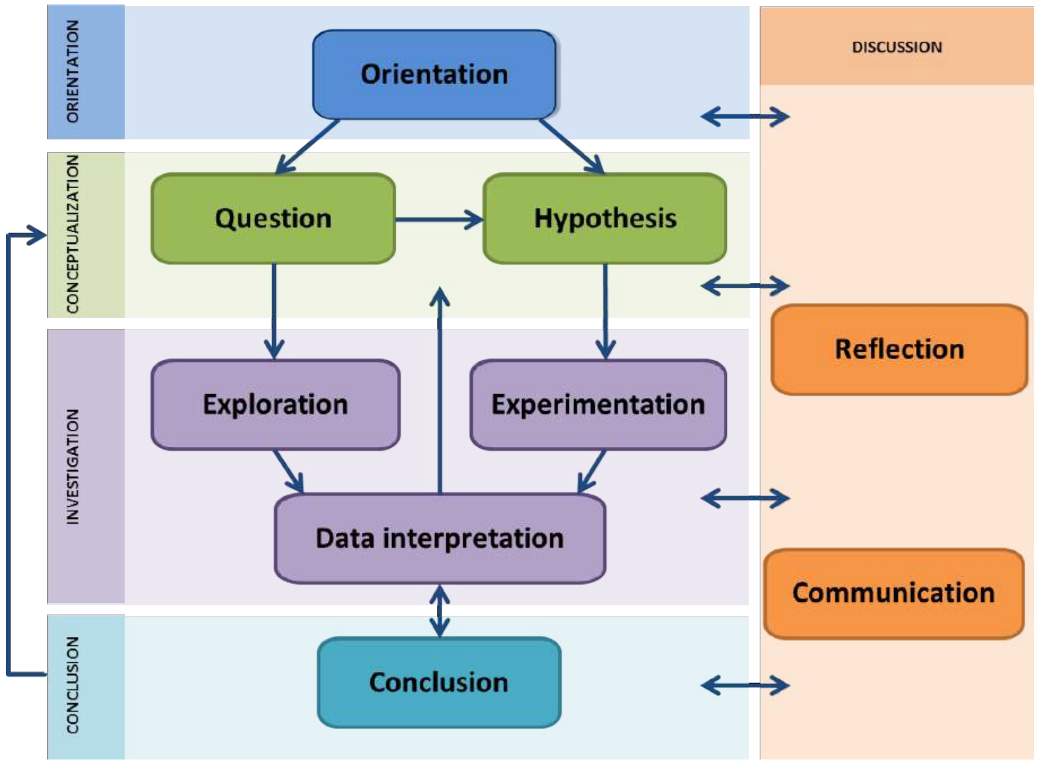


Figure 3. The Go-Lab Inquiry Cycle, graphical representation.

Students who follow the basic scenario presented in Figure 3 (further described in Section 2.2) do not need to go sequentially through all the phases, the scenario allows for a number of routes/possibilities that could be followed (see Section 2.2.1).

The other scenarios presented in this handbook (see Chapter 2) may add new phases to the ones of the basic scenario but also often reuse phases that also exist in the basic scenario, although the specific design of such a phase may differ.

1.3.2 Off-line activities

One of the main purposes of the Go-Lab project is to engage students in inquiry based learning environments through the use of remote and online labs in a way that brings the state of knowledge a step further and that includes all kinds of cognitive activities. There maybe be several reasons, however, to also include off-line activities in a scenario and to combine these off-line activities with the ILS. Potential off-line activities are presented in the next sections.

1.3.2.1 Physical labs

In an ILS lab activities are performed on-line. However, this does not imply that the value of experimentation through physical labs is not acknowledged. In contrast, off-line activities (which take place outside the Go-Lab environment) can be included in the scenarios, based on the affordances that each mode of experimentation offers and the availability of labs (physical, virtual or remote), along with the technical aspects/issues/restrictions that accompany each one of these types of labs. de Jong, Linn, and Zacharia (2013) present a number of the affordances that each type of lab uniquely carries. For example, the physical labs involve all student senses, manipulation of material met in real life and inform students about the safety procedures during the experimentation with physical material/equipment. The remote labs could offer students access to distant equipment (e.g., satellites, telescopes) and equipment rarely or never found in physical school labs (e.g., big size equipment). The virtual labs could offer a safe and measurement error free environment for experimentation, which surpasses time and space limitations. Moreover, they could offer access to the microscopic and conceptual world of science.

Switching between on-line and off-line activities can be done whenever this adds value to the learning process. For instance, whenever an easy access to a physical laboratory is possible, we suggest to make good use of it during students' investigation. Thus, in the occasion of a simple lesson on electric circuits, it's easy to have a number of wires, batteries and light bulbs available in order to provide the students with the opportunity to manipulate the physical materials and explore how a simple electric circuit can be constructed. However, for the investigation of more complex circuits (multiple batteries/light bulbs in series and/or parallel connection), the use of a virtual lab is preferred since it takes less time to construct, reduces the possibility of making any mistakes, takes more accurate measurements and allows students to compare multiple circuits at the same time. This example can be seen as a combination of physical and virtual labs which can have a substantial impact on conceptual knowledge.

1.3.2.2 Individual activities

Sometimes students are used to specific tools or there are better tools available for individual work than can be offered in an ILS. For example, reporting can be written off-line on paper or with general word processors or reporting tools. These reports can be uploaded to Go-lab with for example the file-drop app.

1.3.3 Collaborative activities

Working individually and collaboratively carries its own pros and cons. In the case of the individual mode of learning, the major benefit is that each student could experience a learning process that is better adjusted to his/her individual needs. For example, students could accomplish tasks at their own pace. On the other hand, when using computers individually, you do not offer to the individual the possibility for developing his/her social skills, which are normally part of the regular classroom. In contrast, collaborative group learning has the capability to overcome this possibility of social isolation (Johnson, Johnson, & Stanne, 1985, 1986). Another major advantage of collaborative learning is that students could learn from their peers (e.g., they could share knowledge and experiences, listen to multiple perspectives/arguments/ statements). According to Johnson and Johnson (2004) it is better to have students with diverse interests, expertise, perspectives and skills cooperate than work individually because they can fulfil more learning goals than those achieved by an individual. Several theories (e.g., constructivism, socially shared cognition, distributed learning) and empirical investigations support that students learn well when they work together (Lou, Abrami, & d'Apollonia, 2001), including when working with computer supported inquiry learning environments (Zacharia, Xenofontos, & Manoli, 2011).

In Go-Lab most collaboration between students will take place off-line, since Go-Lab itself, for the moment, doesn’t provide students with chat facilities or shared objects. An exception to that rule is the preparation of learning products by student groups, which will take place online, in the learning environment of a group member. Other members of the group will be able to share the work produced collaborative through the file-drop app. Another exception is the presentation of collaborative work to fellow peers which will also be conducted online. There are three scenarios (Jigsaw, Section 2.3, Six Changing Hats, Section 2.4, and Structured Controversy, Section 2.6) that require students to collaborate. In these scenarios, it is indicated when whole class or collaborative activities take place.

1.4 Choosing a scenario

Choosing the right scenario depends on a number of considerations. These concern the educational objectives of his lessons, the characteristics of his students, more particular the students’ prior knowledge level and the inquiry skills the students possess, and organizational issues. For each scenario we will indicate which if these criteria suggest the use of that particular scenario; this is done per scenario in Chapter 2.

1.4.1 Educational objectives

Each ILS can be accompanied by specific educational objectives. These educational objectives may differ on the type of knowledge (factual, conceptual, procedural, and metacognitive; Anderson & Krathwohl, 2001). The choice for a scenario may depend on the type of knowledge that is the focus of the teaching. For example, choosing a scenario may be different for a focus on the procedural knowledge compared to a focus on conceptual knowledge. In the first case the most suitable scenario would be one that focuses more explicitly on the experimental procedure and the steps that need to be taken before and after the experimentation (e.g., Learning by Critiquing, Section 2.5), in the second case a scenario that focuses on remedying misconceptions is a better candidate to use (e.g., Find the Mistake, Section 0). Concerning the quality of knowledge all scenarios concentrate on the deeper (understand and apply) levels of knowledge and they can help to let students think critically and creatively. Affective objectives are more associated with the three collaborative scenarios (Jigsaw, Thinking Hats, and Structured Controversy).

1.4.2 Student characteristics

Student characteristics are important in selecting relevant scenarios and in adapting these. Two main aspects should be considered: (1) students' inquiry skills and (2) prior knowledge about inquiry learning and content knowledge.

1.4.2.1 Inquiry skills

To perform each of these successfully students need to possess specific skills. In the context of inquiry learning, several skills are needed in particular inquiry stages. For the basic scenario these concern:

Orientation: observing, searching information.

Conceptualization: identifying a problem, defining a problem, questioning, searching information, brainstorming, hypothesizing, making predictions, analysing needs.

Investigation: planning (methods, tasks, equipment, materials and resources, time), exploring, experimenting, observing, collecting data, analysing data (organizing data, finding patterns, assessing data quality), interpreting data, making inferences, modelling.

Conclusion: finding relationships, drawing conclusions, making inferences, reporting.

Discussion: discussing, presenting and elaborating results, finding arguments and justifying statements, communicating, reflecting, presenting, and evaluating the inquiry process and outcomes.

Students either need to have these skills or to receive tools (apps) to help them perform them. If a scenario relies heavily on a skills students do not possess this may be a reason not to choose that scenario.

1.4.2.2 Prior knowledge

The Go-Lab Inquiry Cycle (Figure 3) draws attention to two distinct pathways students can travel when conducting inquiry, one driven by a more open question and one starting from a specified hypothesis. These two pathways relate to Klahr and Dunbar (1988) cognitive model of knowledge acquisition as a search through two problem spaces – a hypothesis space and an experiment space. How learners navigate through the hypothesis space depends greatly on their prior domain knowledge (Klahr, 2000). The two approaches can also be seen as relating to whether an inductive or deductive reasoning strategy is pursued to solve a problem. It is assumed that inductive learning strategies (e.g. trial-and-error) are preferred by students with low domain knowledge (Lazonder, Wilhelm, & Hagemans, 2008). In terms of selecting a Go-Lab scenario that relies mostly on a hypothesis-driven approach, then it is important that students have sufficient prior domain knowledge.

Inquiry is effective if students know what the general goal of inquiry learning is, what stages should be followed in inquiry, what is the aim of each of these stages, how these relate with each other, what is the specific aim of each stage, and how to regulate their learning process (plan, monitor and evaluate). This could be described as general inquiry knowledge (Mäeots & Pedaste, 2013). General inquiry knowledge is a set of knowledge about the nature of a coherent inquiry process as a whole, comprehending knowledge about transformative and regulative inquiry processes. It is not knowledge about how to perform an inquiry activity, e.g., to formulate a hypothesis, but is rather knowledge about the components of the inquiry process as a whole, including knowing the sequence of transformative inquiry stages, the necessity of each stage, and the role of metacognitive processes needed for regulation of inquiry. General inquiry knowledge is important for activating inquiry meta-processes that are needed to plan a general course of regulative and transformative processes to achieve their coherence.

In terms of selecting a Go-Lab scenario then it is important to consider prior experience and familiarity with the components and sequencing of inquiry phases in Go-Lab. A new and more complicated scenario may offer a stimulating challenge to students, but only if have earlier acquainted themselves with a simpler scenario such as the Basic scenario.

1.4.3 Organizational issues

The choice for a specific scenario is also influenced by the organisational constraints. Two important constraints are the number of hours that is available and the possibilities to organise the class.

The didactical hours that are available may for example determine if a full inquiry cycle or only parts of it can be deployed. For example, the choice can be made to use only the Investigation phase as a component of a broader activity that is already planned using mostly the school book and some offline activities. Thus the amount of available hours may affect the number of inquiry steps included in an ILS.

Also class organization is a determinant of the scenario to use. Some scenarios will ask to organise their class into subgroups. This means they will need a certain number of students and sometimes students of specific levels of prior knowledge or skills. In the initial available scenarios, guidelines on how to organize the class will be presented. Judging the composition of knowledge and skills in his class may help to get a better view on what type of organization to choose (students working as: individuals, in homogeneous groups, or heterogeneous groups). If one wishes to organize the class in small groups will be provided with information on different methods of organization (for example the jigsaw puzzle approach, the six hats approach).

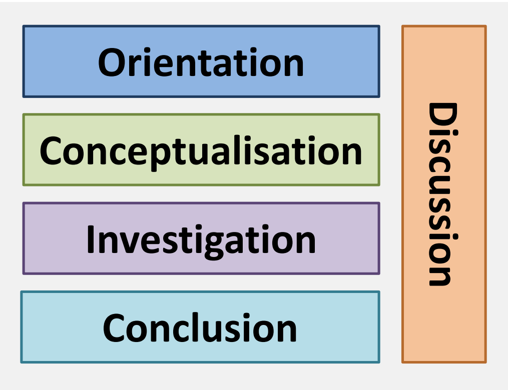
2 Scenarios

In this chapter six different scenarios are described that can be used to shape the didactical structure of an ILS. Each scenario will be described in full detail in the Sections 2.2, and following, but first Section 2.1 presents very brief "teasers" for each of the scenarios to get a quick impression.

2.1 Scenario teasers

2.1.1 Basic scenario

In the Basic scenario student learning is centred around performing fundamental inquiry tasks such as identifying variables, making predictions, conducting experiments and drawing evidence-based conclusions. In order to facilitate the logical and seamless flow of inquiry for students, the Basic scenario conviently organizes inquiry tasks into five major phases: Orientation, Conceptualisation, Investigation, Conclusion and Discussion.



The five inquiry phases structure the learning experience for students so that regardless of their current ability they can achieve optimal results. This is possible because in several of the phases there are multiple options to guide inquiry learning. For example, in the Conceptualisation phase it is possible to direct students towards posing a question which they subsequently explore in the Investigation phase. This is especially beneficial for novice students who have just been introduced to a topic and are curious to explore relationships among concepts that are new to them. However, for students already familiar with a topic then it is possible to guide them to formulate hypotheses in the Conceptualisation phase which they subsequently test by conducting appropriate experiments in the Investigation phase. Systematic testing of hypotheses with controlled experiments is a defining feature of how professional scientists approach problems in real-life.

Overall, the Basic scenario provides a flexible learning experience for students to solve authentic problems in science by following an inquiry way of thinking rather than by simply memorizing established facts.

Further reading

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2.1.2 Jigsaw approach

In a jigsaw puzzle, each part of the picture has to be put in place to depict the whole figure. Accordingly, the Jigsaw Scenario is a type of group learning arrangement, where each student needs to cooperate with his or her peers to achieve learning goals. Each student's contribution is necessary for the preparation of the final outcome.

The Jigsaw Scenario is considered as an essential cooperative strategy for science education. One major characteristic of this perspective is that students have an opportunity to learn from each other by communicating with peers and exchanging information. Students are grouped twice, first in home groups and then in expert groups. The latter will delve deeper into a part of the whole study. When each expert will return to his or her home group, he/she will share the expertise gained with other home group members. Each student's contribution is like a part of the picture that has to be there to shape the whole figure.

In the Jigsaw Scenario, positive outcomes of collaborative learning are catalyzed by fostaring student interaction in expert and home groups. However, this requires that students have the necessary communication skills, such as interpersonal and argumentation skills.

In Go-Lab, the Jigsaw Scenario could be implemented in two alternative learning activity sequences, the Hypothesis Pathway and the Driving Question Pathway. In both cases students first form home groups and then switch to different expert groups to investigate each one dimension of the phenomenon under study. At the end of their expert work, experts return to home groups to communicate their results with peers and draw a final conclusion. The Hypothesis Pathway is to be followed when students have a clear overview of the variables engaged in the phenomenon under study and, therefore, when they could formulate and test hypotheses. When students do not have such a clear overview, they would better choose the Driving Question Pathway and proceed to exploration of the phenomenon.

Further reading

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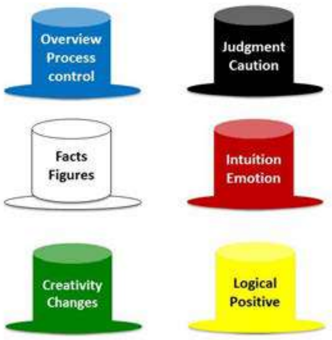
2.1.3 Six thinking hats

Edward de Bono's (1999) *Six Thinking Hats* is a widely adopted creativity technique in various fields, including education. Essentially, *Six Thinking Hats* provides directions for adopting different modes of thinking, characterized by six coloured hats: White, Red, Black, Yellow, Green, and Blue.



Normally this creativity technique is applied in a group setting. Participants can wear real physical hats or imaginative ones (i.e., by asking all group members to utter loudly together the colour of the hat or presenting the image of the hat in a way perceivable by all of them). It is important that putting on and taking off hats is performed as explicit actions of gesturing or verbalizing. Also, group members should use the same colour hat simultaneously. By switching hats, participants can refocus or redirect their thoughts and interactions. Furthermore, the hats can be used in any order that is deemed appropriate and can be repeated as many times as necessary to address the issue at hand.

The Six Thinking Hats technique has successfully been applied to teach STEM subjects and several advantages have been identified such as promoting creativity and problem solving, stimulating diversity of thoughts and empathy, etc.

Further reading

De Bono, E. (1999). *Six thinking hats*. London: Penguin.

Childs, P. (2012). Use of six hats in STEM subjects. In *Proceedings of the High Education Academy STEM Learning and Teaching Conference*, April 12, 2012, London, UK. doi: 10.11120/stem.hea.2012

Garner, A., & Lock. R (2010). Evaluating practical work using de Bono's 'Thinking hats'. *SSR Science Notes, 91*(337), 16-18,

2.1.4 Learning by critiquing!

In the Learning by Critiquing! scenario the major student activity is to judge the quality of an experimental set-up. Students read a report written by others about an experiment that they performed. Learning activities centre aorund presenting and defending opinions by making judgments about information, validity of ideas, or quality of work based on a set of criteria.

In the first part of the scenario students judge the report based on a set of criteria that the teacher has given them. Based on their critique they try to come to a better experiment design. In the second part of the scenario they perform the experiment and write a report about their design, findings and conclusions. In the third part of the scenario students exchange their reports and evaluate the work of another (group of) student(s). Based on the feedback that they receive they finalize their report.

This scenario is used to make students aware of the processes related to scientific reasoning and reporting, and is less focused on teaching a specific topic.

Students should have some basic understanding about the topic at hand. If this is not present the basic information should be presented in the Orientation phase of the scenario.

<u>Further reading</u>

Anderson, L. W., & Krathwohl, D. R., et al (Eds..). (2001) *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives*. Boston, MA: Allyn & Bacon (Pearson Education Group).

Chang, H., & Chang, H. (2012). Scaffolding students' online critiquing of expert- and peer-generated molecular models of chemical reactions. *International Journal of Science Education, 35*, 2028-2056. doi: 10.1080/09500693.2012.733978

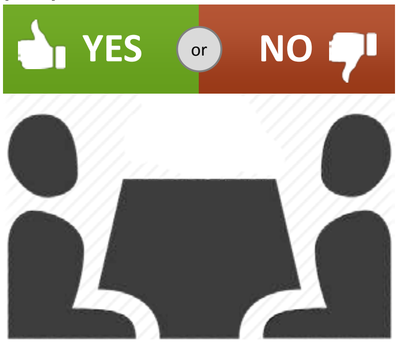
Coughlan, M., Cronin, P., & Ryan, F. (2007). Step-by-step guide to critiquing research. Part 1: Quantitative research. *British Journal of Nursing*, *16*(11), 658-663.

Ryan, F., Coughlan, M., & Cronin, P. (2007). Step-by-step guide to critiquing research. Part 2: Qualitative research. *British Journal of Nursing*, *16*(12), 738-745.

Vance, D. E. (2013). Conducting an article critique for a quantitative research study: perspectives for doctoral students and other novice readers. *Nursing: Research & Reviews, 3*.

2.1.5 Structured controversy

The Structured Controversy scenario is a learning activity that uses a controversial socio-scientific issue to engage students. The scenario essentially pairs inquiry-based science education with civic responsibility. Citizens in democratic societies should be involved in decisions regarding new technologies and scientific innovation when cultural, environmental, social, economic or ethical values are at stake. To prepare students for this important civic responsibility, the Structured Controversy scenario is designed around a socio-scientific controversy that is argued by two opposing sides during a student debate. The controversy is structured in such a way that a compromise position exists in the middle and both opposing sides have a fair chance of contributing arguments towards this compromise.



The Structured Controversy scenario is divided into two lessons. In the the first lesson students work through an ILS to acquire relevant domain knowledge as well as learning to support arguments with empirical evidence. At the end of the ILS students are instructed to prepare for the debate which will occur in the second lesson. In the debate students are split into two teams and work together to present their arguments following a prescribed debate format moderated by the teacher. After the debate the teacher allows time for collaborative group discussion about ways to resolve the controversy with a compromise solution.

The Structured Controversy scenario is mostly focused on providing students with the skills to evaluate science critically and giving them the opportunity to participate in constructive dialogue about socio-scientific issues with their classmates. It assumes that students are able to prepare convincing arguments for their debate by searching for relevant information on their own or together with their team members.

<u>Further reading</u>

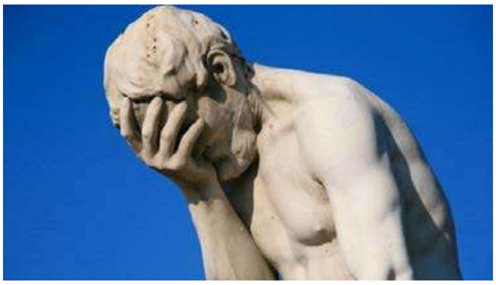
Sadler, T. D. (2009). Situated learning in science education: Socio -scientific iss as contexts for practice. *Studies in Science Education, 45*, 1-42.

Walker, K. A., & Zeidler, D. L. (2007). Promoting discourse about socioscientific issues through scaffolded inquiry. *International Journal of Science Education, 29*, 1387-1410.

Weinberger, A., de Jong, T., Dolonen, J., Hansen, C., Hovardas, A., Pedaste, M.Matteman, Y. (2011). *SCY scenario handbook and pedagogical plans, final version*. Enschede: University of Twente.

2.1.6 Find the mistake

In “Find the mistake!” the inquiry process is organized around spotting mistakes of other (fictitious) students on a specific subject. Research shows that this is a very effective learning apporach since it gives students a clear focus in the inquiry process and helps to tackle common misconceptions. Spotting mistakes in work from others appears to be more effective than spotting own mistakes because own mistakes are often attributed to external causes. Important conditions for success are that students work actively with the mistakes and that feedback is given.



ILSs that follow this scenario introduce the wrong idea(s) from a named person in the orientation or conceptualisation phase and ask students to “translate” these misconceptions into a set of concrete hypotheses (using the hypothesis scracthpad). In the following phases experiments have to be carried out to test these hypotheses and the initial hypotheses need to be corrected. After that students have to reflect on what they think has caused the misconcpetions.

This scenario merely focuses on acquiring understanding of conceptual knowledge.

The Find the Mistake scenario can be used for students who have prior knowledge (including misconceptions) but also by students who are pretty fresh in the domain. In the latter case the “mistakes” need to be embedded in more extensive domain information, also then more support in the form of (partly) designed experiments is needed.

<u>Further reading</u>

Chang, H., & Chang, H. (2012). Scaffolding students’ online critiquing of expert- and peer-generated molecular models of chemical reactions. *International Journal of Science Education, 35*, 2028-2056. doi: 10.1080/09500693.2012.733978

Förster-Kuschel, J., Lützner, S., Fürstenau, B., & Ryssel, J. (2014). Fehlerhafte concept maps im betriebswirtschaftlichen planspielunterricht - lernen aus eigenen vs. Lernen aus fremden fehlern. *Zeitschrift für Berufs- und Wirtschaftspädagogik, 110*, 395-412.

Howard-Jones, P. A., Bogacz, R., Yoo, J. H., Leonards, U., & Demetriou, S. (2010). The neural mechanisms of learning from competitors. *NeuroImage, 53*, 790-799. doi: 10.1016/j.neuroimage.2010.06.027

McLaren, B. M., Adams, D., Durkin, K., Goguadze, G., Mayer, R. E., Rittle-Johnson, B., . . . van Velsen, M. (2012). To err is human, to explain and correct is divine: A study of interactive erroneous examples with middle school math students. In A. Ravenscroft, S. Lindstaedt, C. D. Kloos, & D. Hernández-Leo (Eds.), *21st century learning for 21st century skills* (Vol. 7563, pp. 222-235): Springer Berlin Heidelberg.

Wijnen, F. (2014). *Learning from erroneous models.* Master thesis, University of Twente, Enschede.

2.2 Basic scenario

The *basic Go-Lab inquiry scenario* has been developed based on an extensive review of 32 articles describing inquiry phases and/or inquiry-based learning frameworks (Pedaste, et al., 2015). On the basis of this review we identified five distinct general inquiry phases: Orientation, Conceptualization, Investigation, Conclusion, and Discussion. Some of these phases are divided into sub-phases. In particular, the Conceptualization phase is divided into two (alternative) sub-phases, Questioning and Hypothesis Generation; the Investigation phase is divided into three sub-phases, Exploration or Experimentation leading to Data Interpretation; and the Discussion phase is divided into two sub-phases, Reflection and Communication.

In this framework, inquiry-based learning begins with Orientation and flows through Conceptualization to Investigation, where several cycles are possible. Inquiry-based learning usually ends with the Conclusion phase. The Discussion phase (which includes Communication and Reflection) is potentially present at every point during inquiry-based learning and connects to all the other phases, because it can occur at any time during (discussion in-action) or after inquiry-based learning when looking back (discussion on-action). The basic scenario is graphically depicted in Figure 4.

2.2.1 Inquiry phases and their sequence

In the basic scenario the inquiry-based learning process by default starts with Orientation, where students not only get an idea about the topic to be investigated but are also introduced to the problem to be solved. If students' curiosity is already raised from previous studies or interests, this phase is often not needed. In the following step, a hypothesis-driven approach or a question-driven approach.

If the students have no specific theoretical idea and only a general plan of what to explore, they should start from more open question(s) that guide them to the exploration of a phenomenon (*data-driven approach*). In this case, it is expected that students will return to the Conceptualization phase if they have specified, revised or derived new ideas from the Exploration phase or data gathered, but they can also move directly from Exploration to Data Interpretation and Conclusion. If the students have a more specific, often theory-based idea about what to investigate, then *a hypothesis-driven approach* is suitable. A slight variation combining both approaches could be the question-driven approach, where students have a question and their next goal is to collect background information for stating a specific hypothesis as a possible answer to the question.

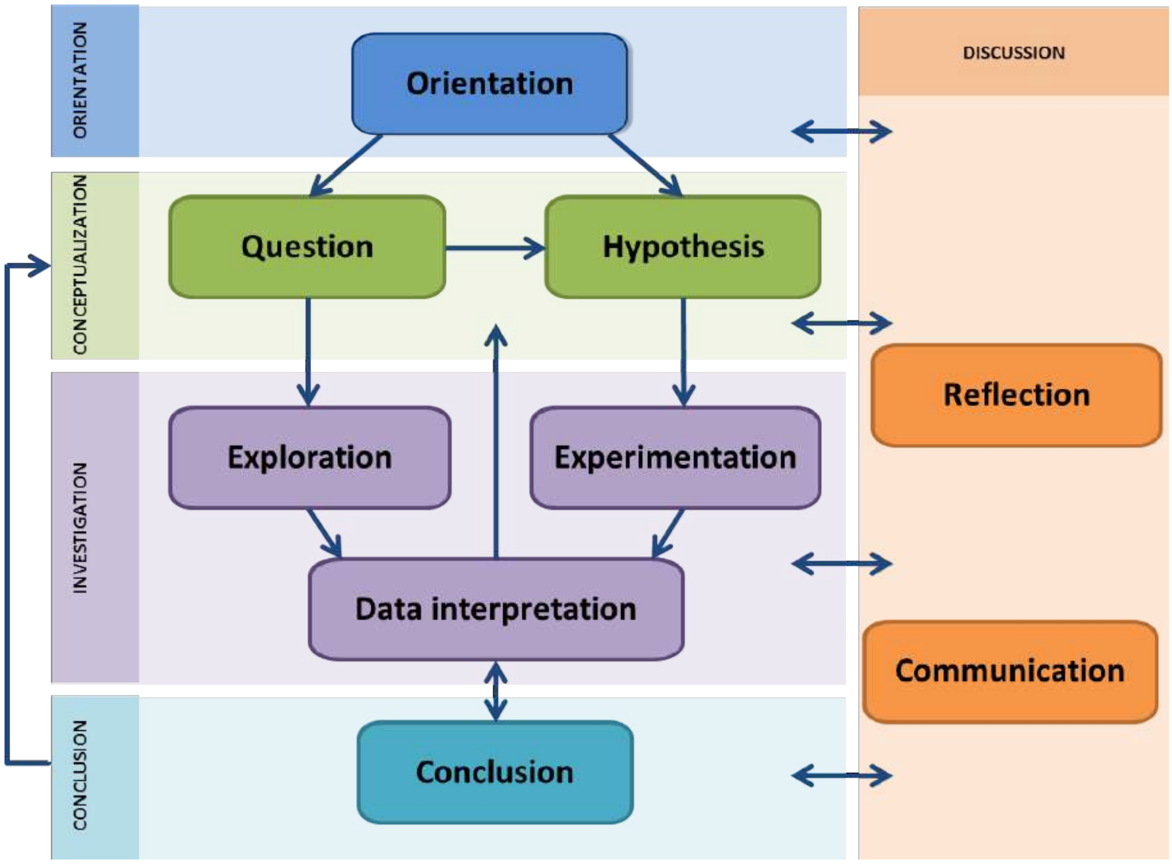


Figure 4[2]. Basic scenario (general phases, sub-phases, and their relations).

The pathway in the *Investigation (Exploration or Experimentation)* phase depends primarily on the actions taken during the Conceptualization phase (this is starting from Question or from Hypothesis). In both Exploration and Experimentation, planning is an important activity to avoid inappropriate use of resources, such as time, materials, and money. Data Interpretation is the next step after either the Exploration or Experimentation sub-phases, where data is collected. Here students analyse data according to a specific strategy and method planned in the Exploration or Experimentation sub-phases, and make their first interpretations of the data. From Data Interpretation, it is possible to move forward to the Conclusion phase or go back to the Conceptualization phase to revise existing or define new questions or hypotheses, which makes inquiry-based learning a cyclical process. If some issues have been discovered in Exploration or Experimentation, it might be a good idea to turn back to change the plan or experiment design made in a particular sub-phase without changing research questions or hypotheses. If a student collected enough data for confirming his or her hypothesis or for answering the stated question(s) then he or she may proceed to the next phase for stating final conclusions.

These are stated in the *Conclusion phase*, where the outcomes of the Investigation phase are compared with the output of the Conceptualization phase. In case the

[2] This figure is the same as Figure 1.

data-collection was not as successful as planned (according to the findings in the Data Interpretation sub-phase), the student can go back to the Conceptualization phase to re-state a question or hypothesis, which serves as new input for the Investigation phase. In this case, the results of Data Interpretation serve the student as new theoretical knowledge for him/her to formulate questions or hypotheses. Moving back may also be in response to new ideas that arise out of the collected data during interpretation.

All phases from Orientation to Conclusion are related to the *Discussion phase*, with its two sub-phases of *Communication* and *Reflection*. Both Communication and Reflection can be seen as on-going processes, which help students receive feedback about their learning process by sharing their domain-related outcomes and process-related ideas with others. This means direct communication among peer students, teacher, etc. However, it could also involve guided monitoring of students' learning process by using reflection activities. Two types of reflection can be distinguished (Schön, 1987): a) *reflection-in-action*, where the students evaluate their study process while conducting the activities of a specific phase and collect particular information for this while planning and monitoring learning activities or b) *reflection-on-action*, where the students evaluate their study process after completing the whole inquiry cycle. In both cases, students use the results of their reflection to revise the activities engaged in during specific phases (e.g., re-stating their research question) or as an input for a new inquiry cycle. Communication can be viewed as 'in-action' communication or 'on-action' communication, i.e. it is either part of an inquiry phase or performed as a separate activity at the end of the inquiry cycle, respectively.

Table 1 presents a brief overview of the phases in the basic scenario and the related student actions.

Table 1
Example guidance for the basic scenario

Phase	Sub-phase	Tool	Description of guidance
Orientation		Concept mapper	*A concept map helps students to visualize the relationships between various concepts. As a start students can be asked to think of as many terms as they can.*
Conceptualization	Research Question Formulation	Questioning Scratchpad	*Before performing experiments students need to form an overview of their research topic and decide what they want to know. They do this by formulating research questions. A research question is a question that can be answered by doing experiments.*
	Hypothesis Generation	Hypothesis Scratchpad	*Hypotheses give predictions of the effects of certain variables. Scientists use all the knowledge and information they have collected about their research topic to make an educated guess about the outcome of the experiments. Ask your students to make an educated guess about the answer of their question(s), based on the knowledge they have collected in the previous phase. This educated guess will be the hypothesis. Indicate that students may formulate more than one hypothesis per question.*
Investigation	Experimentation	Experiment Design Tool	*Ask student to make a plan before they Before start their experiment. Students need to indicate the variable(s) they want to change from one experiment to the next (i.e., independent variables), the variable(s) they want to keep the same (i.e., control variables), and the variable they want to observe/measure (i.e., dependent variable).*
Conclusion		Conclusion Tool	*Stimulate students to think about the data they collected, and ask them to think about which data will help them to confirm or disconfirm their hypothesis?*
Discussion	Reflection	Reflection Tool	*Ask students to think on what should be done differently and similarly next time when performing an inquiry?*

2.2.2 Guidelines per phase

In the basic scenario the full pathway is presented. However, it can be modified by leaving out some phases or focusing more or less on particular phases and/or scaffolds. In this section we present short guidelines on how to design an ILS for the basic scenario and we do this per phase. For each phase we also indicate which tools are most appropriate. Shorter versions of these guidelines can be found in the "scenario ILS" as present in Graasp.

ORIENTATION

The Orientation phase is where students not only get an idea about the topic to be investigated but are also introduced to the problem to be solved. Orientation is focused on stimulating students' interest and curiosity towards the problem at hand. The Orientation phase is also used to activate students' prior and new knowledge.

In designing an ILS you can try to provoke the curiosity of students by:

- Including a stimulating video from YouTube or recording your own personalized video.
- Starting with a surprising or contradictory statement.
- Asking thought-provoking questions such as *How* does it work? *Why* is it so? *What* will happen if? *When* does it occur? *Who* discovered it? *Where* does it come from?

Activation of prior and new knowledge can be achieved by:

- Links to specific websites that define terminology or present background information.
- Using the QuizMaster app to prepare multiple choice questions for your students.
- Using the Input Box app to prepare open-ended questions for your students.
- A group discussion via the Padlet app where students write or add pictures on an online whiteboard.
- Creating a partially finished concept map with the Concept Mapper app that students extend or correct. A concept map helps students better visualize the relationships and organization between differing concepts. You can introduce a concept map with the following text:
    - *A concept map is a visual representation of your thoughts, information and knowledge. It contains concepts and relationships between these concepts that are visually represented by means of arrows and colours. This helps you organize information and provides a structure that makes you come up with new ideas more easily.*

When students are performing the Orientation phase in class you can encourage them to participate in a conversation about the learning topic. Allow them to describe their ideas but do not yet point out mistakes, since students will discover their own mistakes by the end of the lesson. Alternatively, you may note them down and bring them back to their attention at a later stage. Try to monitor the discussion between students and ask them to think critically. For example ask them: "What do think of what your classmate have just said? Do you agree or disagree? Why?" During your discussion with students about the domain topic, make sure to ask scientifically oriented questions to further engage them.

CONCEPTUALIZATION

In the Conceptualization phase students have different possibilities for forming the key concept(s) to be studied in the inquiry activity. The phase offers two (alternative) sub-phases, Question and Hypothesis whose outcomes have similar components. In general, hypothesizing is formulation of a testable statement or set of statements and questioning in this context is a formulation of investigable questions.

When designing this phase using the question-driven approach you can:

- Include the [Question Scratchpad app]() to help students formulate research questions using a simple drag-and-drop method. The Question Scratchpad can be configured to offer ready-made questions, partially completed questions or a selection of predefined terms that a learner combines together to form a complete research question.
- Emphasize that a research question can be answered by doing experiments.
- If you think that students will have difficulty formulating a research question on their own then you can provide one for them. In this case consider prompting students to examine this research question more closely with questions such as:
    - *Can you identify the variables that the research question is interested in studying?*
    - *Please identify the variable that causes something to happen?*
    - *To answer this research question what variable do you think needs to be observed or measured?*

When designing the Conceptualisation phase using the hypothesis-driven approach you can:

- Include the [Hypothesis Scratchpad app]() to help students formulate hypotheses using a simple drag-and-drop method. The Hypothesis Scratchpad can be configured to offer ready-made hypotheses, partially completed hypotheses or a selection of predefined terms that a learner combines together to form a complete hypothesis.
- Emphasize that hypotheses give predictions of the effects of certain variables.
- Consider providing suggestions or hints using the following texts:
    - *A good hypothesis is a testable prediction in the form of "If variable A changes then variable B will change."*
    - *Specify the strength or direction of change (e.g. increases, decreases, stays the same) of your variables.*
    - *Use only one dependent variable at a time when you formulate a hypothesis.*

When students are performing the Conceptualisation phase in class you can review their progress and verbally provide them with hints to formulate a suitable research question or hypothesis.

INVESTIGATION

The Investigation phase is where the curiosity is turned into action in order to respond to a stated research question or hypothesis. Students design plans for experiments, investigate by changing the values of variables, explore (observe), make predictions, and interpret outcomes.

When designing the Investigation phase you can:

- Emphasize that students need to need to indicate the variable(s) they want to change from one experiment to the next (i.e., independent variables), the variable(s) they want to keep the same (i.e., control variables), and the variable they want to observe/measure (i.e., dependent variable).
- Use the Experiment Design Tool to guide your students in planning their scientific experiments. The Experiment Design Tool requires students to select a variable from a predefined list and choose whether it will vary, stay the same or be measured (i.e. students identify independent, dependent and control variables). Once the variables are categorized the Experiment Design Tool requires students to specify values for the independent and control variables, perform the experiment using these values, and finally write the outcome of their dependent variable. Overall the Experiment Design Tool provides a way for students to make a detailed plan for conducting their experiments.
- Use the Observation Tool to help students record their observations made while preparing, conducting and analysing experiments, and later retrieve these observations in the Conclusion Tool as a basis for drawing conclusions.
- Use the Data Viewer to provide features for students to organize and visualize the data from their experiments. A graphical representation is a concise way to display the relationship between independent and dependent variables.
- Consider providing suggestions or hints to guide this phase using the following texts:
    - *Remember to change only one variable at a time and keep notes not only for your data but also about the process itself.*
    - *Have you done all the necessary manipulations before you run the experiment?*
    - *Did you collect enough data?*

When students are performing the Conceptualisation phase in class you can review their progress and prompt them verbally to follow the hints given in the text. Depending on the knowledge and skills of your students you may choose to perform the analysis with the entire class. Determine what kind of data you expect from you students, for example table, a graph, certain calculations. This can depend on the level of your students. Also make sure that all students participate in this activity, not only the best students. Every student should get a chance to offer his or her input and all students should comprehend the performed analysis. Intervene when necessary.

CONCLUSION

The Conclusion phase is where the outcomes of the Investigation phase are compared to the output of the Conceptualization phase and conclusions are drawn.

When designing the Conclusion phase you can:

- Emphasize that students should think about the data they collected and which data will help them confirm or disconfirm their hypotheses
- Use the Conclusion Tool so that students can check whether the results of their experiments in the form of their observations recorded by the Observation Tool support the hypotheses they made in their Hypothesis Scratchpad or are relevant for the questions posed in their Question Scratchpad.

When students are performing the Conclusion phase in class you can review their progress, point out flawed conclusions and encourage them to repeat their experiments/explorations in order to come to the correct conclusion.

DISCUSSION

The Discussion phase is about sharing one's inquiry process and results. It involves the process of describing, critiquing, evaluating and discussing the whole inquiry process or a specific phase. It contains two sub-phases - Communication and Reflection - which help students communicate their findings to others and prompt them to reflect on their actions in order to learn from their experiences.

When designing the Discussion phase you can:

- Use the Reflection Tool to give feedback to students about their use of time working in an ILS and prompt them to reflect on their learning processes during this time. Example text in the Reflection Tool reads as follows:
    - *Reflection involves thinking back about what you did and the choices you made. Please look at the activity time log below to recall how you spent your time in the inquiry phases. A suggested norm time, provided by the ILS creator, has been added to help you make comparisons.*
    - *Did you spend relatively more time than could be expected in one or more of the phases? If so, please consider why this was the case (e.g., a phase particularly difficult or a phase engaged your attention). Explain why you think your time in the inquiry phases differed from the suggested norm time. If your time was the same then explain if you think all inquiry projects follow this general distribution.*
- Use the Input Box to prompt reflective thinking via open-ended questions such as:
    - *What was the hardest phase during your activities and why was this phase the most difficult one?*
    - *Did you change your confidence level for your hypotheses? If yes, which experiments or observations made you change your mind? If*

not, was this because you were right from the start? Did you have enough data and observations to reach your conclusion?

  - *What do you think should be done differently and similarly next time when performing an inquiry?*

- At the conclusion of the inquiry learning activity you may want students to create a report or presentation summarizing the experience. In this case you can use the File Drop app to allow a student to submit a digital file that communicates his/her findings.

If students are making presentations in class about their inquiry findings, then encourage them to have a discussion and make comments to each other. Face-to-face presentation is an important part of how professional scientists communicate their research results in real-life.

2.2.3 When to use this scenario?

The Basic scenario is applicable to achieve two main goals. First, it can be used to understand particular phenomena where one or several independent factors have effect on a dependent variable. Second, it guides students towards understanding of the inquiry approach – its phases, sub-phases and particular tasks. Compared to other Go-Lab scenarios it is the simplest one and could be recommended as the first one for novices in inquiry learning. Because of the simple structure it is also recommended for teachers who are not yet experts in applying inquiry-based learning in their classroom. However, it should be mentioned that is not the most appropriate to discover more complex processes where it might be important to divide the complex problem into sub-problems that can be solved by different groups of students. Therefore, one might consider some other scenarios described in the following chapters.

2.2.4 Example ILSs

The following ILSs can be inspected as examples of this scenario:

Sinking and floating, Craters on Earth and other Planets, Series and parallel circuits, and the biology ILS "Guppies".

2.3 The jigsaw approach

The jigsaw approach is a type of group learning arrangement where each student needs to cooperate with his or her peers to achieve learning goals. In a jigsaw puzzle, each part of the picture has to be there to depict the whole figure. Accordingly, each student's contribution is necessary in the jigsaw approach for the preparation of the final outcome (Aronson, 2002, p. 215). In this scenario, students are grouped twice, first in home groups (where the problem is explored) and then in expert groups (which focus on a specific part of the assignment). After the expert work has been completed, experts return to their home groups and the problem is solved by combining all different expertises. When each expert will return to his or her home group, each student's contribution will be there to shape the whole figure just like a part of a jigsaw puzzle.

2.3.1 Inquiry phases and their sequence

Initially, students form home groups in the Orientation phase and the teacher assigns each home group to test the entire set of variables under investigation (e.g., Figure 6; V1-V3). In the Conceptualization phase, each student of a home group will become more familiarized with a single variable, because he/she will later become an "expert" in handling this variable. At the Investigation phase, students switch from home groups into "expert" groups. Specifically, "experts" from different home groups, who have been assigned the same variable, will come together to form an "expert" group for this variable. The Conclusion phase involves two steps. First, "expert" groups conclude their investigation, and then "experts" will return to "home" groups to share their results and draw final conclusions. This is a reverse switch from "expert" groups back to "home" groups. The number and size of groups will depend on the number of students of the class and computers available.

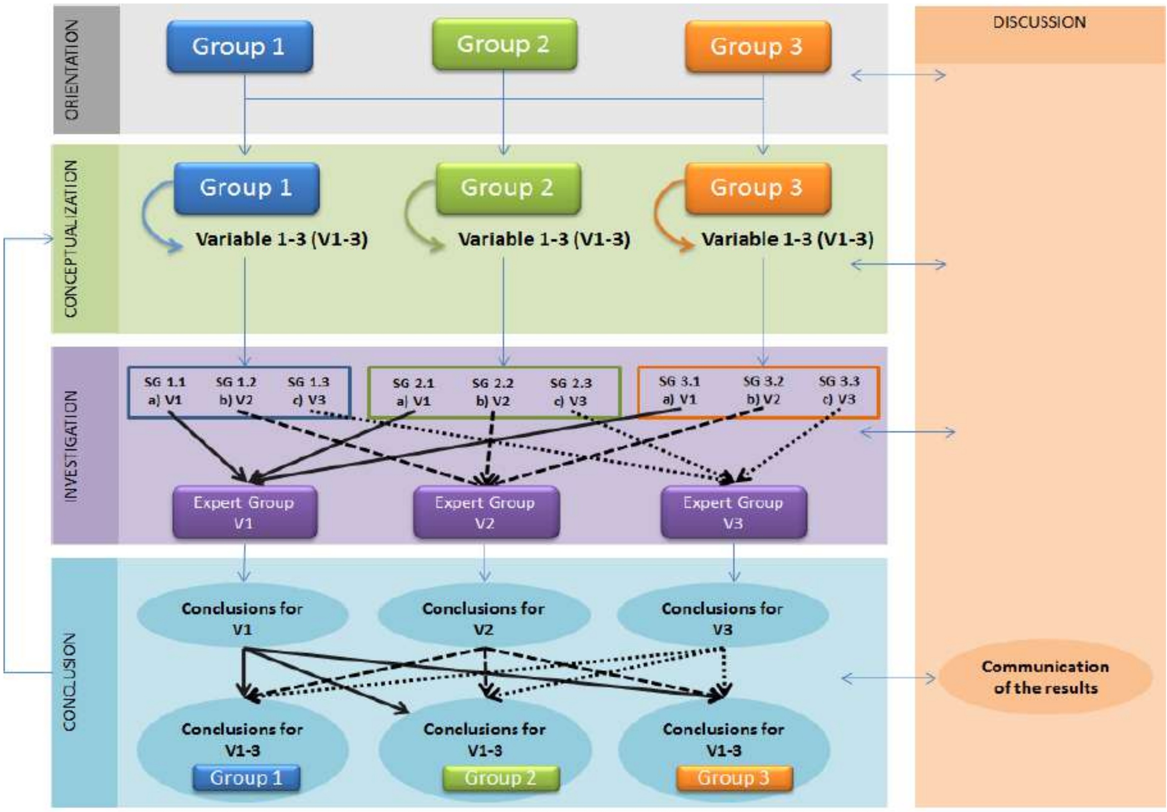


Figure 6. Inquiry phases and their sequence in the jigsaw approach.

The sequencing of the jigsaw approach can follow both pathways of the basic pedagogical scenario, namely, the Driving question or Hypothesis pathway (Figure 7). The teacher will decide which pathway to follow based on student abilities and needs as well as time availability. A teacher may thus choose to use a hypothesis driven inquiry cycle or a more exploratory approach taking the driving question pathway.

The Hypothesis pathway should be selected when students have a clear overview of all variables engaged in the phenomenon under study and are about to start their investigation (i.e., students are ready to test a specific hypothesis). The Driving question pathway should be taken by students who have to start with an open-ended question, because they do not know exactly which are the variables involved in the phenomenon under study (i.e., students need to determine which variables qualify for inclusion in their investigation). More specifically, a sequence of phases for the hypothesis pathway and the driving question pathway are given below:

- The Driving question pathway: Orientation – Question – Exploration – Data interpretation – Conclusion – Communication – Reflection
- Test a Hypothesis pathway: Orientation – Hypothesis – Experimentation – Data interpretation – Conclusion – Communication – Reflection

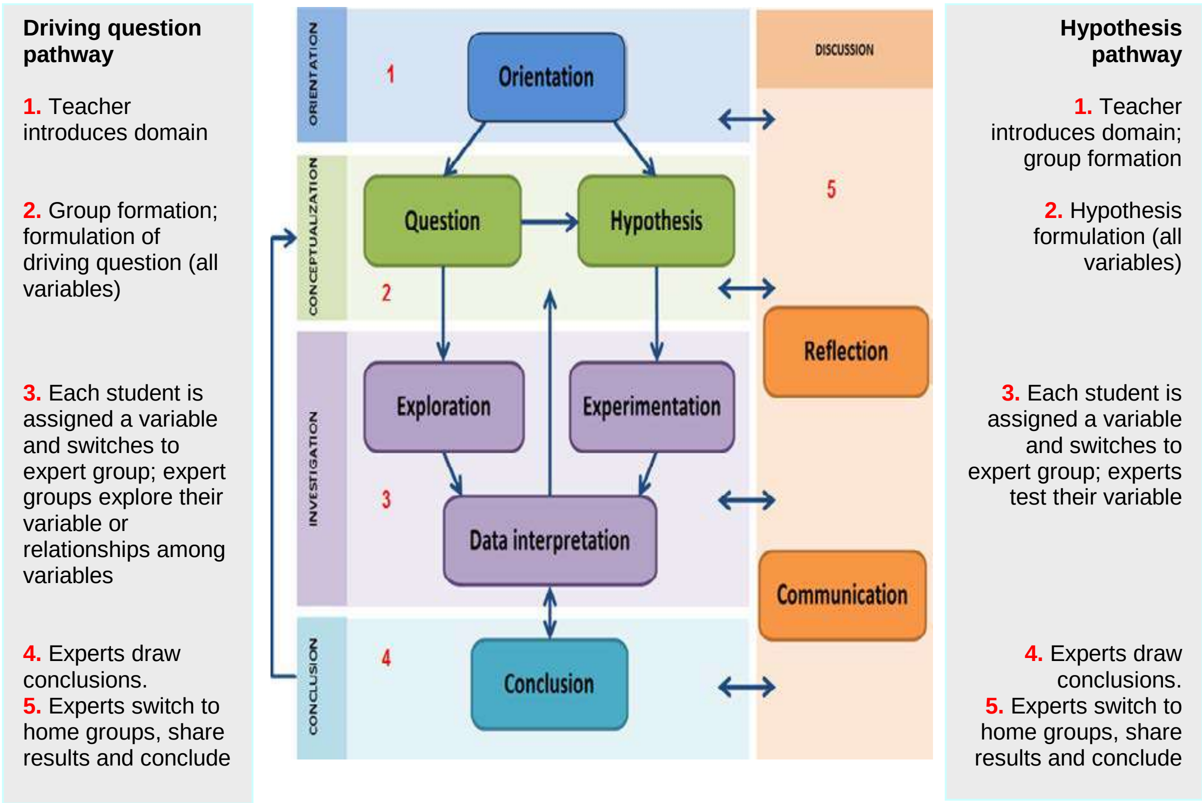


Figure 7. The Driving question and Hypothesis pathways of the inquiry cycle in the jigsaw approach.

In Table 2, specific types of guidance are suggested taking into account the pathway and the phase/sub-phase of the inquiry cycle. Additionally, for each type of guidance a short description is provided, explaining the main function of it.

Table 2
Guidance per pathway and phase of the jigsaw approach

Pathway	Phase/Subphase	Guidance	Description of guidance
Both	All phases	Note taking tool	Keep records either freely or after getting instructed.
Hypothesis	Conceptualization – Hypothesis	Concept Mapper (can be configured)	Organize concepts and depict relations among concepts with arrows.
		Hypothesis Scratchpad (can be configured)	Facilitate formulation of hypotheses.
		Heuristic	Provide the general form of a good hypothesis.
Driving Question	Conceptualization - Question	Questioning Scratchpad (can be modified in app composer)	Facilitate the driving question formulation.
		Heuristics	Provide rules for the formulation of a good driving question.
Hypothesis	Investigation – Experimentation	Experiment Design Tool	Facilitate the experimental plan and the experimental design process.
		Heuristics	Rules of thumb on how to manipulate variables during the design of experiments.
		Prompts	Remind students to save data with a proper name because they will need to retrieve them in the next phase.
Driving Question	Investigation – Exploration	Assignment	Help students conduct a valid exploration with the lab.
		Prompts	Remind students to follow a procedure and promote the identification of the focus of attention.
Hypothesis	Investigation - Data Interpretation	Data Viewer Tool	Facilitate the visualization of data collected during the experiment.
		Prompts	Explain students how to retrieve their data set.
Both	Investigation - Data Interpretation	Guiding questions	Specific questions to support data interpretation.
Hypothesis	Conclusion	Conclusion Tool	Facilitate the formulation of valid conclusions.

Pathway	Phase/Subphase	Guidance	Description of guidance
		Prompts	Remind students to save their conclusion with a proper name because they will need to retrieve it during the next phase.
Both	Conclusion	Heuristics	Monitor the use of evidence to support or reject hypotheses.
Hypothesis	Discussion – Communication	Prompts	Remind students how to retrieve expert conclusions.
Both	Discussion – Reflection	Reflection tool	Support students think critically and evaluate their work.

2.3.2 Guidelines per phase

In the scenario above the full pathway is presented. However, it can be modified by leaving out some phases or focusing more or less on particular phases and/or scaffolds. In this section we present short guidelines on how to design an ILS for the jigsaw scenario and we do this per phase. All guidelines have been prepared for the Hypothesis pathway, but with small scale adjustments they could also be applicable for the Driving question pathway. For each phase we also indicate which tools are most appropriate. Shorter versions of these guidelines can be found in the "scenario ILS" as presented in Graasp.

ORIENTATION

In the Orientation phase, students form home groups and brainstorm about the general topic, familiarize themselves with the specific aspects of the general topic by exploring several resources, and activate their prior knowledge. In this phase, activities 1 and 2 from Table 3 are applied (see page 39), where students brainstorm on the subject matter and elicit their prior knowledge, respectively.

During the first activity, you need to act as a facilitator of the discussion.

The familiarization can be done by:

- One and/or more videos, from YouTube. Alternatively, you can record your own video, in which you will explain the general topic.
- A brief text.
- One and/or more links to specific websites.

In order for students to activate their prior knowledge (second activity), they may:

- Write down, in an Input Box, all the concepts and keywords that they think to be related to the topic.
- Perform a brief multiple choice quiz related to the topic.

CONCEPTUALIZATION

Hypothesis sub phase

In the Hypothesis sub phase, students think about the main concepts that describe the phenomenon under study. Then, they formulate specific hypotheses that they are going to investigate in the next phase. In this phase, activities 3 – 6 from Table 3 are undertaken, namely, students identify variables and relationships between variables, they discuss assumptions for hypothesis formulation, and they formulate hypothesis.

In this phase you may have students try to interrelate the concepts and keywords that they noted in the previous phase by creating a concept map.

Before students start creating their concept map you might provide them with a relevant hint:

"*A concept map is a visual representation of your thoughts, information and knowledge. It contains concepts and relationships between these concepts that are visually represented by means of arrows and colours. This helps you organize information and provides a structure that makes you come up with new ideas more easily.*"

After students have constructed their concept map, you might prompt them with some questions to ensure that the concept map of each student contains at least a subset of variables that are going to be investigated in the next phase.

In their home group students first discuss assumptions for hypothesis formulation and then each member of the home group formulates hypotheses using the Hypothesis Scratchpad. During the hypotheses formulation, students are provided with hints like the following ones:

- *A good hypothesis can be formulated in the form of "IF.. THEN.." statement, which will involve one dependent variable with at least one independent. For example: IF the independent variable increases THEN the dependent variable decreases.*
- *Use only one dependent variable at a time when you formulate a hypothesis.*
- *Remember that a hypothesis might not be confirmed after the experimentation. This is not a problem. Many scientific experiments have led to valuable knowledge because they resulted in the rejection of a hypothesis.*

In general, in this phase make sure that the students use the appropriate variables and encourage them to pay attention to the hints provided to them.

INVESTIGATION

Experimentation sub phase

In the Experimentation sub phase, students form expert groups. Then, they design and carry out their experiments. Each expert group investigates a different variable to confirm or reject a hypothesis. In this phase, activities 7 – 11 from Table 3 are applied, namely, students switch from home groups to expert groups, they get familiarized with the lab to be used, they discuss assumptions for experimental design, they design an experiment, they conduct their experiment, and they write down their observations.

At the beginning of this phase, you can have a brief discussion with your students in each expert group about the aim of expert group formation. Let your students know that each expert group is going to specialize on a different variable. For example, if a home group had been consisted of four members, each member will become expert in one variable under investigation. All students in an expert group will concentrate on a single variable. After this brief discussion, you can make sure that all students in an expert group know which variable they are going to investigate.

Students need to have their first experience with the lab in order to plan their investigations in a proper way. The first impression can be done by letting students familiarize with the lab for a short time (e.g., 5 minutes) or by preparing a short explanatory video, which will explain the main elements and functions of the lab.

The next step for the students is to make a detailed plan for conducting their experiments. This can be done with the Experiment Design Tool. Before each student uses the tool, you can ask them to discuss in their expert group the following questions:

- *Which variable are you going to measure? In other words: Which is your dependent variable? Please explain why you have chosen this variable.*
- *Which variable are you going to change? In other words: Which is your independent variable? Please explain why you have chosen this variable.*
- *Which variables do you need to control - keep constant - in your experiment? In other words: Which are your control variables? Please explain why.*

When students insert their measures in the Experiment Design Tool, all the data are saved automatically in a format that can be used by the Data Viewer, in the next phase. You might also ask students to note down what they have observed during their experiments by means of the Observation Tool.

During the experimentation, you can ask your students a series of reflection questions, like the following ones: "Have you done all the necessary manipulations before you run the experiment?" "Did you collect enough data?"

Data Interpretation sub phase

In the Data Interpretation sub phase, students can use the Data Viewer to prepare data graphs and examine the relation between the variables (independent and dependent), which were investigated in the previous phase. In this phase, activity 12 from Table 3 is applied, namely, students interpret experimental data.

- The Data Viewer is a tool that helps students to create data graphs and/or tables for all the recorded measurements for the independent and dependent variables. Encourage your students to make at least one graphical representation.
- In addition, you can insert an Input Box and provide to the students some guiding questions in order to help them examine relations among variables.
- Prompt your students to return back to the Experimentation phase, if they have not gathered enough data.

CONCLUSION

In the Conclusion phase, students draw conclusions from their experiments by using the Conclusion Tool to retrieve their previous work (hypotheses, graphs, observations). In addition, they discuss their conclusion in their expert groups and prepare expert presentations to communicate their results in their home group. In this phase, activities 13 – 15 from Table 3 are applied, namely, students draw a conclusion, they discuss conclusions in expert groups and they prepare an expert presentation.

Provide your students with some hints during the use of the Conclusion Tool, like the following one:

- *Your conclusion should be justified based on the evidence you have collected during the Investigation phase. This evidence will help you provide an answer whether your hypothesis has to be either supported or rejected.*

In addition, support your students in forming valid conclusions. Point out flawed conclusions and encourage them to repeat their experiments in order to come to a defendable conclusion.

Students can prepare their expert presentation in a Power Point format and upload it in the ILS using the File Drop App. In their expert presentation, students should try to give enough evidence from their experimentation to reject or confirm their hypothesis. Make sure that all expert groups have uploaded their presentation in the File Drop.

Provide your students with some hints during the preparation of their expert presentations, like the following one:

- *A good expert presentation should contain information about the problem studied, the hypotheses examined, the investigation conducted, the data collected and the conclusion extracted.*

DISCUSSION

Communication sub phase

In the Communication sub phase, students return to their home group. They share their conclusions with other group members so that they can reach a final conclusion. In this phase, activities 16 – 20 from Table 3 are applied, namely, students switch back from expert to home groups, they communicate results to home groups, they discuss their conclusion in the home group, they write down the final conclusion and they discuss conclusions of all other groups.

In the first step of this phase, students return to their home group and present to their peers their expert results and conclusions. They can have access to their presentation through the File Drop App.

In the next step, students in their home group must come to a final conclusion and write it to an Input Box.

At the end of this phase, you can have a whole class discussion with your students about their final conclusions. In addition, an elaboration on how their work and outcomes can be applied in different settings can be made, so that students could identify various aspects of scientific practice.

Reflection sub phase

The Reflection sub phase is the last phase of the inquiry cycle, where students engage in reflection activities, which help them to think critically on their learning process. In this phase, activity 21 from Table 3 is applied, namely, students reflect on the activity sequence.

Students can use the Reflection Tool to complete reflection activities or answer reflection questions like the ones below, in an Input Box:

- *Think critically if you have completed all activities correctly.*
- *Evaluate your success or failure across all phases of the learning process.*
- *Consider alternative strategies for doing your work and identify activities that could have been undertaken in a different way.*

Table 3
A prototypical sequence of activities in the Jigsaw scenario

Serial number of activities	Brief description of activities	Phase in the ILS (Pedaste et al. 2015)	Sub-phase in the ILS (Pedaste et al. 2015)	Online/offline mode	Class arrangement (whole class; group; switch; individual)	Online resources to be used
1	Form home groups	Discussion	Communication	Offline	Switch from whole class to home groups	-
2	Brainstorm on the subject matter	Discussion	Communication	Offline	Home group	-
3	Elicitation of prior knowledge	Orientation	Orientation	Online	Individual	Input Box; Uday's Scratchpad
4	Identification of variables and relationships between variables	Conceptualization	Hypothesis generation	Online	Individual	Concept Mapper
5	Discuss assumptions for hypothesis formulation	Discussion	Communication	Offline	Home group	-
6	Formulate hypothesis	Conceptualization	Hypothesis generation	Online	Individual	Hypothesis Scratchpad
7	Form expert groups	Discussion	Communication	Offline	Switch from home groups to expert groups	-
8	Familiarization with the Lab to be used	Investigation	Experimentation	Online	Individual	Online Lab
9	Discuss assumptions for experimental design	Discussion	Communication	Offline	Expert group	-

Serial number of activities	Brief description of activities	Phase in the ILS (Pedaste et al. 2015)	Sub-phase in the ILS (Pedaste et al. 2015)	Online/offline mode	Class arrangement (whole class; group; switch; individual)	Online resources to be used
10	Design an experiment	Investigation	Experimentation	Online	Individual	Experiment Design Tool
11	Conduct experiment and write down observations	Investigation	Experimentation	Online	Individual	Online Lab; Observation Tool
12	Interpret experimental data	Investigation	Data interpretation	Online	Individual	Data Viewer
13	Draw conclusion	Conclusion	Conclusion	Online	Individual	Conclusion Tool
14	Discuss conclusions of expert groups	Discussion	Communication	Offline	Expert group	-
15	Prepare an expert presentation	Discussion	Communication	Online	Expert group	Padlet; File Drop
16	Switch back from expert to home groups	Discussion	Communication	Offline	Switch back from expert to home groups	-
17	Communicate results to home groups	Discussion	Communication	Online	Home group	File Drop
18	Discuss conclusion in the home group	Discussion	Communication	Offline	Home group	-
19	Write down the final conclusion	Discussion	Communication	Online	Individual	Input Box
20	Discuss conclusions of all groups	Discussion	Communication	Offline	Whole class	-
21	Reflect on the activity sequence	Discussion	Reflection	Online	Individual	Reflection Tool

2.3.3 Offline activities

Offline activities must be done whenever this adds value to the learning process. Switching between online and offline activities can be done in any of the five inquiry phases (Orientation, Conceptualization, Investigation, Conclusion, and Discussion). For example, during the Investigation phase, you may let students in the expert group discuss offline assumptions for their experimental design.

During the Discussion phase, where students either reflect on former activities or communicate with each other, offline activities add value to the philosophy of student interaction in home and expert groups. Right from the first few steps of the activity sequence, an offline activity might be beneficial for students to brainstorm on the subject matter. Another time when an offline activity among students would be necessary, is to enable home group and expert group formation. In the latter case, students in their initial/home groups must be encouraged to discuss and decide the expertise they will be building on, so that all the variables under investigation will be distributed among experts.

A next point of attention during the expert work is when experts of the same expertise communicate the results and draw conclusions. The communication of experts takes place offline and they need to create valid conclusions and use enough evidence to support them. When experts return to their initial/home groups, another significant offline discussion occurs. In that case, each expert of a group should inform his/her peers about his/her conclusions, and then the home group needs to think critically about the validity of peers' results and draw the same overall conclusion.

2.3.4 When to use this scenario?

The jigsaw approach is to be employed when there are multiple variables and/or ranges of values of variables to be examined in order to adequately describe a phenomenon. In such cases, the jigsaw approach will distribute tasks across student groups, which will allow for handling a considerable number of variables in lesser time.

Further, the jigsaw approach is suitable when there is much variability expected in data collection procedures, so it would be advisable to have different student groups in order to be able to compare among these groups data they had gathered.

Additionally, the jigsaw approach increases interaction among students and catalyses the effect of collaborative learning. Interaction among students will also involve argumentation, when expert knowledge is diffused among students. In this regard, the jigsaw approach could support the development of argumentation skills.

2.3.5 Example ILS

The Jigsaw example ILS was created on the topic of [Ohm's law].

2.4 Six Thinking Hats

Edward de Bono's[3] *Six Thinking Hats* is a widely adopted creativity technique in various fields such as business management, education, and human-computer interaction. Essentially, *Six Thinking Hats* provides directions for adopting different modes of thinking, characterized by six coloured hats: White (neutral information), Red (feeling and emotion), Black (harsh critique), Yellow (benefit and optimism), Green (energy and freedom), and Blue (control and direction).

2.4.1 Inquiry phases and their sequence

For each of the inquiry phases, more than one coloured hat (i.e., mode of thinking) can be applied. Table 4 depicts which hats are relevant to which inquiry phases.

3 De Bono, E. (1999). *Six Thinking Hats*. Penguin.

Table 4
Six colour hats, focus of thinking and implication to Go-Lab inquiry learning phases

Thinking hats	Focus	Inquiry Learning Phases Applicable
	Facts, Figures Information	*Orientation, Conclusion, Discussion:* Call for information known and needed, which can be provided by a teacher, peers and other sources. Such information may need to be referenced for supporting discussion as well as conclusion.
	Intuition, Feeling & Emotion	*Discussion*: In reflecting and communicating experiences and insights gained in the learning process, students may express feelings and emotions (e.g., fun, pride, frustration, surprise) to make their points.
	Judgment & Caution	*Conceptualization, Investigation*: Spot the difficulties and risks; find out where and why things may go wrong. In formulating questions and hypotheses, it is critical to think about counterarguments and potential pitfalls.
	Logical Positive	*Conceptualization, Investigation, Conclusion*: Explore the positives and probe for value and benefit. Optimism (but remain alert to biases) sustains engagement in the process.
	Creativity & Alternatives	*Conceptualization*: Identify the possibilities, alternatives and new ideas; an opportunity to express new concepts and new perceptions.
	Overview Process control	*All phases*: It works as a control mechanism to ensure that the guidelines for different modes of thinking are observed. It is essentially a meta-cognitive strategy.

Normally this creativity technique is applied in a group setting. Participants can wear real physical hats or mental ones (i.e., by asking all group members to utter loudly together the colour of the hat or presenting the image of the hat in a way perceivable by all of them). To ensure that participants are aware of the specific thinking mode they are in, thereby thinking with the same focus, it is important that putting on and taking off hats are performed as explicit actions (i.e., gesturing or verbalizing the change of hat). Also, group members should use the same colour hat simultaneously. By switching hats, participants can refocus or redirect their thoughts and interactions (verbal as well as non-verbal). Furthermore, the hats can be used in any order that is deemed appropriate and can be repeated as many times as necessary to address the issue at hand.

Implementing *Six Thinking Hats* in the Go-Lab basic pedagogical model is relatively straightforward, as illustrated and described in Figure 5. Note that the teacher is required to orchestrate the process of switching hats, because it is a collaborative activity. However, if the class size is big, synchronizing the process may be somewhat difficult. Alternatively, the class can be split into smaller groups. For each group, a group leader is identified; he or she is responsible to coordinate the timing for changing hats and to ensure that members are applying the same focus to think about the issue under scrutiny.

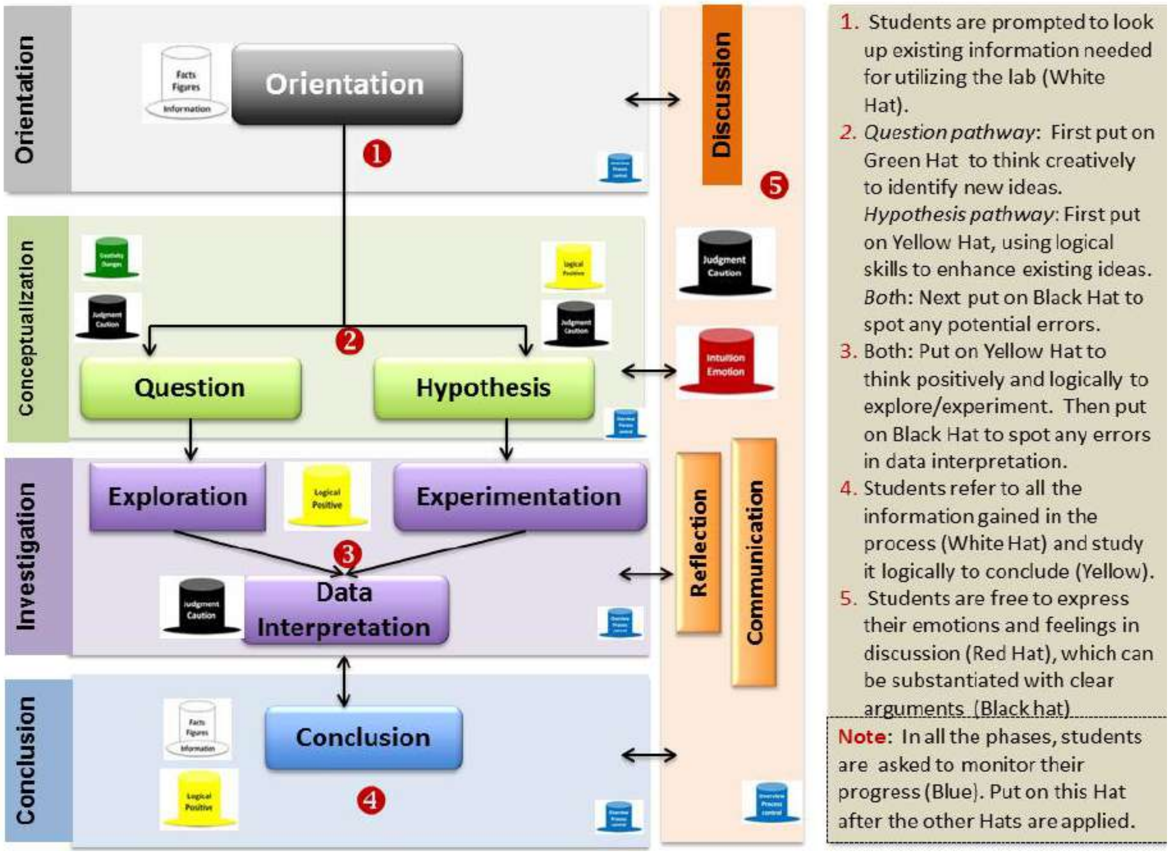


Figure 5. Example of applying Six Thinking Hats to the inquiry learning phases.

While Figure 5 illustrates which colour Hats are applicable for which inquiry learning phases, there is much leeway for a teacher (or a student group leader) to adapt the use of Hats based on the abilities as well as preferences of group members, the group dynamics, and certain situational factors.

As indicated in Figure 5 there are two pathways – Hypothesis (the right hand side path) and Question (the left hand side path), which imply the use of different colour hats or thinking modes. The choice of the pathway depends on the *student readiness*. The Hypothesis pathway should be selected if students have already identified all variables related to the topic of interest and they are ready to test specific hypotheses (i.e., the investigation phase). The Question pathway should be taken if students aim to explore the topic of interest without knowing exactly which variables are relevant or having any specific hypothesis to test.

Furthermore, while in most of the inquiry phases and sub-phases, the two pathways share similar patterns of hat usage (or thinking mode sequence), there are some unique cases. For instance, in the phase of Conceptualization, the Hypothesis pathway starts with Yellow Hat (logical thinking) followed by Black hat (judgment and caution) whereas the Question pathway starts with Green hat (creativity and alternatives) followed also by Black hat. Note that Blue hat is applicable in all phases to manage, monitor and control the related process, working as a kind of meta-cognitive strategy.

Table 5
Guidance per pathway and phase with the relevant coloured hats

Pathway	Phase/ Sub-phases	Description of guidance				
		Hats			Scaffolds	
Hypothesis	Orientation	White		Blue (Manage, Monitor and Control)	Note taking tool	
Question					Note taking tool	
Hypothesis	Conceptualization	Yellow	Black		Concept Mapper	Hypothesis scratchpad
Question		Green	Black		Questioning scratchpad	
Hypothesis	Exploration & Experimentation	Yellow			Experiment design tool	
Question		Green			Guiding questions	
Hypothesis	Data Interpretation	Black			Data viewer tool	
Question					Guiding questions	
Hypothesis	Conclusion	White	Yellow		Conclusion Tool	
Question						
Hypothesis	Discussion	Black	Red		Reflection tool	
Question						

2.4.2 Guidelines per phase

In the scenario above the full pathway is presented. However, it can be modified by leaving out some phases or focusing more or less on particular phases and/or scaffolds. In this section we present short guidelines on how to design an ILS for the Six Thinking Hats scenario and we do this per phase. For each phase we also indicate which tools are most appropriate. Shorter versions of these guidelines can be found in the “scenario ILS” as selected in Graasp.

The Hypothesis pathway is taken as the default scenario of Six Thinking Hat, given the assumption that a teacher typically provides students with a clear overview of the variables to be studied in an experiment.

Each student (or group of student) should be given a stack of six coloured cards with each showing the corresponding key feature of that coloured hat (Figure 6), serving as cues for reminding students of the thinking mode they are supposed to be in.

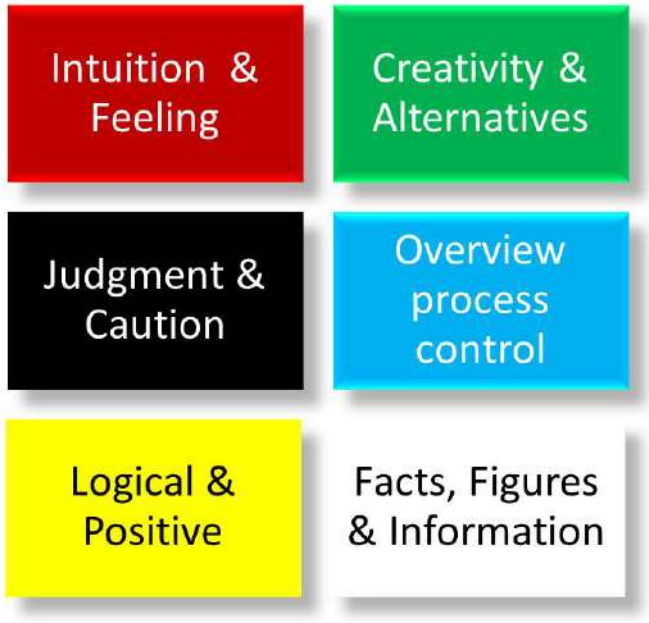


Figure 6. Six coloured cards showing the key features of the corresponding hats.

If the class size is about 15 or less, the teacher can orchestrate which hat to be taken for which phase/sub-phase by calling out aloud the colour of the hat that the students should "wear". The students then put the corresponding coloured card in a highly visible place to be conscious of the associated thinking mode. It is critical that the students are in sync, being engaged in the same inquiry phase with the same cognitive/affective process. If the class size is above 15, then the students should be divided into groups of five. For each group, a group leader is elected or appointed whose responsibility is to coordinate the change of hat, echoing the teacher's call out and displaying the card. To be qualified as a group leader, a student should be articulate and confident of delivering instructions to others. The class size of 15 is a recommended threshold: under or above which the hat-changing activities are conducted in plenum or in groups, respectively. Nonetheless, this threshold can vary, depending on the classroom setting and on students' preferences as well as behaviours.

ORIENTATION

In the Orientation phase, students are advised to put on their White Hat, implying that they should explore basic facts and information pertaining to the topic of interest. The teacher can provide students with several resources or ask students to locate such resources, for instance, school libraries, dedicated websites, YouTube videos, and TV documentaries. Students should read the resources identified to familiarize with the topic, preparing themselves for the following phases. To facilitate their understanding of the information in the resources, students are encouraged to use the note taking tool.

CONCEPTUALIZATION

Depending on the path to be taken, this phase starts with the Yellow Hat for the Hypothesis path and with the Green Hat for the Question path.

Hypothesis path: Wearing the Yellow Hat implies that students explore the key concepts related to the lab/phenomenon of interest, identifying its positive aspects, values and benefits (e.g., relevance to their everyday life; improved logical thinking skills). Nonetheless, students should be alert to potential biases, which can be mitigated through group discussions that may also help sustain their engagement in the process. In addition, two tools supporting the process are Concept Mapper and Hypothesis Scratchpad. Students should be asked to wear Black Hat when using either of the tools. Accordingly, they should be advised to analyse associated difficulties and risks, finding out where and why things may go wrong and how to remedy them. Upon completing a concept map or formulating a hypothesis, students should check it critically to identify any potential pitfalls or omission. The map/hypothesis created in this phase should enable them to work smoothly in next phase.

Question path: Wearing the Queen Hat implies that students be encouraged to exercise their creativity to identify new ideas. Based on the facts and information gathered in the Orientation phase, students can use the tool - Question Scratchpad - to build new questions for exploring alternative ideas. For the effective use of the tool, the following hint can be given: "Good questions can stimulate you to explore a certain topic. To construct a relevant question, you can use typical question words "how", "what", "when", and phrases like "if … then" "larger than" or "increase" to query possible relationships among variables." Similar to the Hypothesis path, students are asked to wear Black Hat to identify potential flaws.

INVESTIGATION

Exploration and Experimentation sub-phase:

Students following the Hypothesis path will be asked to wear the Yellow Hat (see the characterization of this Hat in the Conceptualization phase) and to use the Experiment Design Tool (EDT) for making a detailed plan for their experiments. Prior to this plan-making process, students should familiarize with the lab by, for instance, watching a video (cf. the Orientation phase).

Students following the Question path are asked to wear their Green Hat (cf. see the characterization of this Hat in the Conceptualization phase), instead of using EDT, students can be asked to think about the following questions: Which variable will you measure and why? Which variable will you change and why? Which variables do you need to control in your experiment and why?

Data Interpretation sub-phase:

Students are advised to wear their Black Hat, examining the data with critical minds. Specifically, students need to be cautious when judging whether the hypotheses/questions formulated can be verified/answered. Counterarguments should be considered. The tool Data Viewer can be used to look at the data automatically saved in EDT, thereby preparing graphs and analysing the relations among the variables investigated in the earlier phase. Furthermore, some guiding questions can be given to students to help them deduce the relations among variables. In case students do not have enough data, they should be prompted to return back to the Experimentation sub-phase to collect more.

CONCLUSION

In the Conclusion phase, students from both the Hypothesis and Question paths are asked to wear their White Hat followed by Yellow Hat, and subsequently put on one of them contingent on the need arising. The implication is that students need to revisit the facts and information studied in the Orientation phase and then evaluate logically positive and negative findings of the experiments. Students can use the Conclusion Tool to retrieve the hypotheses/questions, data, graphs and other related work achieved in the earlier phases. The tool can also help them prepare presentations to communicate their results.

DISCUSSION

In Discussion phase, for both Hypothesis and Question paths, students are asked to wear their Black Hat *with* Red Hat. The implication is that students should communicate their arguments and juxtaposition both positive and negative ones. This enables them to think critically about possible flaws. In reflecting and communicating their insights and experiences gained in the inquiry learning process, students can express their feelings (e.g., proud, amused, frustrated, surprised) to make their points. Students can use Reflection Tool to support their work in this phase. It is a tool that provides students with feedback on their usage of an ILS. Specifically, it displays the percentage of time a student has spent each of the inquiry phases as compared to a norm (to be set by their teacher). Students are then prompted to reflect on their ILS use pattern with some questions, for instance: Why have you spent a much longer time in a certain phase?

Note: In all inquiry phases, students always wear Blue Hat *together with* the other Hats. The implication is that students should monitor their own attitudes and behaviours to make sure that they observe the guidelines for different modes of thinking. It is essentially a meta-cognitive strategy.

2.4.3 Offline activities

For the Six Thinking Hat scenario, one critical thing is to familiarize students with the implications of each of the six coloured hats. The hats symbolize six thinking modes, which, however, are not entirely orthogonal; some students may get confused. To safeguard this risk, presenting examples and practices prior to the planned lab sessions are highly recommended. As this teaching approach is applicable to a broad range of domains, it is beneficial or cost-justifying to spend some time in training up students to acquire the technique. If some students are identified to be particularly skilful in applying the hats, they can be appointed as group leaders to ‘manage’ the hat changing process in their group. This is especially useful for a large class when synchronizing fifteen or more students is deemed difficult. Another preparation needs to be done is the six colour cue cards, which should better be laminated for long-term usage.

With regard to the inquiry process itself, offline activities should be conducted if time is allowed. The implications of the inquiry phases and sub-phases may not be intuitive to some students. It is strongly advisable that you explain them with appropriate examples in a physical lab and demonstrate how the applications in the physical setting can be transferred to its virtual counterpart.

2.4.4 When to use this scenario?

In fact, the Six Thinking Hats technique has been applied to teach STEM subjects (Childs, 2012; Garner & Lock, 2010) with several advantages being identified. In summary, it can:

- reflect the process of experimentation within STEM subjects;
- help simplify and hence provide focus on one process at a time;
- enable a collaborative group learning activity;
- provide a common language within a group, while removing ego and reducing confrontation;
- promote creativity and problem solving;
- stimulate diversity of thought and empathy;
- foster evaluation skills leading back to improving processes and testing new hypothesis.

This scenario is particularly powerful when it is applied in a class of *a relatively small size* (less than 15 students), because it entails the synchronization of hat changing and at the same time integration with the inquiry phases/sub-phases. As there are playful elements in the scenario - the hat changing process, the calling out of the teacher/group leaders, the colours of the hats already make the setting livelier than otherwise, it can be effective in building positive and enjoyable learning atmosphere as well as trust among the participants.

2.4.5 Example ILS

A Six Thinking Hat example ILS was created for the topic of Archimedes' principle.

2.5 Learning by critiquing

Learning by critiquing other persons' experimental approach is considered as a powerful way of learning and to be able to critique a research method is also seen as a skill that signifies that students master inquiry (National Research Council, 2000). To evaluate if a chosen scientific approach is appropriate for reaching specific conclusions is seen as a pivotal skill in real scientific work and also in student inquiry learning. Davis (2004, p. 92), for example, suggest to present students with prompts like "How good are the methods for this evidence ..?" There is proof that through critiquing a scientific method students acquire better inquiry skills (Linn & Eylon, 2006) and to present critique is therefore recommended as an explicit part of an inquiry learning cycle (see e.g., Sampson, Grooms, & Walker, 2011). The basic task that is presented to the learner in this scenario is to judge if the method used to test a hypothesis or answer a question in a presented study can be improved.

This scenario differs from the 'Find the mistake' scenario (see Section 0) that in the 'Find the mistake' scenario students have to critique an interpretation of a domain, whereas in 'Learning by critiquing" they have to critique a scientific method.

2.5.1 Inquiry phases and their sequence

The central and characteristic phase in this scenario is the "critical reflection" phase, here students are presented with an experimental set-up (in the form of a method section from a journal paper or a description of how a fictitious student would do the experiment) which they have to evaluate and to design their alternative approach. Before this, they are presented with the general approach in the ILS (Introduction) and they are given a (general and specific) orientation to the topic that includes reviving their prior knowledge. In the conclusion phase students have to draw conclusions from their own experiment and they can compare their results and approach with those of other students. These phases are summarized in Figure 7.

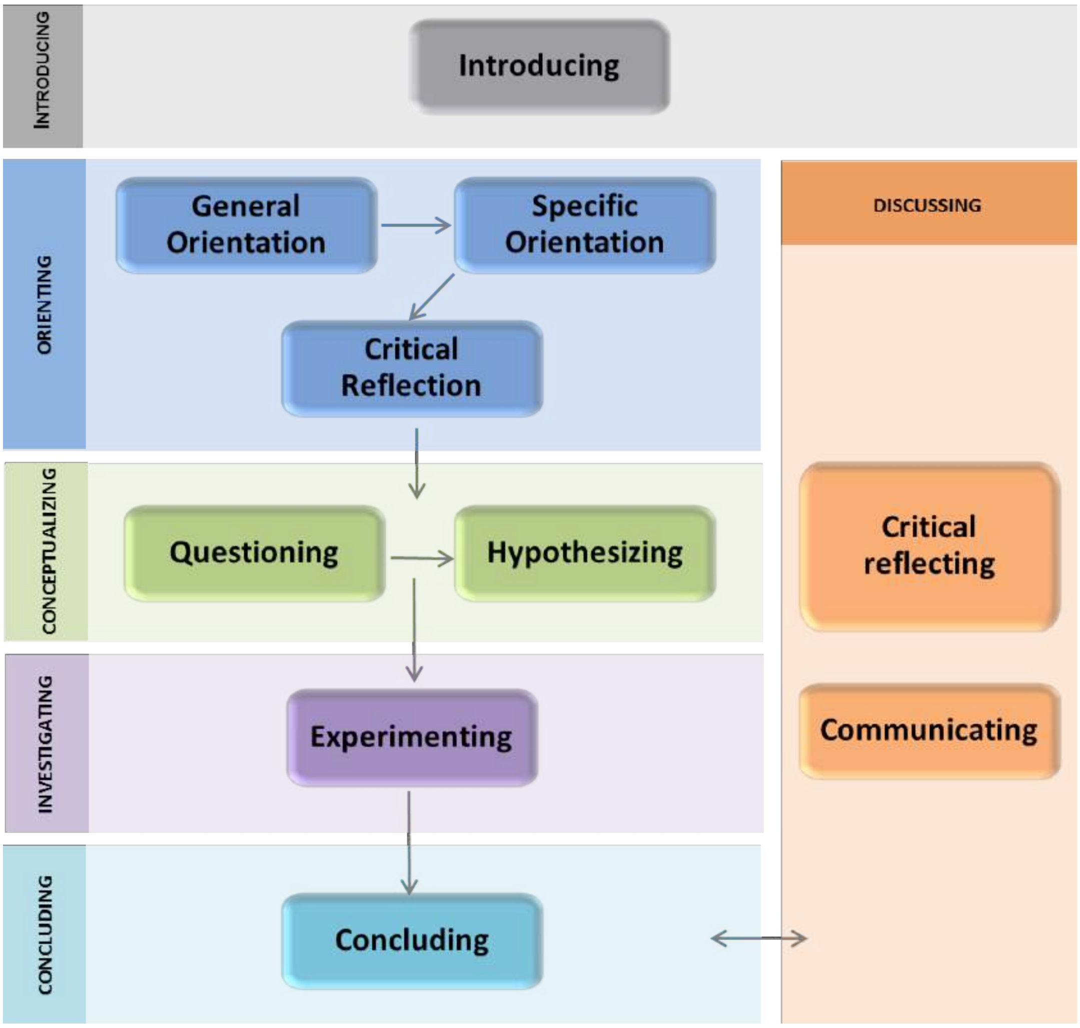


Figure 7. Overview of the Learning by critiquing phases.

Table 6
Example guidance for learning by critiquing

Phase	Sub-phase	Tool	Description of guidance
Introduction			*Explanation of learning goals, structure of the ILS and possible technical requirements.*
General Orientation		Free input field Concept map MC quiz	*Students receive a general introduction and their prior knowledge is recapped.*
Specific Orientation			*Here students are required to perform specific predictions using a lab or videos*
Critical reflection		Free input field	*An experimental set-up is presented that needs to be critiqued*
Investigation		Experiment Design tool Data Viewer Observation tool	*Students perform their own experiments which are alternatives to the presented ones*
Conclusion		Conclusion Tool	*Think about the data you collected, which data will help you to confirm or disconfirm your hypothesis?*
Discussion		File drop tool	*Reports are handed in and students can compare their own set-up and results with those of other students*

2.5.2 Guidelines per phase

In the scenario above the full pathway is presented. However, it can be modified by leaving out some phases or focusing more or less on particular phases and/or scaffolds. In this section we present short guidelines on how to design an ILS for the basic scenario and we do this per phase. For each phase we also indicate which tools are most appropriate. Shorter versions of these guidelines can be found in the "scenario ILS" as selected in Graasp.

INTRODUCTION

The function of the introduction is to equip the students with the overall goals and structure of the work that lies ahead. Here, also more practical requirements can be listed.

The intro contains:

- The learning goals of the ILS. These learning goals are aimed at knowledge about the domain ("Gain knowledge about the chemistry of acids and bases and on the process of diazotation") or at skills ("Measure accurately, determine whether measurements are reliable"). In the Learning by Critiquing Scenario one of the goals should always be to be able to judge the quality of an experiment set-up.
- The structure of the ILS: The phases students will go through and their function should be briefly explained
- The (technical) requirements for running the ILS

For example if specific plug is are needed to run the specific lab that is explained here, possibly with a link to a page where the plugin is explained.

GENERAL ORIENTATION

The function of this phase is to give students an introduction to the general topic and to activate their (prior and new) knowledge.

The introduction can be done by

- a video, from YouTube or you can record your own video in which you personally explain the general topic.
    - a brief text
    - a link to specific web page.

Activation can be achieved by letting students:

- write a summary of what they have seen or read in the introduction (you can use a free input text field or let students upload a file)
- create a concept map. For students with less prior knowledge you could also provide them with a partly finished concept map. (you can explain the concept map as follows: "A concept map is a visual representation of your thoughts, information and knowledge. A concept map contains concepts and relationships between these concepts that are visually represented by means of arrows and colours.
- perform a brief multiple choice quiz on the topic.

SPECIFIC ORIENTATION

The function of this phase is give the students direct information on the specific topic of the ILS and raise the students' curiosity which can be done by asking them to make specific prediction and then let them compare their answers with the "correct" answers.

This phase may consist of the following components:

- A brief text/video explain the specific topic;
- A question (or more questions) that ask(s) students to predict what will happen in a specific case followed by a video and/or example lab in which students can check if their predictions were correct;
- An interactive app that allows students to explore the topic (if this app is available).

CRITICAL REFLECTION

The function of this phase is to let students think critically about a given experimental set-up.

This experimental set-up can be presented in the form of a:

- scientific paper of a study on the domain of the lab
- a description of a set of experiments that you have made yourself (and in which you introduce a number of characteristic mistakes).

After having read this experimental set-up, you can ask your students some of the following questions:

- What variables are used in the set-up of the presented study? What is/are the independent variable, the dependent variable(s) and the control variable(s) in the experiment?
- Did the researchers forget any control variables? If so, which ones?
- Did the researcher(s) choose the adequate values for these variables when conducting the experiment? Make these questions very specific for your students. (For example, did Haenen et al. choose a suitable temperature?)
- Did the researcher(s) use the correct measurement procedure? (For example, did they read off the graph to a correct significant figure?)
- Did the researcher(s) use the correct number of measurements,

After each question you can give a free input text field. You may consider providing students with the correct answers after they have attempted to answer those themselves. You can do so for example by including a link to a webpage with the answers at the end of this phase.

Classroom organization:

You may consider letting students work in pairs when answering the questions above. This will help them in the process of critical reflection.

INVESTIGATION

In this phase students will perform their own investigation. Ask your student to make a plan and tell the students that they need to think carefully how you can test if your hypothesis is correct or not and or how to give a concrete answer to the research questions.

In making a detailed research plan students can use the Experiment Design Tool . Before they start using this tool you can ask them to consider the following questions:

- What variable are you going to measure? In other words: what is your dependent variable? Please explain why you choose this variable;
- What variable are you going to change? In other words: what is your independent variable? Please explain why you choose this variable;
- Which variables and factors do you need to control - keep constant - in your experiment? In other words: what are your control variables? Please explain why;
- Do you need repeated measurements? Explain why (not).

After having filled in the EDT you can present the lab here to the students. Results from the students experiment are, depending on the lab, saved in a format that can be used by the Data Viewer. If you do not wish or cannot use the data viewer you can ask students to note down what they see in their experiments in the Observation Tool.

CONCLUSION

In the conclusion phase students draw conclusions from their experiment(s). For this they need to combine their research question(s) and /or hypotheses with their data and observations.

When you have included the data viewer and/or observation tool in the previous phase you can use the Conclusion Tool.

DISCUSSION

In the discussion phase students are asked the report their findings.

The format students should use to report their finding can be adapted to your students and to the time you have available. One suggestion is to let your students write a "scientific" paper like in the example ILS about Methyl Orange. They can do this in any editor they wish (e.g., Word) and upload this via the file drop tool. But you can also choose to let your students give presentations or organize a group discussion.

As an add-on you can ask your students to swap their article with another group and give comments to each other. Here you can suggest your students to examine if:

The (in)dependent variables are visible in the inquiry question.

- All relevant control variables are considered;
- The observations are accurate;
- The results are well presented;
- The right calculations are made;
- The discussion and conclusions are valid..

2.5.3 Offline activities

After the Orientation phase the teacher could discuss topics like reliability, validity and errors in measurements. Furthermore the working of the equipment can be elaborated.

After the Conceptualisation phase is finished by the students, one could consider a classroom discussion in which the questions that have to be answered in this phase can be discussed.

After the review in the Discussion phase one could implement a session with the tutor to see whether (s)he agrees with the comments that were given.

2.5.4 When to use this scenario?

Use this scenario to make students aware of the processes related to scientific reasoning and reporting, the specific topic is secondary although students will also learn (better) about the topic at hand. This scenario is mainly meant for more advanced (older) students but if the experiment set-up is very simple also younger students can follow this scenario.

2.5.5 Example ILS

An example ILS on the chemistry domain of methyl orange can be found here: http://graasp.eu/ils/561b7cb5b8fd4d2280c74225/?lang=en

Also, an example ILS for the domain of buoyancy is available.

2.6 Structured Controversy

This scenario is inspired by the *Structured Controversy with Role Playing* (SCRP) scenario found in the SCY project Scenario Handbook (http://scy-net.eu/scenarios/index.php/Collaborative_Controversies) see also Weinberger, et al. (2011). In the SCRP scenario a teacher structures a controversy between a technological innovation and its potentially harmful societal effects. The students are then guided to examine the pros and cons of the issue, asked to role play one side, debate with the opposing side, and finally search for a compromise solution. In the process of examining the issue students improve their meta-skills and domain specific knowledge.

In a Go-Lab adaptation of the SCRP scenario we first had to acknowledge that online laboratories are often well-structured environments that yield a single "correct" answer when an appropriate algorithm is followed. This is in contrast to socio-scientific problems, which are generally ill-structured, open-ended and may have multiple possible solutions. Therefore, in order to integrate a socio-scientific issue into the Go-Lab experience the Structured Controversy scenario divides the learning activity into two parts. In the first part students are introduced to a controversial topic and are directed to work individually in the online Go-Lab inquiry learning environment to acquire evidence-based scientific content knowledge about the topic, as well as improve their skill to support arguments with empirical evidence. In the second part of the Structured Controversy scenario the controversial issue is structured into a debate format with only two sides to the argument. Students are split into opposing teams to argue the topic. The teacher acts as a neutral debate moderator who holds the teams to time limits and tries to keep the participants from straying off topic. At the end of the debate the teacher allows time for a collaborative group discussion about ways to resolve the debate by searching for a compromise solution.

It is likely that arguments made during the debate part of the Structured Controversy scenario do not rely on data collected and analysed during the online experimentation part. This is acceptable since a key objective of the first part of the scenario is to cultivate in students an awareness that convincing arguments come from solid evidence and reasoning. In the second part, it is important that the controversy is structured to allow for a compromise solution, since a key objective here is to promote civil discourse and a willingness of students to search for compromise solutions.

Overall, the combination of two parts allows the Structured Controversy scenario to improve essential student skills in inquiry, critical thinking, argumentation, reflection and teamwork.

2.6.1 Inquiry phases and their sequence

Inquiry phases are sequenced similarly to the basic scenario that was described in Section 2.2. Considering this the learning goes through five main inquiry phases. Orientation, Conceptualization, Investigation, Conclusion and Discussion. But there is an additional phase—Debate—that changes the sequence of inquiry phases described in the Go-lab basic scenario. The sequence of inquiry phases in this scenario are: Orientation, Conceptualization, Investigation, Conclusion, Debate and

Discussion. If other phases are described several times already in the previous and current deliverable then Debate is first time mentioned. Debate is a teacher moderated phase. Since the phases other than debate follow very closely the traditional Basic scenario, teachers can use the guidelines presented in Table 1, if they want to adapt specific tools (e.g., the hypothesis scratchpad).

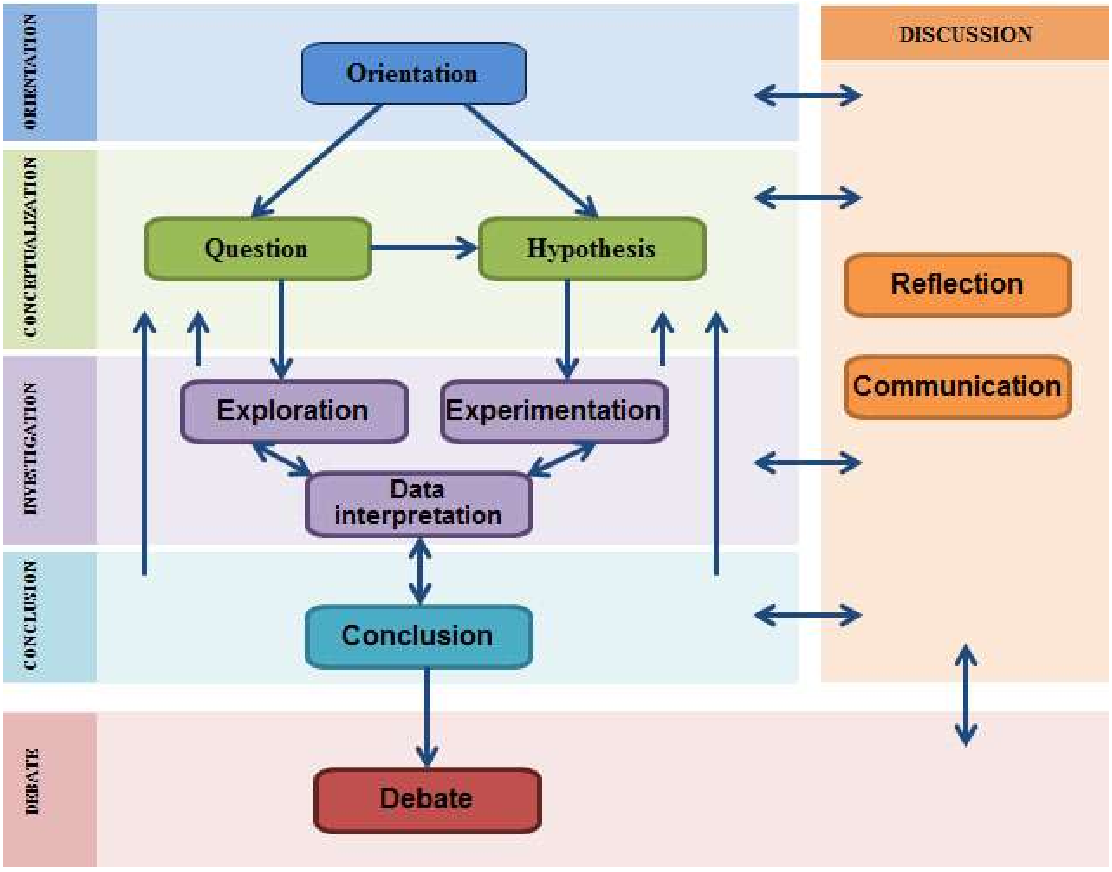


Figure 8. The inquiry cycle for the Structured Controversy scenario.

2.6.2 Guidelines per phase

In the scenario above the full pathway is presented. However, it can be modified by leaving out some phases or focusing more or less on particular phases and/or scaffolds. In this section we present short guidelines on how to design an ILS for the Structured Controversy scenario and we do this per phase. For each phase we also indicate which tools are most appropriate. Shorter versions of these guidelines can be found in the “scenario ILS” as selected in Graasp.

ORIENTATION

The Orientation phase is where students not only get an idea about the topic to be investigated but are also introduced to the problem to be solved. Orientation is focused on stimulating students' interest and curiosity towards the problem at hand. The Orientation phase is also used to activate students’ prior and new knowledge.

In the context of the Structured Controversy scenario the Orientation phase introduces relevant domain knowledge that relates to the controversial socio-scientific issue. In designing this phase you can:

- Choose a title for your ILS that is in the form of a Yes/No question. The Structured Controversy requires an arguable topic that can be debated by two opposing sides. A title with a Yes/No question already anticipates the Debate phase which will occur in the second lesson.
- Anticipate what a reasonable compromise position looks like and check that the two opposing sides have a fair chance of equally contributing arguments towards this compromise. Sometimes it might be necessary to polarize the debate topic (e.g. "Should dangerous household chemicals be banned?" rather than "Should dangerous household chemicals be regulated?") in order to balance the two sides and allow them to both contribute to a compromise solution.
- Relate the controversy to a relevant social context. When people think of controversial topics in science they usually think of media stories related to risks to human health or the environment. For example, a physic lesson on motion and forces could suggest debate topics such as "Should the maximum highway speed limit be set to 80 km/h (50 mph)?" or "Should bridges be routinely inspected?" Remember that in the Structured Controversy scenario the first lesson introduces domain knowledge as well as the inquiry approach, while the second lesson provides students with the opportunity to connect science to the needs, values and expectations of society.
- For students unfamiliar to the inquiry approach, the Structured Controversy scenario can be presented in a narrative story format involving fictional characters who have to solve inquiry problems. Students are invited to help the fictional characters solve these problems. (see the example ILS Should dangerous household chemicals be banned?).

Activation of prior and new knowledge can be achieved the same way as in the Basic scenario. For example, the QuizMaster app and Input Box app can be used to prepare questions for students and the Concept Mapper app to prepare a partially finished concept map. Alternatively, the Orientation phase can introduce a problem(s) and unresolved questions through the narrative story format involving fictional characters.

CONCEPTUALIZATION

In the Structured Controversy context the Conceptualisation phase can follow the same design as in the Basic scenario (i.e. applying the Question Scratchpad or Hypothesis Scratchpad apps) or alternatively follow narrative story format.

When designing the Conceptualisation phase using the narrative story format you can:

- Briefly introduce the online laboratory and allow students to freely play with it. Students have a chance to see which variables can be changed, which variables can be measured or observed, and which variables affect each other. They can use this information, in connection with their prior or new knowledge, to formulate research questions or hypotheses.
- For novice learners it may be necessary to explicitly provide research questions to students. You can then explain that the fictional characters have formulated research questions together with the help of their school teacher and now they must perform experiments to answer these questions.

- Emphasize should be placed on identifying potential causal relationships between variables and how experimentation can provide evidence to justify these relationships. In the Structured Controversy debate good arguments will rely on convincing evidence for support and students should learn to identify the structure of good arguments.

INVESTIGATION

In the Structured Controversy context the Investigation phase can follow the same design as in the Basic scenario (i.e. appropriate use of the Experiment Design Tool, Observation Tool, and the Data Viewer) or alternatively follow the narrative story format.

When designing the Investigation phase using the narrative story format you can:

- Introduce a pseudo-controversy between your fictional characters that students must resolve through experimentation. For example, the fictional characters may disagree over two conflicting hypotheses and students use the Hypothesis Scratchpad to choose the correct hypothesis, while controlling its validity by conducting experiments with the online lab.
- Introduce an incomplete hypothesis by your fictional characters that your students must complete by conducting experiments with the online lab and using the Hypothesis Scratchpad to enter the correct hypothesis.
- Have your fictional characters identify the necessary terms to formulate a hypothesis but allow students to put together these terms using the Hypothesis Tool and test the hypothesis by conducting experiments with the online lab.
- Emphasize should be on drawing attention to the fact that hypotheses require experimental verification and that arguments which *feel* right may prove to be wrong after experimentation.

CONCLUSION

In the Structured Controversy context the Conclusion phase can follow the same design as in the Basic scenario (i.e. appropriate use the Conclusion Tool) or alternatively follow the narrative story format.

When designing the Conclusion phase using the narrative story format you can:

- Use the Conclusion Tool to summarize the various pseudo-controversies or problems that the students helped the fictional characters solve in the Investigation phase. Here you can relate the results to the research questions posed in the Conceptualisation phase.
- Review the inquiry skill of collecting relevant experimental evidence to make justified conclusions that answer scientific research questions. Remind students to always remain critical about arguments when evidence is lacking.
- You can end the Conclusion phase by instructing students to prepare for the Structured Controversy debate. Remind them of the debate question which should be in Yes/No form. Connect the domain knowledge they just learnt with how it will inform them in their debate.

DEBATE

The Debate phase is specific to the Structured Controversy scenario and is where students argue over a controversial issue under the moderation of a teacher. In the debate students are split into two teams and work together to present their arguments following a prescribed debate format moderated by the teacher. After the debate the teacher allows time for collaborative group discussion about ways to resolve the controversy with a compromise solution.

When designing the Debate phase you can:

- Have students prepare for the debate using the Padlet app as a homework assignment. Although the debate occurs offline you may want to assign an online homework task where students can prepare their arguments in advance. For this task the Padlet app can be used to allow team members to collaborate to construct their arguments together.
- Provide students with an example debate format so that they know how it will be conducted in practice.
- Provide tips to students that describe good debating techniques using the example text:
    - *Refer to and cite significant facts, quotes, and sources to support your position.*
    - *Anticipate your opponents' arguments beforehand and find potential weaknesses.*
    - *Keep your emotions under control and stay focused during the debate.*
- Moderate the debate time very strictly in order to ensure that the entire debate format can be completed during the lesson period.
- If arguments stray off-topic for too long then interject and redirect the discussion back to the original point or move on to the other team's response.
- If a team is having trouble rebutting then help by pointing out weak points in an argument and prompt them to comment.
- In general, help teams refine their arguments, elicit rebuttals and keep the discussion from straying off-topic.

DISCUSSION

The Discussion phase can more or less follow the design in the Basic scenario (i.e. reflective questions about the inquiry process and its outcomes). In addition, questions about the Structured Controversy debate can be included as follows:

- *Which argument from the opposing side did you find most convincing and why?*
- *What do you think you should do differently and similarly next time when you engage in a debate?*
- *What debate techniques did you witness that were effective? Ineffective?*

2.6.3 Offline activities

The debate occurs offline. An example 40 minute in-class debate format is shown in Table 7.

Table 7
Debate format for the Structured Controversy scenario

	TEAM	ACTIVITY	TIME (MINUTES
Preparation			
	BOTH	YES team members meet with each other and discuss which arguments to present and who will present them. NO team members meet with each other and do the same.	5
Opening statements and clarification			
	YES	Presents opening statements using three arguments	5
	NO	Asks any clarifying questions	2
	YES	Presents opening statements using three arguments	5
	NO	Asks any clarifying questions	2
Rebuttal (No new arguments presented)			
	YES	Repeats their opponents' arguments and tells what is wrong with the positions	3
	NO	Repeats their opponents' arguments and tells what is wrong with the positions	3
Summary			
	YES	Summarizes their position by speaking to their opponents' counterpoints and closes with why their argument is best	3
	NO	Summarizes their position by speaking to their opponents' counterpoints and closes with why their argument is best	3
Resolution			
	BOTH	Both teams seek to resolve the dispute through a compromise	5
	BOTH	The compromise is discussed with the teacher	4
		TOTAL	**40**

This scenario needs more teacher attention and thus gives teacher a bigger role in the whole learning process. In general, teachers' first role is to guide students if they meet a problem with a specific inquiry phase and secondly teachers are moderators in the Debate phase.

2.6.4 When to use this scenario?

This scenario is well suited for initiating student collective discussion on a controversial issue. In the case of an actual socio-scientific issue, this scenario promotes examining a controversy from both a scientific and ethical position. Even if the controversy is apparent, this scenario promotes active collaboration among students to find a compromise solution. It encourages learners to share their thoughts and ideas about a topic, support a position using evidence, listen to the arguments presented by an opposing side and finally work together to find a compromise solution.

2.6.5 Example ILS

The Structured Controversy scenario usually includes two ILSs in order to allow students debating the pro-side to prepare independently from students preparing for the con-side. These two example ILSs were created in the domain of chemistry.

2.7 Find the mistake

In inquiry learning students are asked to start from an idea (question, hypothesis) that they generate themselves. Another approach is to let students start from an idea from someone else (who of course can be a fictitious person). This (fictitious) person may have a wrong idea that then needs to be corrected. This approach can be very powerful since it give students a concrete starting point. Wijnen (2014), for example examined students who worked with a modelling tool and compared three groups of students who were involved in learning a biology topic (the glucose regulation of the blood). The first group could simulate a correct model, the second group had to complete an incomplete model, and the third group had to correct errors in a model. Wijnen (2014) found clear indications that correcting errors was the most successful approach.

Despite these advantages experimental studies not always show these advantages (for an overview, seeWijnen, 2014). It is therefore important to identify the circumstances that makes learning from mistakes a fruitful approach. McLaren et al. (2012) analysed research on learning from errors and describe three condition to make this approach successful. First, the errors should come from someone else, who could be a fictitious person. As these authors state, having to correct errors from your self can be confronting and embarrassing. Förster-Kuschel, Lützner, Fürstenau, and Ryssel (2014) assumed that learning from own mistakes is less effective than learning from other's mistakes because own mistakes are attributed to external causes and other's mistakes are studies intensively and used to avoid similar mistakes oneself. They investigated this in students who had to correct erroneous concept maps and found this effect to be trend wise supported. The fact that people learn from other's mistakes is also confirmed in brain research (Howard-Jones, Bogacz, Yoo, Leonards, & Demetriou, 2010). Second, to be an effective approach according to McLaren, et al. (2012), student should be asked to be active in correcting the errors and they should receive feedback. In this context, Chang and Chang (2012) provide students with prompts to give critique but also with predefined sentences of critique to bootstrap the process. Third, errors that are introduced should represent errors that students often make, so they should be characteristic misconceptions.

2.7.1 Inquiry phases and their sequence

The inquiry phases of “Finding the mistake” (see Figure 9) resemble those of the basic scenario, what differs is their content.

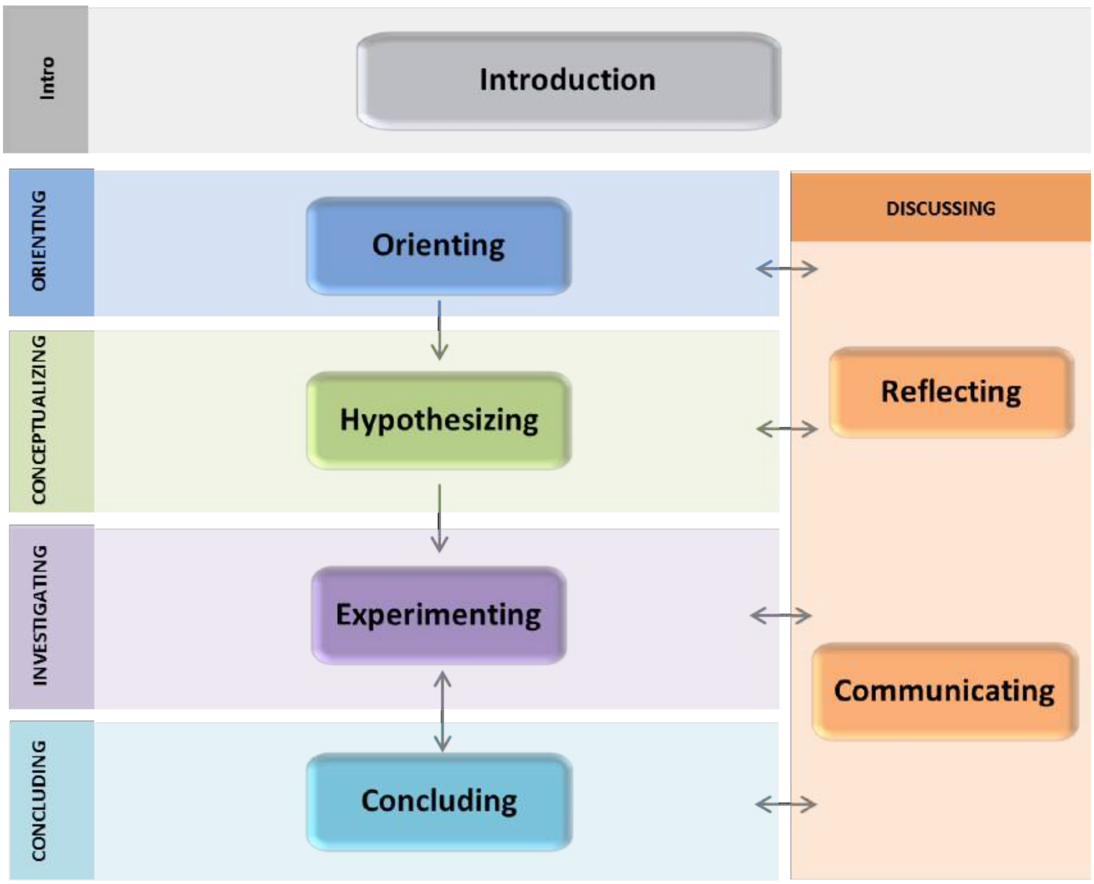


Figure 9. The inquiry phases for find the mistake.

Table 8 close summarises the main characteristics of each phase and the tools (apps) that are suggested.

Table 8
Example guidance for the Finding the Mistake scenario

Phase	Sub-phase	Tool	Description of guidance
Introduction			*Students are informed that will work with mistakes of others*
Orientation		Open text field Quiz	*Student get a general idea of the domain and prior knowledge is refreshed*
Conceptualization		Hypothesis Scratchpad	*The misconceptions of the fictitious person are presented and students are requested to 'translate' these misconception in the hypothesis scratchpad.*
Investigation	Experimentation	Observation tool	*Students check the hypotheses based on the ideas of the fictitious student by performing experiments in the lab*
Conclusion		Conclusion Tool	*Students decide on the hypothesis on the basis of their data.*
Discussion	Reflection	Free text format File upload Concept map	*Students reflect on why the fictitious student could have made this mistake. As an alternative you can prepare a concept map with the mistakes of the fictitious person and ask the student to correct this concept map.*

2.7.2 Guidelines per phase

In the scenario above the full pathway is presented. However, it can be modified by leaving out some phases or focusing more or less on particular phases and/or scaffolds. In this section we present short guidelines on how to design an ILS for the basic scenario and we do this per phase. For each phase we also indicate which tools are most appropriate. Shorter versions of these guidelines can be found in the "scenario ILS" as selected in Graasp.

GENERAL

Learning from mistakes is meant for students who have basic knowledge of the domain but still may have some misconceptions.

INTRODUCTION

In the introduction phase you can prepare students on the task ahead. In learning from mistakes this means that you can tell the students that they will need to find mistakes in the work of others.

You may start with a proverb like:

- In Russian there is an expression: *The wise man learns from someone else's mistakes, the smart man learns from his own, and the stupid one never learns*.
- The only real mistake is the one from which we learn nothing. *John Powell*
- Experience is simply the name we give our mistakes. *Oscar Wilde*

ORIENTATION

In the orientation phase you introduce the domain to the students. Often you will show how the theories within the domain can be applied in practice, giving some real world examples. You can use some videos that show the phenomenon in a real situation for example.

In the orientation phase you can also help the students to revive their relevant prior knowledge. This can be done by asking them some questions and let then fill in an open text field or by presenting them a quiz or you may point to some other more basic ILSs that have treated the phenomenon.

You may choose to already introduce some “mistakes” here but you may also do so in the conceptualisation phase.

CONCEPTUALISATION

In the conceptualisation phase you introduce the “mistakes. You can do so by introducing one or more fictional student(s) who explain a situation in the domain (if you give these students a name don’t choose names of students already in your classroom). This explanation will contain mistakes. The best would be if you could base these mistakes on known misconceptions in this domain. Your students will need to find and correct these misconceptions that may also be their own.

An alternative is to present a number of “ideas” of which one is correct and the others are based on misconceptions. The task of your student is to find out who (if you use fictional students) is correct.

You may then ask the students to “rewrite” these misconceptions into hypotheses using the hypothesis scratchpad. Based on the skills of your students, you can choose to prepare the hypotheses yourself and offer them ready made in the scratchpad, present partly finished hypotheses that your students need to complete, or let your students prepare the hypotheses on their own. Do not forget to adapt the terms in the scratchpad to the domain in the ILS.

INVESTIGATION

In the investigation phase you introduce the lab and ask the students to check if the hypothesis or hypotheses hold that you prepared or that they created on the basis of the mistakes of the fictitious student hold. You may want to repeat these hypotheses here.

Ask the students to write down what they have found in their experiments, preferably in the observation tool.

You may let the students test the mistakes in one investigation phase or you may create one tab for each mistake (or correct idea) and the related investigation.

CONCLUSION

In the conclusion phase you let the students decide on which of the “ideas” is the correct one or let them decide on the value of each idea and related hypothesis. You can use the conclusion tool here or you can use an open text field to let students fill in their conclusions. Also ask student to write down the evidence they have found in favour or against each presented idea.

DISCUSSION

In the discussion phase you can ask students to reflect on why they thought the fictional student made this mistake. This demands deep knowledge of the domain from your students.

An alternative is to ask the student to explain to the fictional student why this student was wrong and how he or she should correct his or her ideas. You can use the free text format field or the file upload app here.

An another way to let students reflect and think again on what they found is to present them with a concept map that has similar mistakes (you need to prepare this concept map yourself) as the ones introduced at the start and ask them to correct this concept map. In this way students have to rethink the mistakes again in another format.

2.7.3 Offline activities

This scenario has no specific offline activities.

2.7.4 When to use this scenario?

This scenario can be used when it is known that in a domain students have very specific misconceptions that need to be repaired. In principle it could be used by students who have prior knowledge (including misconceptions) but also by students who are pretty fresh in the domain. In the latter case the “mistakes” need to be really embedded in more extensive domain information but students can then start exploring a domain through concrete false ideas which gives them immediately a right track. In the latter case more support in the form of (partly) designed experiments is needed. This scenario is merely focused on acquiring conceptual knowledge and the understanding of that knowledge.

2.7.5 Example ILS

There are two example ILS for this scenario.

One on electricity: http://graasp.eu/ils/55f80694b8fd4d2280c73f68/?lang=en

and one on “gears”: http://graasp.eu/ils/55f80694b8fd4d2280c73f68/?lang=en

3 Tips & Tricks

These T&Ts can also be found online at: http://go-lab-project.eu/tips-tricks. T&Ts are constantly updated and extended.

3.1 Inquiry is more than a set of prescribed steps

One of the key characteristics of inquiry learning is that students have to find out something themselves, an investigation is always the backbone of an inquiry process. As part of the student's initiation and guidance, it may be a good idea to include a much guided, structured, and step-by-step, exercise, but inquiry also means that student-led investigations are present. Therefore, an ILS should not be a mere sequence of step-by-step instructions for the student to follow like a recipe cookbook. There must be an inquiry aspect where the student searches for and tries various possible solutions. It is ok if the student initially fails and repeats a process. So, instead of telling a student which values to fill in for each variable, students should find out themselves what are the interesting values to use; of course, you can give them predefined experiment to follow (and you can define those experiments in the Experiment Design Tool), but there should be freedom for students as well.

3.2 Prior knowledge of the students

If an Inquiry Learning Space (ILS) is used in a stand-alone version, care must be taken that students have the necessary background knowledge and understand all the terminology that is used in the ILS. If this is not the case, this information can be given concurrently with the ILS. There are a few options to do this:

- In the orientation and conceptualisation phase, necessary prior domain information can be directly displayed (as text, diagrams, videos, etc.).
- Internet links to background information can be included in each phase (using the insert link icon), some permanent information can also be displayed under the tools bottom bar.

3.3 The place of information and the lab

Learning with online labs generally means that there is an interaction between extracting information from the lab itself and learning with other, more direct resources. Basically there are two standpoints:

- Labs and/or simulations are best used before other instructional materials (online resources, books, lectures), so that students are sensitive for the information to extract from the expository material.
- Before learning with an online lab, students should have sufficient knowledge to profit from their lab experiences.

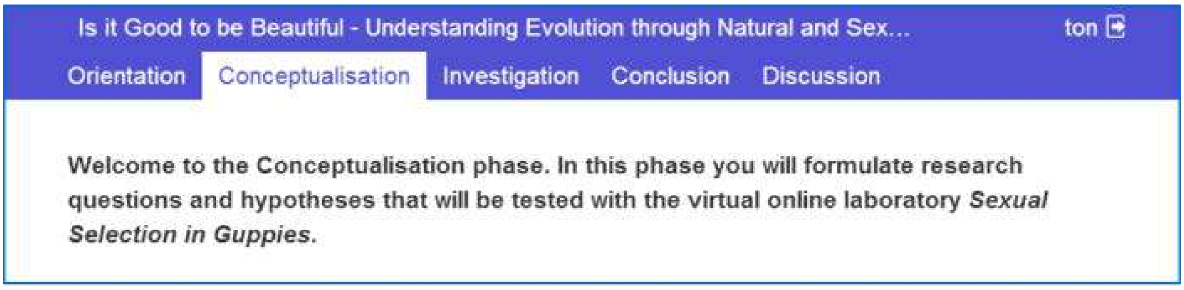
As a general recommendation, it seems appropriate to use both approaches. This can be achieved by giving a brief preview of the lab in the orientation phase, so that students can make themselves familiar with the lab and get sensitive for the issues they need to find out. In the conceptualization phase, background information can be presented. This can be done directly in the conceptualization phase by linking to other web sources, or offline in a lecture. In the investigation phase, students then return to the lab and make their full inquiry.

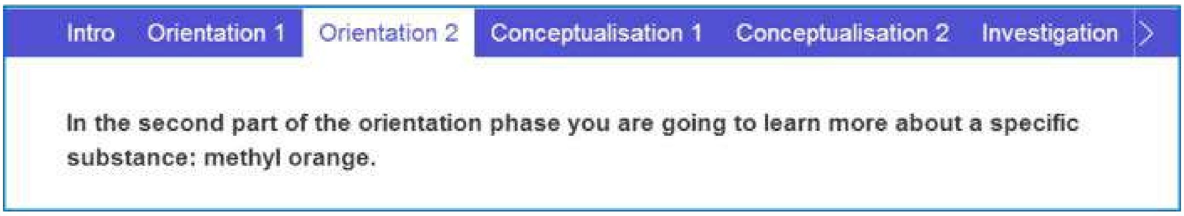
3.4 The introduction tab

The Inquiry Learning Space (ILS) can start with an information tab that tells the students what to expect and explains them the learning goals and structure of the ILS (see the figure below for an example). The difference with orientation phase is that in the orientation phase the prior knowledge of the students is revitalised, the main concepts of the domain are introduced and a general problem statement is given. The Intro phase is not there by default, so if you like to include it you have to create this phase yourself in the Go-Lab authoring environment Graasp (please see the Tips “You can change the phases of the inquiry cycle” and “Naming of the Inquiry Phases”).

3.5 Explaining an inquiry phase

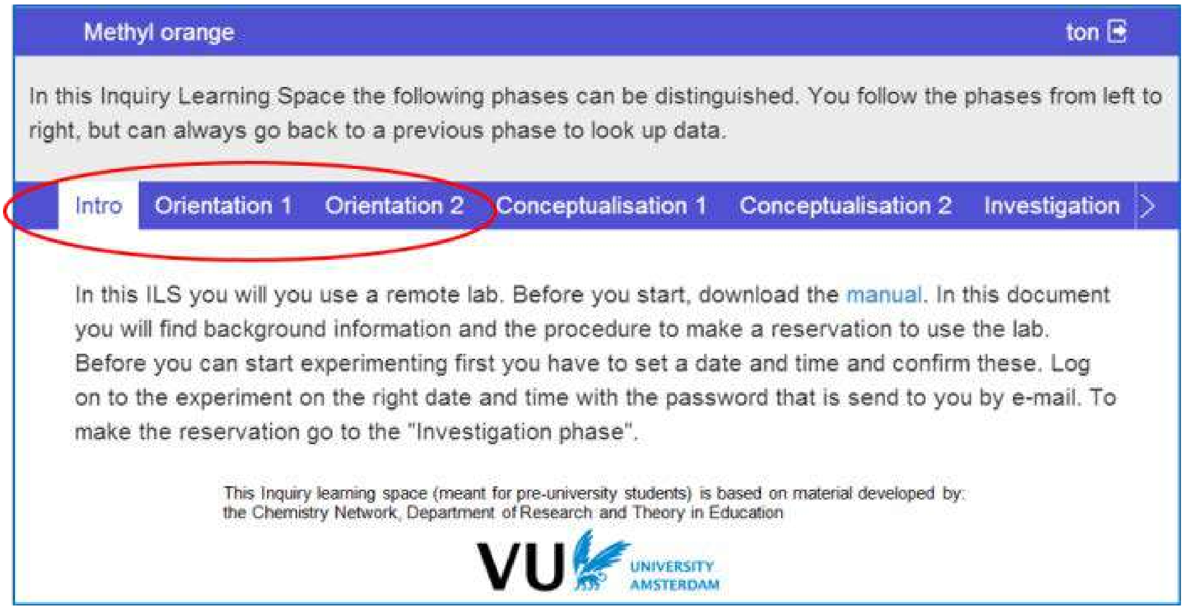
Introduce the main goals and expectations of each inquiry phase at the beginning of the phase.



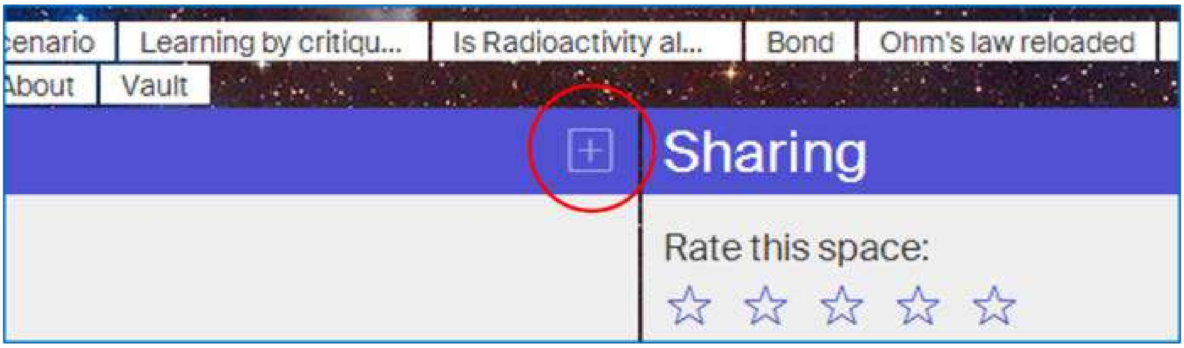


3.6 You can change the phases of an inquiry cycle

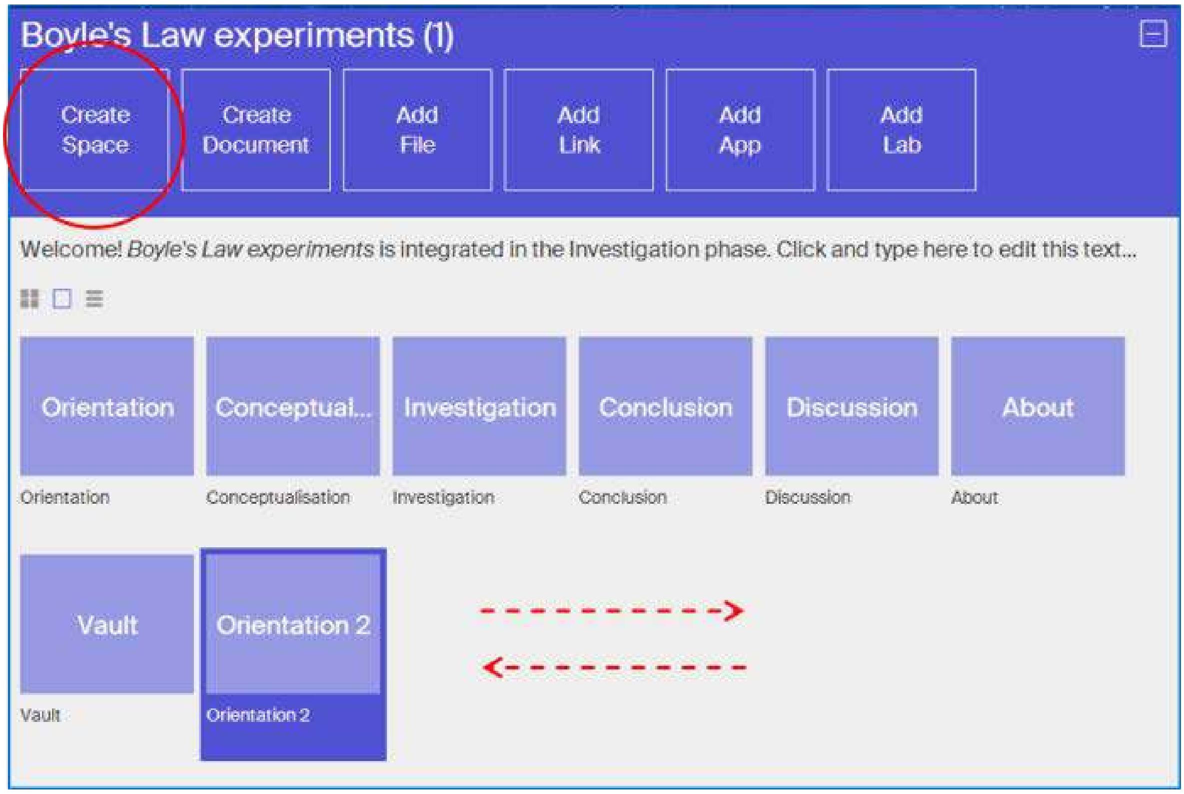
When you create an Inquiry Learning Space from a lab, Go-Lab offers you a set of predefined phases. You can add phases as you like and also rename them as you like (please see the Tip “Naming of the Inquiry Phases”). See this ILS as an example:



Adding a phase can easily be done by clicking the “+” sign in Graasp (the Go-Lab authoring environment).

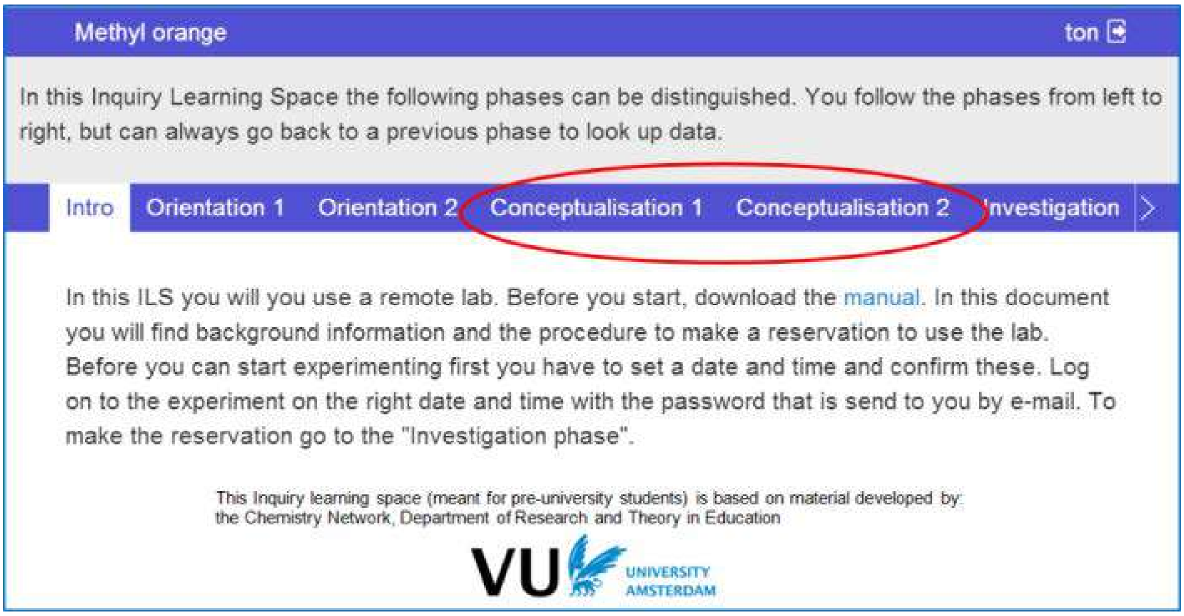


Then use the create space button. Order of spaces can be changed by dragging them around.



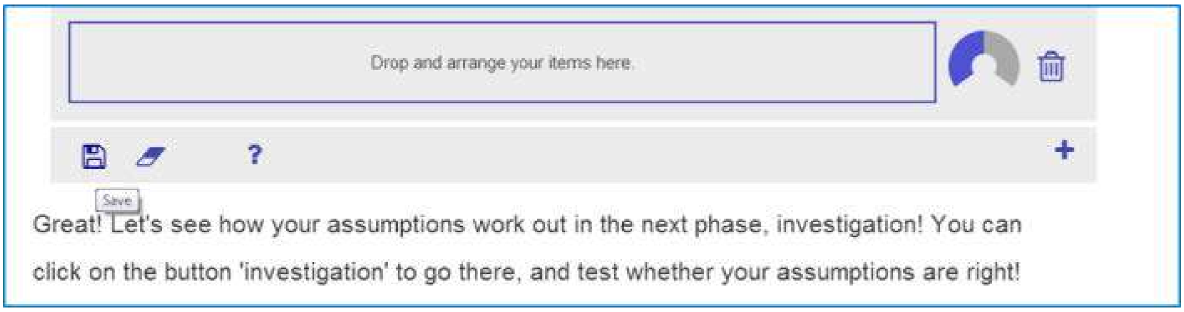
3.7 The length of an inquiry phase

If a phase in an Inquiry learning Space (ILS) is too long, students may lose focus as they have to scroll down too much. In this case you may decide to split a phase into two smaller phases (two tabs in the Inquiry Learning Space) and make sure you provide a connection between them. See the Tip "You can change the phases of the inquiry cycle" on how to add Phases to an ILS.



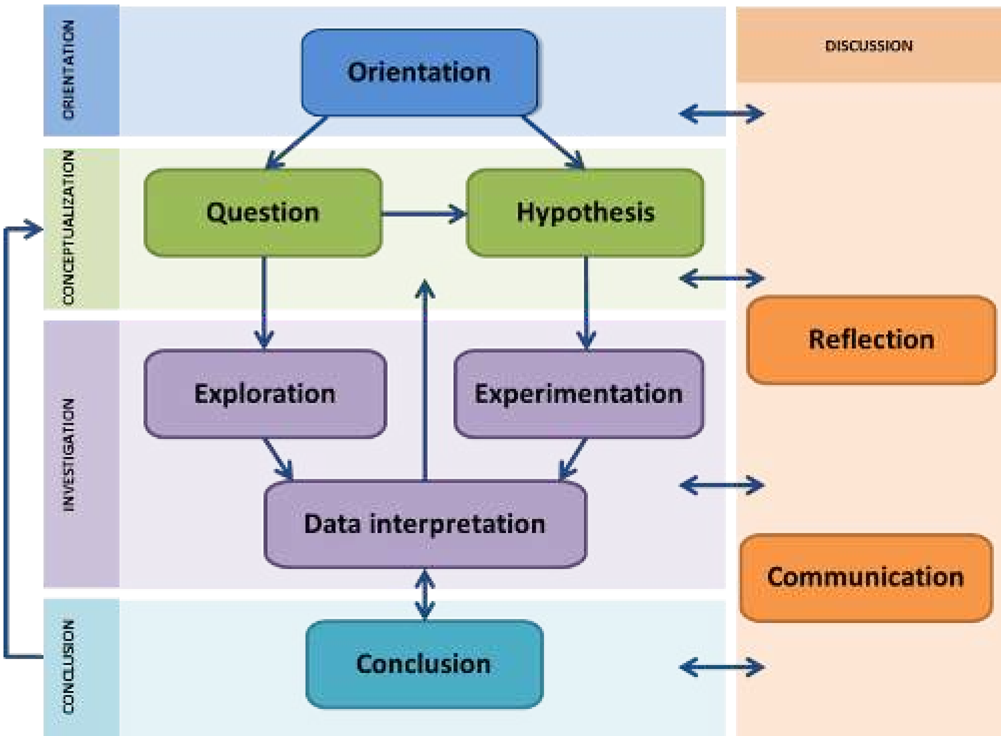
3.8 Transition between phases

There should be a connection between inquiry phases so the students progress logically from phase to phase. You can reach that by including at the end of each phase a brief sentence that marks the transition to the next phase. See this example:



3.9 Naming of the inquiry phases

The Go-Lab inquiry cycle has a number of phases for which we have chosen names that characterize the main cognitive activities for students. The Go-Lab names are: Orientation, Conceptualisation, Investigation, Conclusion, and Discussion. Within Conceptualisation and Investigation, there are two alternative routes (Question–Exploration and Hypothesis–Experimentation). Investigation, further, has as a sub-phase Data Interpretation, and Discussion has as its two sub-phases Reflection and Communication.



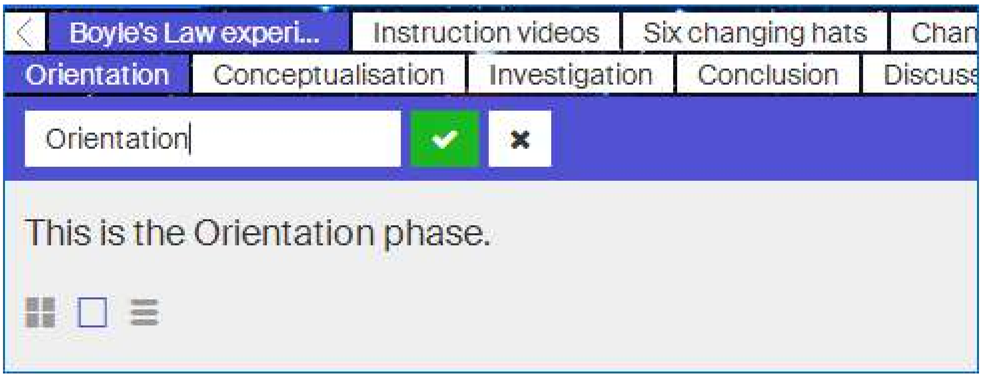
Using the Go-Lab authoring system, teachers (or other designers/authors) can change the order of the phases and add phases to meet their specific wishes. Also the names of the specific phases can be changed and adapted to the terminology that is familiar and/or known to the target group of students. This is important since students (and especially young children) often lack the scientific vocabulary to understand what is meant by “scientific language” which may also hamper their inquiry behaviour.

The next table displays some alternatives for labelling each of the phases.

Orientation	What is this about? First conjectures;
Conceptualisation	Theory; What do you think?
• Question	Issue; Challenge
• Hypothesis	Idea; proposition
Investigation	Study
• Exploration	Play around
• Experimentation	Research
• Data Interpretation	What do I see?
Conclusion	Decision; Result
Discussion	Dialogue; Deliberation
• Reflection	Consideration
• Communication	How to tell someone else?

Also within the phases it is important to adapt the level of academic language to the students’ knowledge. They may, for example, miss the understanding of words such as “dependent and independent variables”.

You can change the name of a phase in Graasp by clicking this name and typing the new name, and confirm by clicking the green symbol.



3.10 *Conclusion phase*

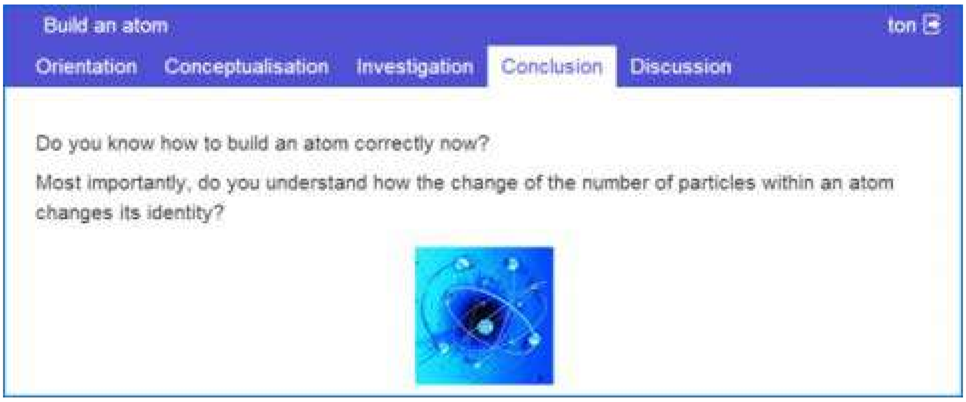
The most obvious approach in the conclusion phase is to ask the students to revise their hypothesis, select relevant data sets and observations, and adapt, if necessary, the hypothesis. This activity can be supported with the Go-Lab Conclusion tool.

To further support students, some statements or questions can be defined to be answered by the students. In some cases, the students may have to go back to previous phases to view those statements.

Examples:

- What is the influence of the sea breeze on the development of clouds?
- Is the total momentum (on the x-y plane) you calculated zero? If not, why is it not zero?

You can use the Input Box app to give students the opportunity to note down their answers.



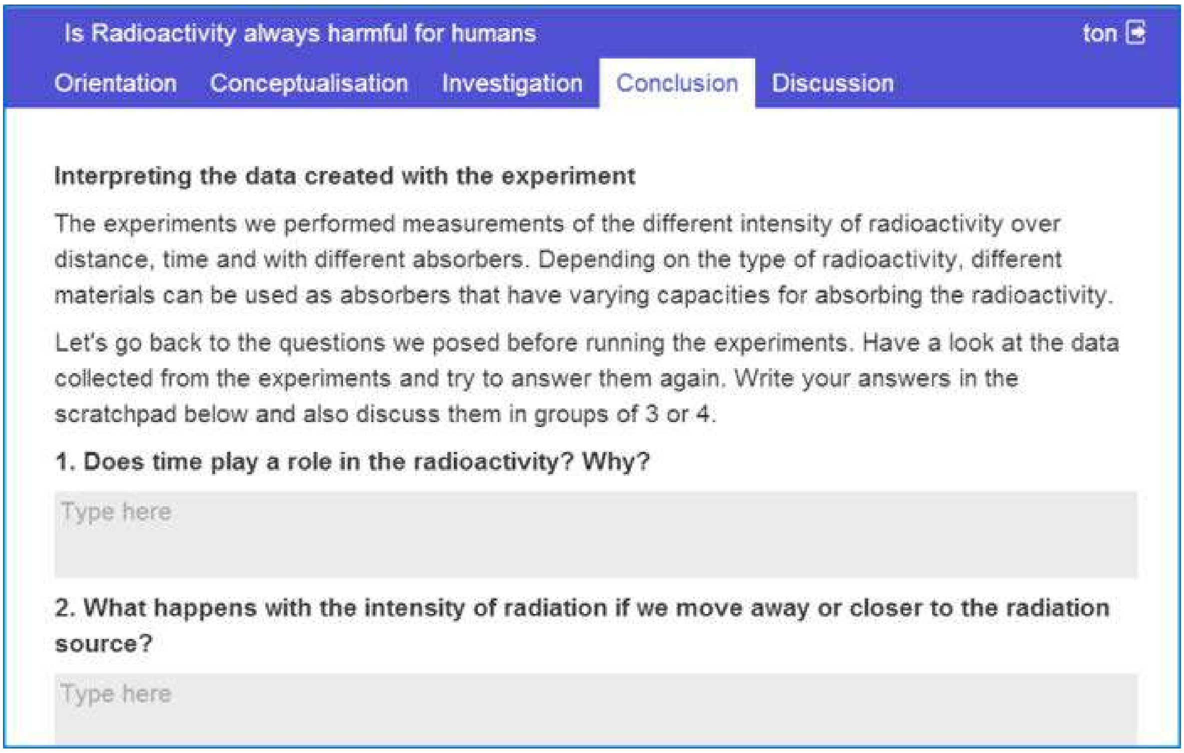
3.11 *Use of questions*

Questions for the students can be posed through the Quiz Master app. These questions are multiple choice questions, but you can also place questions in the ILS as such. In the latter case:

- Questions should be written in such a way that a simple Yes or No answer is insufficient. Students need to justify their answers by explicitly explaining the thought process behind how or why they did something.
- Questions should be answerable in a text editing tool (e.g., Scratchpad tool) or indirectly answerable in a tooling tool (e.g., Concept Mapper). Rhetorical questions that cannot be answered somewhere in the ILS are not advised.

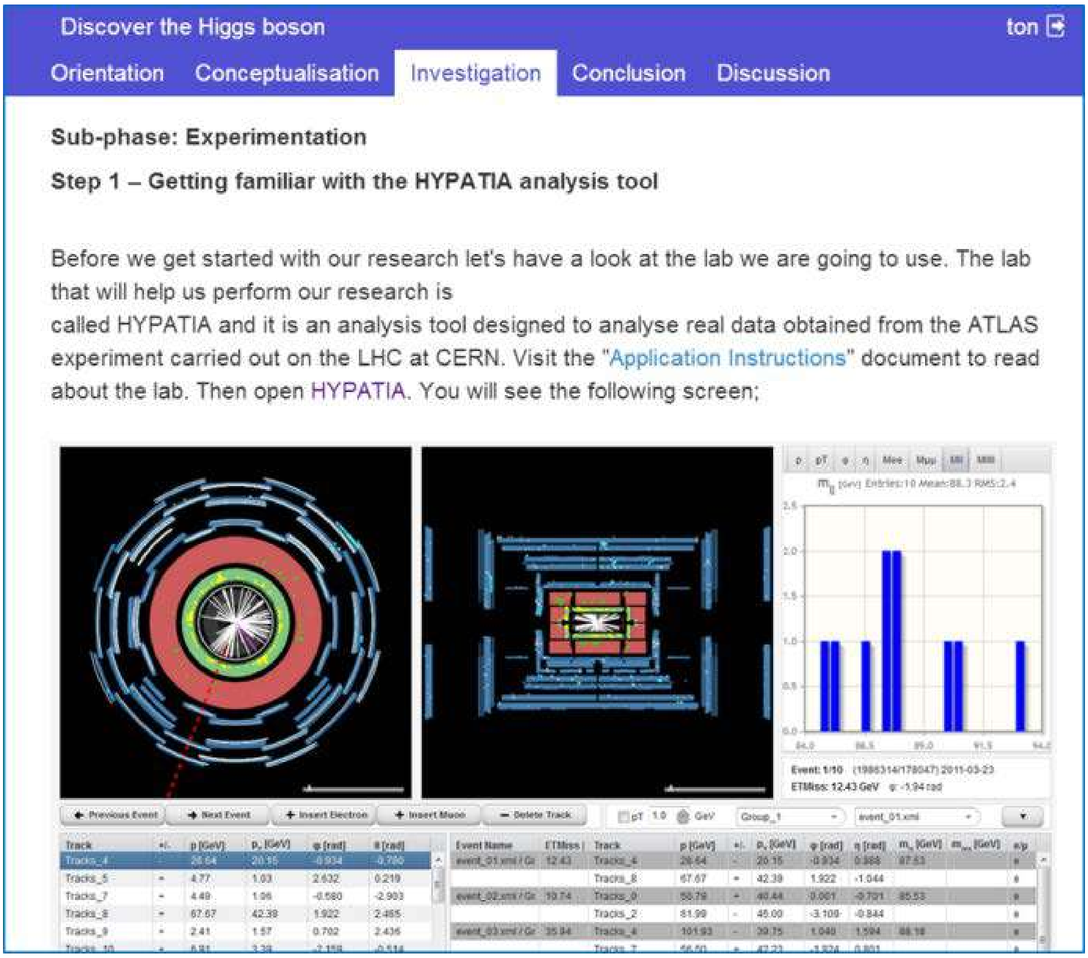
3.12 When introducing the questioning or hypothesis scratchpad get back to these in a later phase

In the conceptualization phase, you may ask the students to explicate their current ideas by introducing the Question and/or Hypothesis Scratchpad. Students can then perform experiments to see if their questions are answered or their hypotheses are confirmed or refuted. To relate questions and/or hypotheses with the data from the experiments, you may want to use the Conclusion Tool from the Go-Lab set of tools. But, if you don't, in any case, in the conclusion phase come back to the questions or hypotheses students have raised or the questions you may have raised yourself in the start of Inquiry Learning Space (ILS).



3.13 Give a good instruction to the lab you use

Here, make sure that you provide enough information about how to use the lab. If working with a complicated simulation or lab, chop the investigation into different parts with different assignments, so your students don't get overwhelmed. You can include a lab multiple times in your ILS. You can include a small video or manual before students start using the lab.

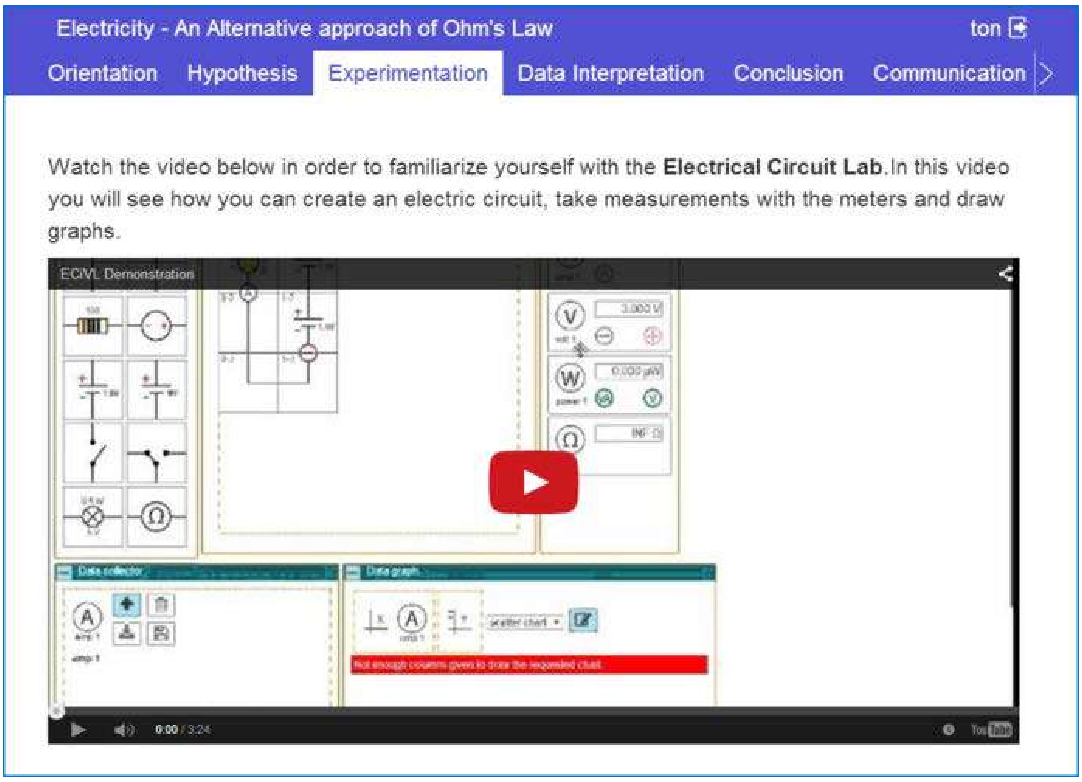

Discover the Higgs boson ton

Orientation Conceptualisation Investigation Conclusion Discussion

Sub-phase: Experimentation

Step 1 – Getting familiar with the HYPATIA analysis tool

Before we get started with our research let's have a look at the lab we are going to use. The lab that will help us perform our research is
called HYPATIA and it is an analysis tool designed to analyse real data obtained from the ATLAS experiment carried out on the LHC at CERN. Visit the "Application Instructions" document to read about the lab. Then open HYPATIA. You will see the following screen;


Electricity - An Alternative approach of Ohm's Law ton

Orientation Hypothesis Experimentation Data Interpretation Conclusion Communication

Watch the video below in order to familiarize yourself with the **Electrical Circuit Lab**.In this video you will see how you can create an electric circuit, take measurements with the meters and draw graphs.

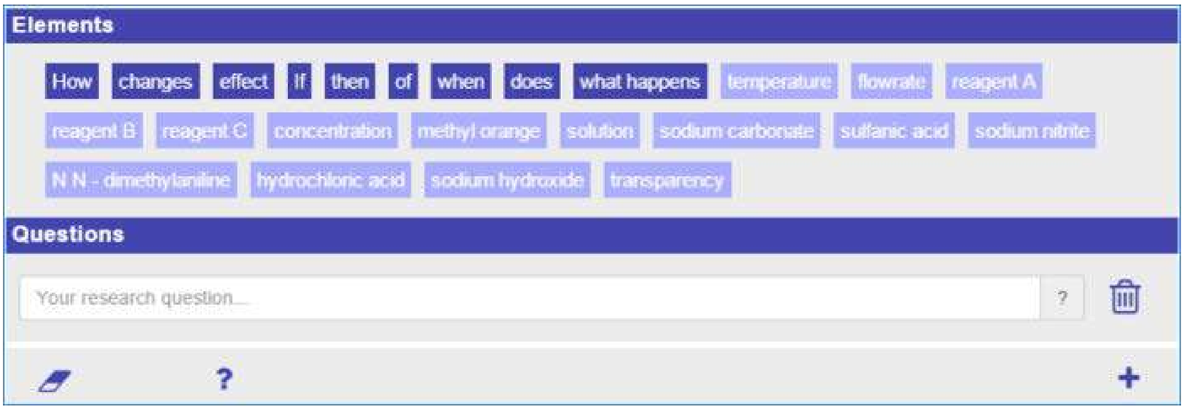
3.14 Do not underestimate the time it takes to complete an ILS

Inquiry learning is a time consuming process, especially if it is new for students. This may take more time than you had expected. If you are in doubt, only use a limited number of Go-Lab tools (inquiry learning apps).

3.15 Domain specific tools

Go-Lab tools (or Go-Lab inquiry apps, e.g., the concept mapper, the hypothesis/question scratchpad, the experiment design tool) can give students pre-defined concepts for the domain. These concepts can be inserted through the configuration option ( ) on the Go-Lab tools when you are editing your ILS. So, for example, in the concept map students can use your pre-defined concepts and then it looks like this for the students:

Or students can compose a question with the elements you have prepared for them.



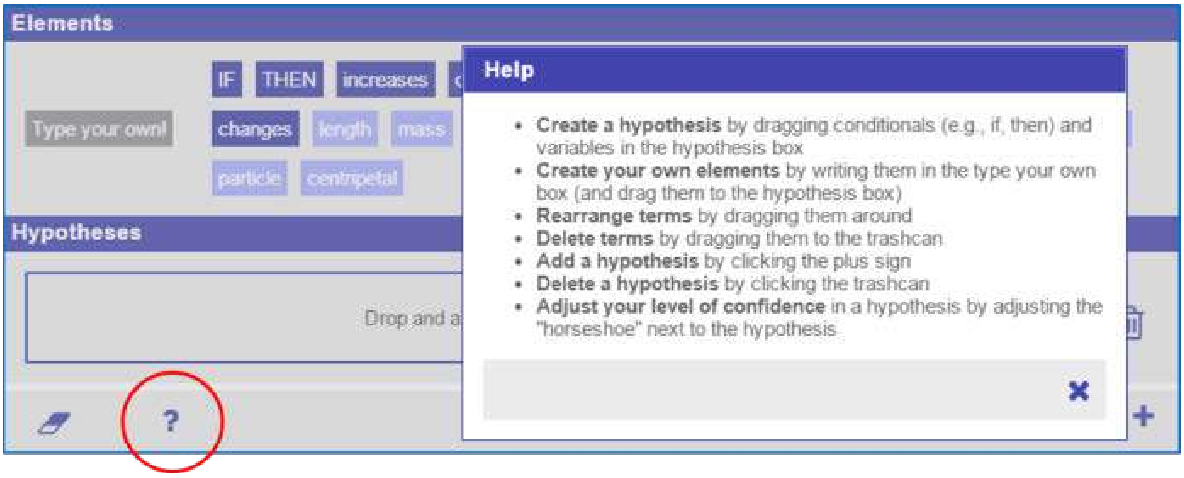
Providing students with partially filled tools may help students who are not as yet very proficient in the larger domain and/or experimentation. You can make (partially) filled tools (e.g., an incomplete concept map or a set of hypotheses) by creating them yourself in the authoring (Graasp) view. What you create there will be shown to the students when they start up the ILS.

3.16 Explanation of Go-Lab tools

Tools (or Go-Lab inquiry apps) that are offered in an Inquiry Learning Space (ILS) are most probably new for students. This means that a tool should be accompanied by some instruction for students on how to use it. This also, or maybe even stronger, holds for general tools such as note pads. If students are asked to fill these notepads in, it might be effective to give them topics or headings to use and in any case make explicit what is expected from them. Also, if you ask students to make questions or hypotheses, it may be wise to tell them, especially for inexperienced students, how many you expect. Go-Lab scaffolds have a help function

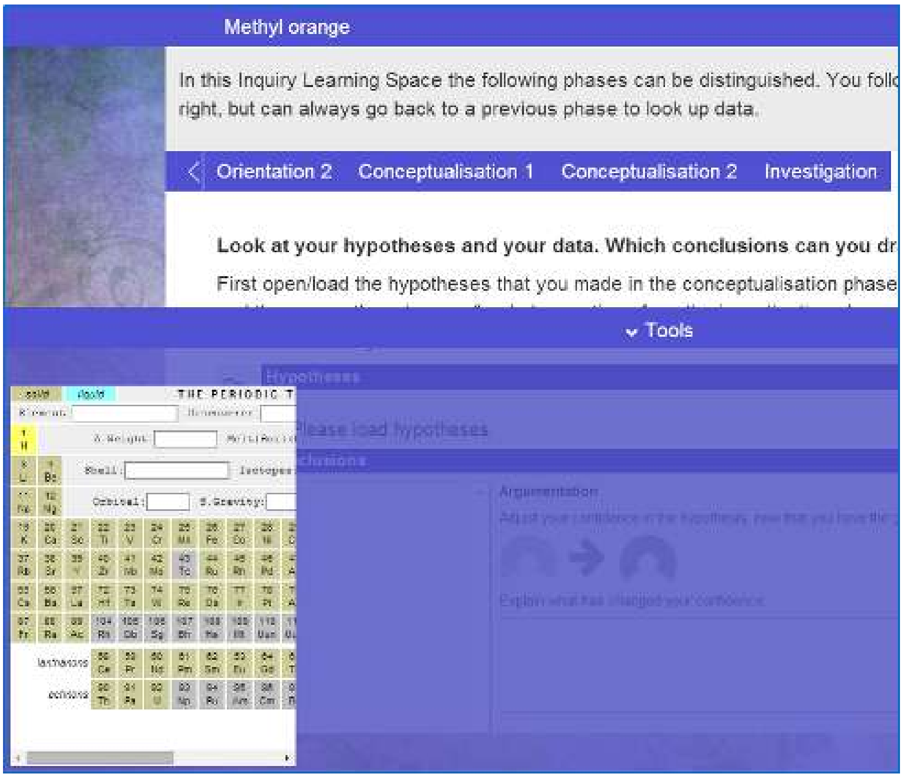
3.17 Go-Lab tools have a help for students.

Go-Lab tools (or Go-Lab inquiry apps) have a help button for students. As an author, you can adapt this help through the configuration button in the authoring phase. The help becomes visible when students click the "?" button on the tool. - See more at:



3.18 Make use of the general tool facility

You can use Go-Lab tools (inquiry learning apps such as the hypothesis scratchpad) in different phases of an Inquiry Learning Space. You can also make general tools (such as a calculator or a periodic table) available for all phases through the bottom tool bar of an ILS.



You can add a tool to the general toolbar by adding it in Graasp at the same level as the ILS phases; it will then automatically appear in the bottom toolbar for the students. See the calculator example below.

3.19 Not all students need the same amount of guidance

Provide students who have little prior knowledge with more guidance:

- Include the Experiment Design Tool (EDT) to help them plan their experiments. Explain the purpose of experimentation (and the importance of varying one thing at a time if appropriate) and give an elaborate demonstration of how to operate the EDT.
- Tell them which variable they need to vary in their experiment, and which variables they need to keep constant, instead of letting them figure this out themselves. This helps them conduct well-designed experiments from which they can better draw conclusions. You can do this by configuring the EDT with a readymade experiment yourself, so that students will start with this experiment when they go in their ILS.

Provide students who have some prior knowledge with less guidance.

- Do not include the Experiment Design Tool (EDT) for students who have already quite prior knowledge. They will gain an equal amount of knowledge when they use the EDT compared to when they don't use the EDT, but they can get frustrated because they already know what they need to do.
- Do not tell them which variable they need to vary in their experiment and which variables they need to keep constant. They don't need this additional guidance; just let them figure it out themselves!

3.20 Media use in the ILS

Try to use a diversity of information sources (videos, text, animations, pictures, diagrams etc.). For complex concepts, use text plus multimedia resources (animations, videos) to reinforce learning the domain specific content (do not rely on one method of delivering information!).

3.21 Number and length of videos

Do not include too many videos and don't choose too long videos - two minutes should be the approximate maximum (although there will be exceptions, of course).

Videos should have good visual and sound quality (i.e., brightness needs to be suitable to see what is happening and sound should not include excessive static or background noise).

Videos accompanied only with music (no voice-over explanations) should have accurate textual cues to explain what is happening during the viewing of the visual imagery.

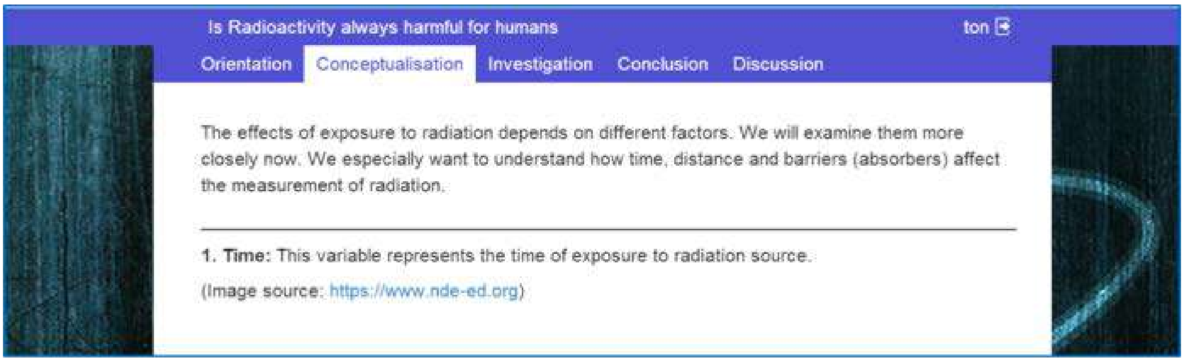
Also please note that if you embed videos in Graasp (by dragging them into the ILS) and many students start the ILS at the same time (when your lesson begins) this may result in longer loading times. You may reduce this by linking the videos from YouTube.

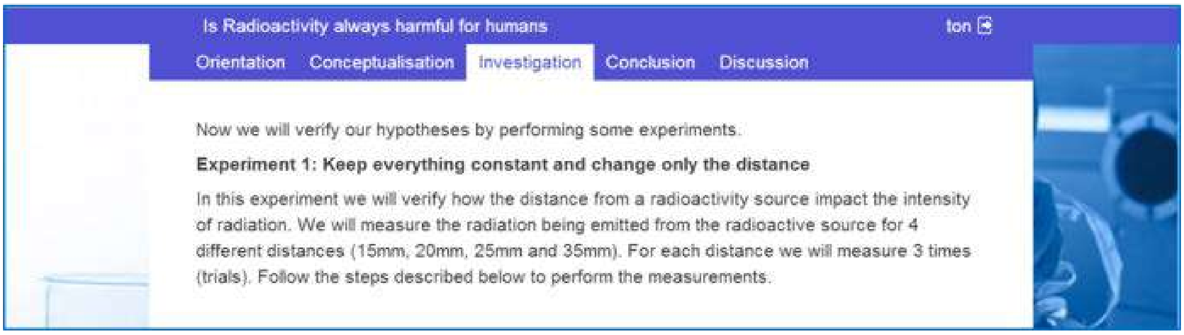
3.22 Resizing of pictures in Graasp

If you add a picture in your ILS you can resize it by using the "gear" symbol at picture that you had inserted.

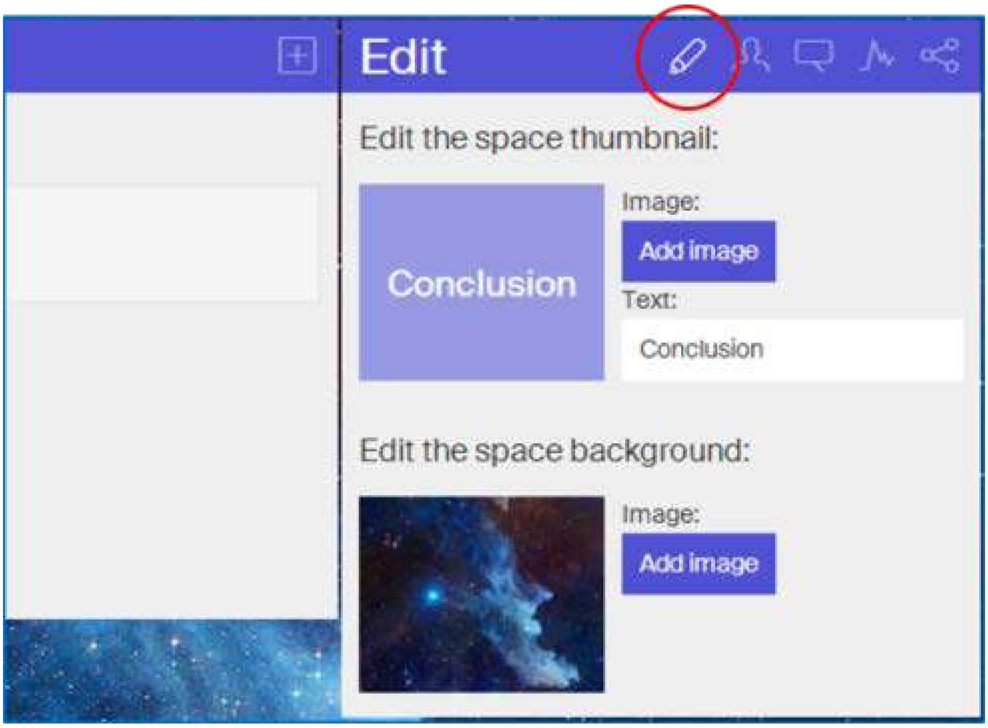
3.23 Use different background for the different phases.

You can make the Inquiry Learning Space (ILS) visually more attractive by using different background images for each phase. This will make it also more clear for students that they are changing phases.



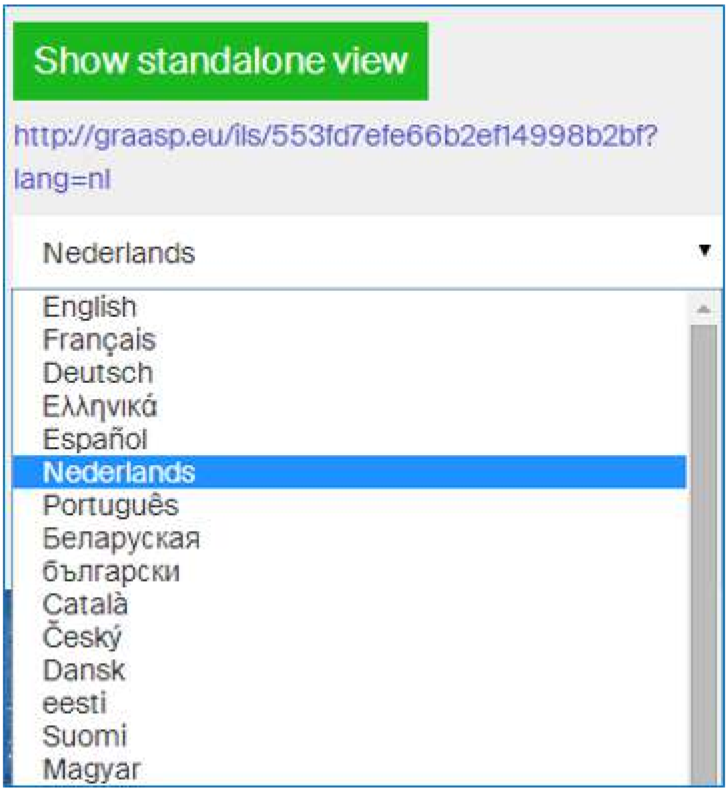


You can change the background of a phase in Graasp by clicking the pencil next to a phase.



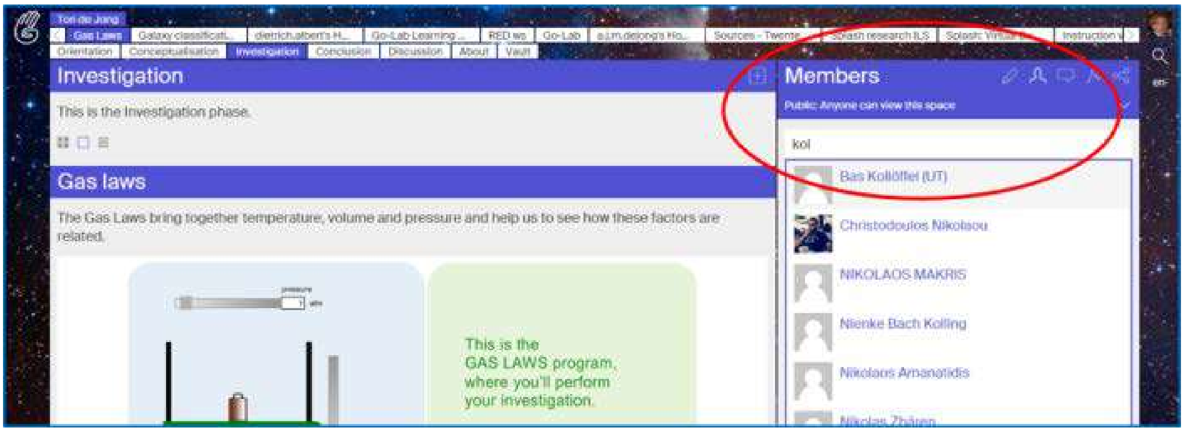
3.24 Choose your own language

You can present Inquiry Learning Spaces in many different languages. If you select your language in Graasp, the language of all Go-Lab tools (inquiry learning apps) will be automatically adapted (if all terms have been translated). You should still translate the names of the ILS phases yourself (please see the Tip "Naming of the Inquiry Phases").

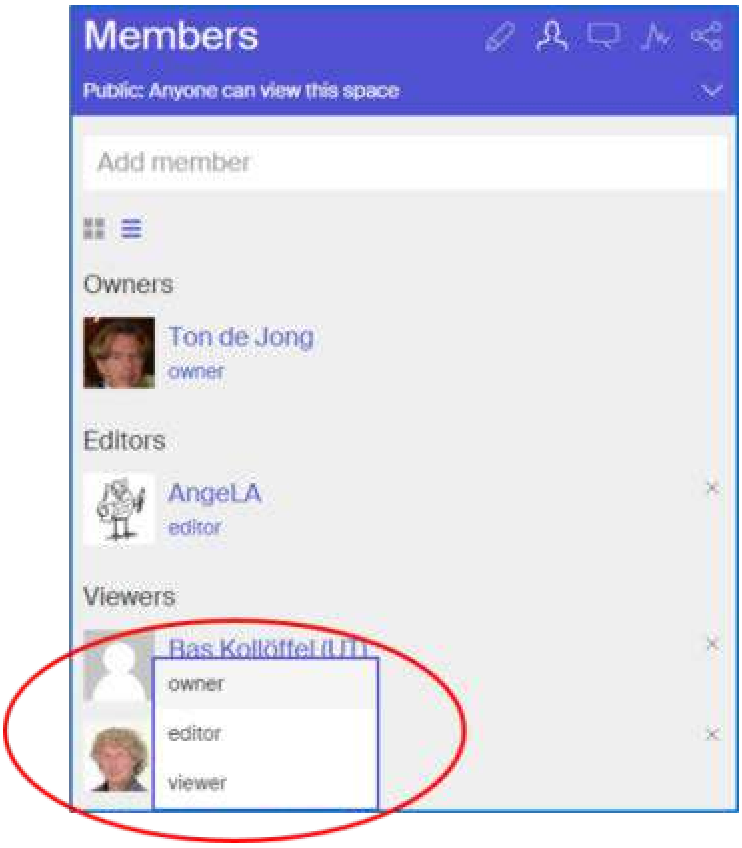


3.25 You can cooperate with colleagues when designing an ILS

When you create an ILS you can work together with a colleague and share responsibility for the ILS creation. You can easily invite a colleague in Graasp (the Go-Lab authoring facility) to become co-author. Go the upper right hand part of your screen and select “members”. Type the name of your colleague (who needs a Graasp account) and enter the name:

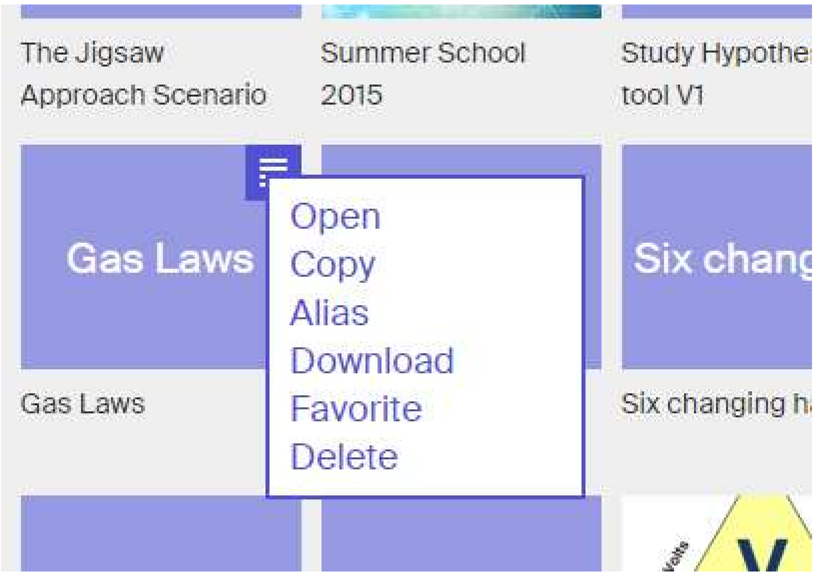


Click on the “viewer” underneath the person’s name and change the person’s role from “viewer” to “editor” or “owner”.



3.26 You can make a copy of your ILS

The Go-Lab authoring tool uses “autosave” which means that you never have to worry about saving your work. This process, however, always overwrites older versions. If, for example, you like to experiment with your ILS and like to keep the old version you may want to make a copy. This is easily done by opening the dialogue at your ILS icon. This process is further explained with a short movie at: http://www.golabz.eu/videos.



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